S P E C I A L   P R O V I S I O N

AMENDMENT TO SECTION 550 -- STRUCTURAL STEEL

PART I of III -- PROJECT-SPECIFIC REQUIREMENTS

This special provision amends Section 550 and applies to the coating of new structural steel as shown on the plans or otherwise specified to be painted. This special provision consists of three parts. Part I amends the general requirements of Part II with project-specific requirements. Part III contains Section 708, Paints.

Amend 550.3.13.1.2 to read:

1.2 DESCRIPTION OF BRIDGE(S)

1.2.1 The description of newly fabricated structural steel to be painted is stated herein. All descriptions regarding the bridge(s) and surface area(s) are intended to be generally, but not guaranteed to be precisely, accurate.

1.1.2.1 Br. No. 246/083 US Rte 1 over Scott Avenue in the City of Portsmouth, NH. This bridge is immediately adjacent to the Memorial Bridge and part of the contract items, as described in the contract documents.

1.1.2.2 Br. No. 247/084 US Rte 1 Memorial Bridge over the Piscataqua River connecting the City of Portsmouth, NH with the Town of Kittery, Maine. The Kittery approach spans are considered part of this bridge for work items as described in the contract documents.

DESCRIPTION OF BRIDGES - SUMMARY TABLE 1.2.1				
Town	Br. No.	Route	over	No. spans & length
Portsmouth, NH	246/083	US Route 1	Scott Avenue	2 span girder - 125± ft
Portsmouth, NH - Kittery, ME	247/084	US Route 1 (Memorial Bridge)	Piscataqua River	3-truss spans @ 300± ft, total 900± ft, plus 300± ft Kittery approach span viaduct

Amend 550.3.13.1.3 to read:

1.3 SCOPE OF WORK

SCOPE OF WORK - SUMMARY TABLE 1.3			
Item number. & structural steel surfaces to be painted, as shown on the plans	Surface Preparation	Required Paint System	Final Color
SCOTT AVENUE BRIDGE			
550.101 Structural Steel (all interior steel surfaces) 550.201 Bridge Shoes	SSPC-SP10 & SC 2	3-coat system C (with Finish #1)	Dark Green Fed # 24109
550.101 Structural Steel (fascia surfaces of fascia beams)	SSPC-SP10 & SC 2	4-coat system C with Finish #1 & #3)	Dark Green Fed # 24109
MEMORIAL BRIDGE			
550.1021 Structural Steel (Lift Span - Truss) 550.1031 Structural Steel (Fixed Spans -Truss) 550.1041 Structural Steel (Towers)	SSPC-SP10 & SC 2	4-coat system C with Finish #1 & #3)	Dark Green Fed # 24109
550.1071 Structural Steel (Kittery Approach. Spans) (fascia surfaces of fascia beams)	SSPC-SP10 & SC 2	4-coat system C with Finish #1 & #3)	Dark Green Fed # 24109
550.1071 Structural Steel (Kittery Approach. Spans) (all interior structural steel surfaces)	SSPC-SP10 & SC 2	3-coat system C (with Finish #1)	Dark Green Fed # 24109
550.1022 Structural Steel (Lift Span -Floor Framing) 550.1032 Structural Steel (Fixed Span -Floor Framing) 550.202 Bridge Shoes (Lift Truss Span) 550.203 Bridge Shoes (Fixed Truss Spans) 550.204 Bridge Shoes (Kittery Approach Spans)	SSPC-SP10 & SC 2	3-coat system E	Black Fed # 27038

1.3.1 Surfaces to be painted. All new steel surfaces, including main components and appurtenances, shall be cleaned and painted, as shown on the plans or as described herein for the applicable item. See Table 1.3.

1.3.1.1 Finished bearing surfaces. When bearings are to be painted, the surface preparation and painting shall include the machined finish for rolling (but not for sliding) surfaces.

1.3.2 Required Surface Preparation. All steel surfaces to be painted shall be cleaned in conformance to SSPC-SP10 and the chloride level remediated to SC 2 (see Section 3.2.6.7).

1.3.3 Required Paint System

1.3.3.1 The complete paint system shall be shop applied to the structural steel as described in Table 1.3 and shown on the plans, except for areas masked for field welding or bolted connections (see Section 3.4.12), or as directed. Field bolted connections and retrofit plates shall receive one application of primer prior to installation of the member, and the remaining coats of the system after installation. New top flange surfaces to be embedded in deck concrete shall receive a light rust preventative dust coat of 0.5 to 1.5 mils (13-38 microns) of primer only. Beam ends to be encased in back wall concrete (if applicable) shall receive the full paint system.

1.3.3.1.1 Steel surfaces with a non-skid finish shall meet the requirements of 2.1.1 and 3.4.13.

1.3.3.2 The finish color and paint system for Items 550.xxx <u>SHALL BE THE SAME AS FOR ITEM 556</u>, Painting Existing Structural Steel, if applicable. See Table 1.3. It is the Design-Builder's responsibility to coordinate suppliers to achieve this requirement.

1.3.3.3 The finish color shall be as shown in Table 1.3.

<u>Add</u> to 550.1.7.3 the following:

Batch samples for testing are not required. Provide to the Materials Lab a certificate of conformance from the coating manufacturer including a batch analysis for each production lot for each coating.

<u>Add</u> the following to 2.2. Coatings:

10. Coatings containing lead or chromium, other than naturally occurring trace amounts associated with the coating pigments, are not permitted.

11. A dry film sample of each coat (e.g. primer, intermediate, and finish) shall be tested by a laboratory certified by AIHA or A2LA under the ELLAP program (Environmental Lead Laboratory Accreditation Program) to determine its total lead content. The analytical test method shall be sufficient to provide a minimum detection limit no greater than 100 ppm. Acceptable test methods include: ASTM D 3335 (Atomic Absorption Spectroscopy), AOAC 974.02 (Lead in Paint), and ASTM E1613 (Inductively Coupled Plasma (ICP) spectroscopy).

12. The percentage of total lead in each coating shall be reported to the Department and shall not exceed 0.01 percent (100 ppm).

13. A written certificate of conformance shall be submitted to the Department for the coatings supplied stating that the paint is "lead-free".

Revision date	**LIST OF REVISIONS** (generally stated - see specification for actual wording)
11/18/10	• Update Part III - Section 708 approved paint systems.
4/19/10	• 2.2 - Reduce maximum total lead content from 600 ppm to 100 ppm;
2/11/10	• 2.2.9 - Change color number for dark brown to 20062. • Update Part III - Section 708 approved paint systems.
9/25/09	• 2.2 - Add requirement coatings with more than trace amounts of lead and chromium are not permitted; • 2.2 - Add requirement to test for lead, report results to the Department, limit total lead content to 600 ppm max., and submit "lead-free" certificate of conformance for coatings;
10/24/08	• Update Part III - Section 708 approved paint systems.
10/24/07	• 3.1.4 - add wording that quality control be performed daily and per SSPC-QP1 • 3.6.2 - add requirement to provide lighting for inspectors • 4.1.2 (4) - add requirement for neat and uniform final appearance
6/8/07	• 4.1.2 (3) - add requirement to clean off concrete spatter and drippings • 2.2.3 - add VOC max limit of 2.8 lb/gal (340 g/L) for intermediate and topcoats.
10/5/06	• 708 - update QPL
1/13/06	• Remove proprietary reference to 3M Scotch-Brite™ Clean and Strip discs
4/11/05	• 2.1.2 - add requirements for non-skid grain • 2.2 - add Paint System E • 3.4.11 (2) - reword the number of DFT readings to be taken by QA inspection • 3.4.13 - add requirements for a non-skid walking surface finish • 3.2.11 - extend the warranty to 3 years and clarify the definition of coating failure. • 708 - update QPL

PART II of III -- GENERAL REQUIREMENTS

Part II states general requirements for painting new structural steel as amended by project specific requirements of Part I.

Amend **3.2.3** to read:

3.2.3.1 Shop painting certification. Fabricators supplying shop applied painted or metalized steel products shall be certified with the American Institute of Steel Construction (AISC) Sophisticated Paint Endorsement (SPE), or with the Society for Protective Coatings (SSPC) Quality Procedure 3 “Standard Procedure for Evaluating Qualifications of Shop Painting Contractors (QP3).

3.2.3.2 Field painting contractor certification. Painting contractors and subcontractors shall be certified by the Society for Protective Coatings (SSPC) Painting Contractor Certification Program (PCCP) to the requirements of SSPC-QP1 for all field painting work, and to the requirements of SSPC-QP2 for work involving the removal or overcoating of lead-based paint.

Amend **3.13** to read:

3.13 PAINTING NEW STRUCTURAL STEEL

OUTLINE OF SECTION 550.3.13

4.5 One Year Anniversary Inspection

Note: The sections of this specification to follow are numbered in the manner of the outline above without the prefix “550.3.13”, which is implied.

DESCRIPTION

1.1 GENERAL

1.1.1 General Description. This work shall consist of the cleaning, surface preparation, and painting of new structural steel, including the proper preparation of the steel surfaces, the application, drying, cure, and protection of coatings, both in the shop and in the field, and worker and environmental protection, as described herein or as directed.

1.2. DESCRIPTION OF BRIDGE

(See Section 550 Part I)

1.3 SCOPE OF WORK

(See Section 550 Part I)

1.4 REGULATORY COMPLIANCE

1.4.1 Comply with the requirements of this Item and all applicable Federal, State and local laws, codes, and regulations, including, but not limited to the regulations of the United States Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), and the New Hampshire Department of Environmental Services (NHDES) in conformance to Section 107.

1.4.2 Identification of the items below which are of specific interest to NHDOT in no way relieves the Design-Builder of the responsibility to comply with all OSHA and EPA requirements, nor should it be construed that the NHDOT, the EPA, NHDES, or other State and City regulators are only interested in these items. If a Federal, State, or City regulation is more restrictive than the requirements of this Item, follow the more restrictive requirements.

1.5 DESIGN-BUILDER RESPONSIBILITY. The Design-Builder is responsible for performing the requirements stated herein, whether the specification wording states this explicitly (e.g. "The Design-Builder shall conduct all operations...") or implicitly (e.g. "Conduct all operations..."), unless the wording specifically names a different party (e.g. 3.6.1 "The Department will inspect...").

1.6 REFERENCE STANDARDS

1.6.1 The latest edition of the following standards and regulations in effect at the time of the Bid form a part of this Specification. A copy of the reference standards applicable to the work shall be available at the shop painting facility and in the field.

1.6.2 American Society for Testing and Materials (ASTM)

1. ASTM D3359, Standard Test Methods for Measuring Adhesion by Tape Test

2. ASTM D4138, Standard Test Method for Measurement of Dry Paint Thickness of Protective Coating Systems by Destructive Means
3. ASTM D4285, Standard Test Method for Indicating Oil or Water in Compressed Air
4. ASTM D4414, Standard Practice for Measurement of Wet Film Thickness by Notch Gages
5. ASTM D4417, Standard Test Methods for field Measurement of Surface Profile of Blast Cleaned Steel
6. ASTM D4541, Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers
7. ASTM D4752, Standard Test Method for Measuring MEK Resistance of Ethyl Silicate Zinc-Rich Primers by Solvent Rub

1.6.3 Society for Protective Coatings (SSPC)

1. SSPC-SP 1, Solvent Cleaning
2. SSPC-SP 2, Hand Tool Cleaning
3. SSPC-SP 3, Power Tool Cleaning
4. SSPC-SP 5 / NACE No. 1, White Metal Blast Cleaning
5. SSPC-SP 7 / NACE No. 4, Brush Off Blast Cleaning
6. SSPC-SP 10 / NACE No. 2, Near-White Metal Blast Cleaning
7. SSPC-SP 11, Power Tool Cleaning to Bare Metal
8. SSPC-SP 12 / NACE No. 5, Surface Preparation and Cleaning of Steel and Other Hard Metals by High- and Ultrahigh- Pressure Water Jetting Prior to Recoating
9. SSPC-AB 1, Mineral and Slag Abrasives
10. SSPC-AB 2, Specification for Cleanliness of Recycled Ferrous Metallic Abrasives.
11. SSPC-AB 3, Newly Manufactured or Re-Manufactured Steel Abrasives
12. SSPC-PA 1, Shop, Field, and Maintenance Painting
13. SSPC-PA 2, Measurement of Dry Film Thickness with Magnetic Gages
14. SSPC-SP COM, Surface Preparation and Abrasives Commentary, SSPC Painting Manual, Vol. 2, “Systems and Specifications”
15. SSPC-TU4, Field Methods for Retrieval and Analysis of Soluble Salts on Substrates.
16. SSPC-VIS 1, Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blasting
17. SSPC-VIS 3, Visual Standard for Power- and Hand- Tool Cleaned Steel
18. SSPC QP1, "Standard Procedure for Evaluating Painting Contractors (Field Application to Complex Industrial Structures)", August 1, 1998
19. SSPC QP2, "Standard Procedure for Evaluating the Qualifications of Painting Contractors to Remove Hazardous Paint", August 1, 1995
20. SSPC-QP3, Standard Procedure for Evaluating Qualifications of Shop Painting Contractors

1.6.4 American Association of State and Highway Transportation Officials (AASHTO)

1. AASHTO Standard Specification for Highway Bridges, Division II Construction, Section 13, Painting
2. AASHTO/NSBA Steel Bridge Collaboration, S8.1-2001, Standard Specification for Coating Systems with Inorganic Zinc-Rich Primer, November 2001

1.6.5 American Institute for Steel Construction (AISC)

1. Sophisticated Paint Endorsement (SPE)

1.6.6 Research Council on Structural Connections (RCSC)

1. Specification for Structural Joints Using ASTM A325 or A490 Bolts, Section 5(b), endorsed by the Research Council on Structural Connections

1.7 SUBMITTALS

1.7.1 Surface Preparation/Painting Plan. Provide the following surface preparation / painting plan to the Department for documentation in conformance to 105.02.

1. Provide written procedures covering such items as the paint manufacturer, wet and dry film thickness, cure time between coatings, protection and treatment of faying surfaces, repair of typical damage and defects in the coating, and other information needed to successfully apply all coats of paint in the shop.

1.7.2 Coating Material Documentation

1. Identify the coating materials to be applied. Include the manufacturer's name, product names, and product numbers. Provide material product data sheets, volatile organic compound (VOC) levels, MSD sheets, and written application instructions including mixing requirements, specified thinners, and thinner amounts.

2. The finish coat color shall be as shown in Section 550 Part I as per Federal Standard 595 (see 2.2.(9)). Provide a 3 x 6 inch (75 x 150 mm) panel coated with the finish color to the Department for approval prior to application.

3. Submit documentation that the complete system meets the specified standard of 708 and a Certificate of Compliance for the paint material, in conformance to the requirements of 106.04.

4. In the event of a conflict between the manufacturer's technical data and the requirements of this Item, comply with this Item unless the requirements of the manufacturer are more restrictive. In these cases, advise the Department of the discrepancies in writing, and comply with the Department's written resolution.

1.7.3 Coating Samples for Testing

1. If required, submit one sample of each initial coating material batch to the NHDOT Bureau of Materials and Research lab for testing and acceptance (Stickney Ave., Concord, NH 03301 Tel. 603-271-1660).

2. Provide original, unopened, one-pint (0.47 L) samples directly from the manufacturer, or 5-gallon (18.9 L) containers directly from the jobsite. Mark all samples with the job-specific project name and number.

3. Submit the samples a minimum of ten (10) days prior to the commencement of field painting operations.

4. Provide samples of subsequent batches as directed by the Department throughout the course of the project.

5. When samples are requested, paint from the respective batches cannot be used until authorized by the Department.

MATERIALS

2.1 ABRASIVES

1. Provide abrasives that are dry and free of oil, grease, and corrosion producing, or other deleterious contaminants. Only recyclable metal (steel or aluminum oxide) abrasives shall be used for dry abrasive blast cleaning and shall be tested daily (or as otherwise approved) to meet the cleanliness standards of SSPC-AB2 or AB3.

2. Provide an abrasive mixture of shot and grit that is sized to produce a sharp, angular, uniform anchor pattern profile height of 1.0 to 3.0 mils (25 to 75 microns), unless the requirements of the coating manufacturer are more restrictive.

3. Provide the abrasives to the jobsite in original packaging or in bulk, and store in a clean, dry environment.

2.1.2 Non-skid grain. Grains when required for non-skid walking surfaces shall be aluminum oxide granules passing No. 18 screen having sharp and angular surfaces similar to metal grit abrasive. The coating manufacturer in writing shall approve the non-skid grain or recommend a comparable substitute.

2.2 COATINGS

1. Provide the type and quantity of coating materials, thinners, and cleaning solvents needed to paint all surfaces as required (1.1.3.1). A listing of pre-approved coating systems is found in Part III, 708 Paint.

TABLE 2.2 - COATING AND FILM THICKNESS

Coat	Material	Film thickness (mils)	Film thickness (microns)

PAINT SYSTEM A:

Primer:	708-NH 1.70 Inorganic zinc rich	3-5 mils DFT	(75-125 microns)
Intermediate:	708-NH 3.21 High build epoxy polyamide	4-6 mils DFT	(100-150 microns)
Stripe coat:	(Intermediate coat)	Uniform Coat	Uniform Coat
Finish:	708-NH 3.81 Aliphatic polyurethane	2-4 mils DFT	(50-100 microns)
	Total system thickness	9-15 mils DFT	(225-375 microns)

PAINT SYSTEM B:

Primer:	708-NH 1.20 Organic zinc rich primer	3-5 mils DFT	(75-125 microns)
Intermediate:	708-NH 3.21 High build epoxy polyamide	4-6 mils DFT	(100-150 microns)
Stripe coat:	(Intermediate coat)	Uniform Coat	Uniform Coat
Finish:	708-NH 3.81 Aliphatic polyurethane	2-4 mils DFT	(50-100 microns)
	Total system thickness	9-15 mils DFT	(225-375 microns)

PAINT SYSTEM C:

Primer:	708-NH 1.40 Single-component moisture-cure zinc-rich polyurethane	3-5 mils DFT	(75-125 microns)
Intermediate:	708-NH 2.40 Single-component moisture-cure aromatic polyurethane with micaceous iron oxide	3-5 mils DFT	(75-125 microns)
Stripe coat:	(Intermediate coat)	Uniform Coat	Uniform Coat
Finish #1:	708-NH 3.41 Single-component moisture-cure aliphatic polyurethane with micaceous iron oxide	2-4 mils DFT	(50-100 microns)
Finish #2:	708-NH 3.43 Single-component moisture-cure aliphatic polyurethane	2-4 mils DFT	(50-100 microns)
	Total system thickness	8-14 mils DFT	(225-325 microns)

PAINT SYSTEM E:

Primer:	708-NH 1.43 Single-component moisture-cure micaceous iron oxide zinc-rich polyurethane	3-5 mils DFT	(75-125 microns)
Intermediate:	708-NH 2.42 Single-component moisture-cure refined coal tar aromatic polyurethane with micaceous iron oxide	4-6 mils DFT	(100-150 microns)
Stripe coat:	(Intermediate coat)	Uniform Coat	Uniform Coat
Finish:	708-NH 3.42 Single-component moisture-cure refined coal tar aromatic polyurethane with micaceous iron oxide	4-6 mils DFT	(100-150 microns)
	Total system thickness	11-17 mils DFT	(275-425 microns)

2. Film thicknesses shall be as shown in Table 2.2 unless the coating manufacturer's recommended thickness range differs. In such cases, the manufacturer shall provide written documentation that the range cited satisfies the Department's performance requirements.

3. Use coatings that are compliant with Federal and State VOC regulations at the time of application. The maximum VOC limit for the State of NH is 3.5 Lb./Gal. (420 g/L) at the time of application for zinc-rich primers and 2.8 Lb./Gal. (340 g/L) for all other coats. (See Section 550 Part III, 708 Paint). This includes the use of any required thinners.

4. Use the same manufacturer for all coats on a given structure, including thinners and additives. Do not co-mix coating products or components produced by different manufacturers under any circumstances.

5. Provide each coat of paint in sufficiently contrasting color to facilitate proper coverage and to distinguish it from cleaned steel and previously applied coatings.

6. Order all paint, thinner, and cleaning materials well in advance of intended use. Maintain an adequate supply of all materials on site at all times so as to not delay the work.

7. Provide all paint materials in sealed, original, containers that are properly marked and labeled to allow verification with applicable material safety data sheets, application precautions, and instructions. Verify that the labeling includes the manufacturer's name, type of material, brand name, color designation, shelf life, contract or order number under which the material has been ordered, lot and batch numbers, and quantity.

8. Provide a 3 x 6 inch (75 x 150 mm) panel coated with the finish color with the submittals.

9. The finish color, as specified in Section 550 Part I, shall match the required Federal Standard 595 Color number as follows:

SAGE GREEN	Federal Color #	24227
LIGHT (ODOT) GREEN		24272
DARK (DARTMOUTH) GREEN		24109
DARK BROWN		20059
ALUMINUM		27178
LIGHT GRAY		26152
BLACK		27038

2.3 EQUIPMENT

2.3.1 Surface Preparation and Painting Equipment.

1. Provide all brushes, discs, wheels, scrapers, descalers, blast cleaning, and other surface preparation equipment to conduct the work as specified in this Item.

2. Use equipment and materials that are clean and sized properly to accomplish the work, including the required surface profile and finish as required by this Item.

3. Provide paint brushes, rollers, daubers, and spray equipment to conduct the work as specified in this Item.

2.3.2 Personal Protective Equipment.

1. Provide all of the necessary personal protective equipment (PPE), such as respirators, for workers to assure protection from hazards during surface preparation, coating application, and clean-up activities. Make the equipment available for use by one Department Representatives per shift

2. Repair or replace PPE as required to assure that it continues to provide its intended purpose.

2.3.3 Inspection Equipment

1. Provide all of the inspection and testing equipment needed, for use in the shop or in the field, to verify the quality of the entire surface preparation and painting process, including mirrors to inspect hard to reach areas.

2. Make the equipment available for use by the Department.

SHOP PAINTING

3.1 GENERAL

3.1.1 Provide all materials, apparatus, and labor necessary to perform the scope of work whether or not the material or apparatus is specifically identified in this Item. Conduct all surface preparation and painting operations in a neat and workmanlike manner to the satisfaction of the Department. At the completion of the work painted surfaces shall be clean, undamaged, and present an acceptable appearance to the Department.

3.1.2 Specifications**.** The work shall be performed in conformance to the Contract requirements, the reference standards (1.6), and the coating manufacturer's instruction, respectively.

3.1.3 Safety**.** Conduct all work in strict conformance to the relevant OSHA regulations and the safety and protection requirements stipulated by equipment and material manufacturers.

3.1.4 Quality Control. The applicator (i.e. fabricator or field painting contractor) is required to conduct and document quality control inspection of the cleaning and painting operations on a daily basis by an individual meeting the requirements of SSPC QP1, including at a minimum, all measurements required by SSPC QP1 and those specified in 3.6, including ambient conditions, surface profile, surface cleanliness, dry film coating thickness, and visual inspection for coating defects.

3.1.5 Technical representation by coating manufacturer

3.1.5.1 Arrange for a technical representative (not a sales representative) of the coating manufacturer to make one visit of the work at the project startup if necessary to inspect the work in the shop and in the field to verify that the quality of surface preparation and cleaning are satisfactory for the coating system, that the mixing and application are satisfactory, and that the coating system will perform as expected.

3.1.5.2 Have the manufacturer summarize the results of the inspection in writing, together with recommendations. Provide the report to the Department within one week of the representative's visit.

3.2 SURFACE PREPARATION

3.2.1 Surface Preparation Plans. Prepare all surfaces in conformance to the requirements of this Item, and the approved Surface Preparation/Painting Plan provided under 1.7, Submittals.

3.2.2 Grinding.

3.2.2.1 Corners. All corners of sheared or flame cut edges of members to be painted shall be blunted or flattened, i.e. chamfered to a small 45° chamfer (approximately 1/16 inch (2 mm), by passing a grinder or other suitable devise along the corner, normally in a single pass, prior to blast cleaning.

3.2.2.2 Flame-cut edge surfaces. All flame-cut edge surfaces of members to be painted shall be conditioned before blasting to achieve the proper profile by grounding to bright metal to remove the hardened flame cut surface. Light grinding is generally sufficient to remove this hardened material and is only necessary if the hardness interferes with achieving the desired profile during blast cleaning.

3.2.3 Steel defects and weld irregularities. All visually evident detrimental surface imperfections (e.g. fins, tears, scabs, projections, slivers, and weld spatter) that are present on any steel member shall be removed by grinding to produce an acceptable surface. When surface imperfections discovered after blast cleaning are removed, the profile of the repair area shall be restored by blast cleaning or by mechanical tools in conformance to SSPC-SP11. The cost shall be subsidiary to Item 550.

3.2.4 Compressed Air Cleanliness

1. Provide compressed air that is free from moisture and oil contamination.

2. Conduct a white blotter test in conformance to ASTM D 4285 to verify the cleanliness of the compressed air. Conduct the test at least once per shift for each compressor system. Sufficient freedom from oil and moisture is confirmed if soiling or discoloration is not visible on the paper.

3. If air contamination is evidenced, change filters, clean traps, add moisture separators or filters, or make other adjustments as necessary to achieve clean, dry air.

3.2.5 Ambient Conditions. Do not conduct final surface preparation which exposes bare steel under damp environmental conditions, or when the surface temperature is less than 5°F above the dew point temperature of the surrounding air, except as permitted otherwise by the coating manufacturer. See 3.4.5(3).

3.2.6 Surface Cleaning Requirements - Steel Substrates. Section 550, Part I, identifies the degree of cleaning required for the project. Definitions for the specified degree(s) of cleaning are provided below:

1. SSPC-SP 1 Solvent Cleaning

a) Remove all visible oil, grease, dust, soil, drawing and cutting compounds, and other soluble contaminants from the surface in conformance to SSPC-SP 1, Method 4.1.1 only, prior to coating removal (with emphasis on using clean rags or brushes).

b) Only use solvents or detergents that are acceptable to the coating manufacturer in writing and the Department.

2. SSPC-SP 2 Hand Tool Cleaning

a) Upon approval of the Department, use scrapers, putty knives, wire brushes, chipping hammers and other similar tools to thoroughly clean any surfaces that cannot be adequately addressed using abrasive blasting or power tool cleaning. Comply with the requirements of SSPC-SP 2 to remove all loose mill scale, loose rust, loose paint, and other loose foreign matter on a best effort basis.

b) It is not intended that adherent mill scale, rust, and paint be removed by this process. Mill scale, rust, and paint are considered to be adherent if they cannot be removed by lifting with a dull putty knife.

c) SSPC-VIS 3 may be used as an aid in determining the quality of cleaning.

3. SSPC-SP 3 Power Tool Cleaning

a) Use power assisted hand tools such as sanding discs or non-woven open-web abrasive rotary discs, wire brushes, needle guns, or similar tools to thoroughly clean corrosion and disbonded coating on surfaces specified in 1.1.3, Scope of Work. Comply with the requirements of SSPC-SP 3 to remove all loose mill scale, loose rust, loose paint, and other loose foreign matter.

b) It is not intended that adherent mill scale, rust, and paint be removed by this process. Mill scale, rust, and paint are considered adherent if they cannot be removed by lifting with a dull putty knife.

c) Feather the coating surrounding each prepared area to provide a smooth tapered transition into the surrounding existing intact coating. Verify that the edges of the coating around the periphery of the prepared areas are tight and intact by probing with a putty knife in conformance to the requirements of SSPC-SP3.

d) SSPC-VIS 3 may be used as an aid in determining the quality of cleaning.

4. SSPC-SP 7 Brush-off Blast Cleaning

a) When abrasive blast cleaning preparation of the newly applied coating is required for the purposes of overcoating or repair, thoroughly clean all surfaces designated by the Department. Comply with the requirements of SSPC-SP 7 to remove all loose paint, loose rust, loose mill scale, and other foreign matter. Verify that the surfaces have been exposed to the abrasive and that the surfaces are densely and uniformly roughened.

b) It is not intended that adherent paint be removed by this process. Paint is considered to be adherent if it cannot be removed by lifting with a dull putty knife. Verify that the edges remaining paint are feathered.

c) Unless restricted otherwise by the Department, accomplish the SP 7 degree of cleaning using any of the following: dry blast cleaning with recyclable abrasives, wet abrasive blast cleaning, water jetting with abrasive injection, or vacuum blast cleaning.

d) SSPC-VIS 1 may be used as an aid in determining the quality of cleaning.

5. SSPC-SP 11 Power Tool Cleaning to Bare Metal

a) Use power assisted hand tools such as needle guns, Roto peening equipment, or similar tools to thoroughly clean all surfaces specified in Section 550, Part I. Comply with the requirements of SSPC-SP 11 to remove all visible oil, grease, dirt, dust, mill scale, rust, paint, oxide, corrosion products, and other foreign matter. Slight residues of rust and paint may be left in the lower portions of pits if the original surface is pitted.

b) Provide a minimum surface profile of 1 mil (25 microns) on all prepared surfaces or a profile of greater depth if required by the coating manufacturer or the Department. Measure the surface profile using the Testex Replica Tape in conformance to ASTM D4417.

c) SSPC-VIS 3 may be used as an aid in determining the quality of cleaning.

6. SSPC-SP 10 Near-White Blast Cleaning

a) Thoroughly blast clean all surfaces specified in 1.3, Scope of Work. Comply with the requirements of SSPC-SP 10 to remove all visible oil, grease, dirt, dust, mill scale, rust, paint, oxides, corrosion products, and other foreign matter, except for staining.

b) Provide a sharp, angular, uniform surface profile of 1.0 to 3.0 mils (25 to 75 microns) for abrasive blast cleaning unless the requirements of the coating manufacturer are more restrictive. Measure the surface profile using extra course Testex Replica Tape in conformance to ASTM D4417, Method C, at least once per shift, and when the abrasive mixture is changed.

c) Allow staining to remain on no more than 5 percent of each nine square inch increment of surface area. Acceptable staining is limited to light shadows, slight streaks, or minor discolorations caused by stains of rust, stains of mill scale, or stains of previously applied paint.

d) Accomplish the SP 10 degree of cleaning using dry blast cleaning with recyclable metal abrasives. Allow the surface to thoroughly dry prior to painting, and apply the primer before any visible rusting occurs.

e) SSPC-VIS 1 shall be used as an aid in determining the quality of cleaning.

7. Remediation of Chlorides

a) Verify that residual chloride levels on the structural steel (e.g. in previously rusted areas as well as unrusted areas) are remediated to a surface cleanliness condition of SC-2 (7 $\mu g/cm^2$) in accordance with SSPC-SP12, as determined by the Chlor*Test™, manufactured by Chlor*Rid International Inc. (Tel. 800-422-3217).

b) Methods of chloride removal may include, but are not limited to, steam cleaning or pressure washing and scrubbing, reblasting, or blast cleaning with blends of fine and course abrasives. Describe the proposed method(s) of chloride remediation in the submitted Surface Preparation/Painting Plan.

c) Test for chlorides at a minimum frequency of <u>two</u> representative locations per project. Test locations are to be determined by the Department.

d) If unacceptable levels of chlorides remain, test at a greater frequency, and reclean the affected areas until acceptable results are achieved.

3.3 PAINT STORAGE, MIXING, AND HANDLING

3.3.1 Paint Storage

1. Store all paint, thinners, and solvents in conformance to OSHA regulations and the requirements of the paint manufacturer. Store the paint and solvents under cover, out of direct sunlight, and protected from vandalism.

2. Maintain the storage temperature between 40°F and 90°F (5°C and 33°C), unless the requirements of the manufacturer are more restrictive.

3. Maintain MSD sheets for all materials.

3.3.2 Mixing and Thinning of Coating Materials

1. Verify that the paint to be mixed has not exceeded its shelf life. When required by the manufacturer, warm paints stored at less than 50°F (10°C) to above 50°F (10°C) prior to mixing.

2. Utilize proper ventilation in the mixing area to prevent injury to workmen or the accumulation of volatile gases.

3. Mix all coatings in conformance to the requirements of the coating manufacturer using mechanical equipment such as a Jiffy mixer. Do not create a vortex when using the power mixer.

4. Do not thin any paints unless approved in writing by the paint manufacturer and the Department. If thinning is required and authorized, use only those types, brands, and amounts of thinner stipulated by the coating manufacturer. Carefully measure the amount of thinner added. Do not “eye ball.”

5. Strain materials after mixing to remove agglomerations.

3.4 COATING APPLICATION

3.4.1 Painting Plans. Apply all coatings in conformance to the requirements of this Item, the coating manufacturer’s instructions, and the approved Surface Preparation/Painting Plan provided under 1.7, Submittals.

3.4.2 Applicator Proficiency. Unless directed otherwise by the Department, have each applicator demonstrate his or her proficiency in applying the coating system to test areas prior to commencing the production application.

3.4.3 Quality of Surface Preparation Prior to Painting

1. Verify that the surface exhibits the specified degree of hand, power tool, or abrasive blast cleaning immediately prior to painting.

2. Apply the first coat before rusting or degradation of the surface occurs, but in no case allow the prepared surface to stand for more than 24 hours in the shop prior to painting. Reclean rusted or degraded surfaces, or those surfaces that have stood for more than 24 hours prior to painting. In the field the maximum time limit is 8 hours.

3.4.4 Surface Cleanliness Prior to Painting and Between Coats

1. Thoroughly clean the surface of each coat prior to the application of the next to remove spent abrasive, dirt, dust, cement spatter, and other interference material.

2. If grease or oil have become deposited on the bare steel or on the surface of any of the applied coats, remove by solvent cleaning in conformance to SSPC-SP1 prior to the application of the next coat. Use solvents that are compatible with the coating being cleaned. Upon completion of the cleaning, verify that the grease and oil have been removed by wiping the surface with a clean, white cloth and inspecting the cloth for residue. If a residue is visible on the cloth, conduct additional cleaning.

3. Prior to applying a spot prime coat to areas of hand or power tool surface preparation, verify that the existing coatings have been thoroughly cleaned in the overlap areas, and that pockets are dry and free of mud, dirt, and other accumulations.

3.4.5 Ambient Conditions during Coating Application. Apply coatings under the following conditions unless the requirements of the coating manufacturer are more restrictive. Do not apply coatings under less restrictive conditions without written approval of the coating manufacturer, and specific written authorization from the Department.

1. Surface and Air Temperatures – Between 40°F (5°C) and 100°F (38°C). For coating system C the low temperature is 35°F (2°C).

2. Relative Humidity – Less than 85%. For coating system C, R.H. less than 98%.

3. Dew Point – Surface temperature above the dew point. Normal dew point restrictions apply (i.e. 5 °F (2.7°C) spread). For coating system C the restriction is 2°F (1°C), and do not apply the coating to surfaces that are visibly damp.

4. Frost/Rain - Do not apply coatings to surfaces containing frost or free standing water, or during rain, fog, or similar detrimental weather conditions, but only to surfaces that are thoroughly dry.

5. Remove and replace any paint that is exposed to unacceptable conditions (e.g. rain) prior to adequate curing.

3.4.6 Methods of Application - Apply all coats by the methods shown below, unless the methods recommended by the paint manufacturer are more restrictive.

1. Brush application. Use round or oval brushes. Use flat brushes only on large plate surfaces between connections, and only upon approval of the Department. Brush apply the paint using a series of small circles to thoroughly fill in all surface irregularities, and end with a series of parallel strokes to smooth the finish.

2. Roller application. Use rollers only on large plate surfaces between connections, and only upon approval of the Department. Select a nap size and roller quality that will properly wet the substrate and produce a smooth, uniform film. Apply the coating in a such a manner as to achieve complete and thorough coverage of the surface and all irregularities. Back-roll the surface after application to create a smooth, uniform finish.

3. Daubers. On metal surfaces that are inaccessible for paint brushes, use sheepskins or daubers especially constructed for the purpose.

4. Airless or conventional spray application. If conventional spray is approved for use, verify that the compressed air supply is clean and dry as determined by the blotter test in conformance to ASTM D 4285. When spraying, use extreme care and appropriate containment to avoid contamination of surrounding areas or property by overspray.

3.4.7 Recoat Times

1. Apply each coat only after the previous coat has been allowed to dry as required by the manufacturer's written instructions, but as soon as possible to minimize the length of time that the coating is exposed to dust and contamination.

2. Do not allow any coat to remain exposed for longer than 14 days prior to overcoating.

3. If a coat is exposed over the winter months prior to the application of the next coat, or the applied coat(s) exceed the manufacturer's maximum recoat times or 14 days for any reason, remove and replace the coating. As an alternative, provide written instructions from the coating manufacturer for the specialized preparation that can be undertaken (e.g. scarifying the surface) to properly prepare the surface to receive the next coat. The specialized steps can be undertaken only if approved by the Department. Perform the specialized cleaning or removal and replacement of the coatings at no additional cost to the Department.

3.4.8 Coverage, Continuity, and Stripe Coating

1. Apply each coat in a neat and workmanlike manner to assure thorough wetting of the substrate or underlying coat, and to achieve a smooth, streamline surface relatively free of dryspray, overspray, and orange peel. Shadow-through, pinholes, bubbles, skips, misses, lap marks between applications, or other visible discontinuities in any coat are unacceptable. Runs or sags may be brushed out while the material remains wet.

2. Remove dryspray and overspray (e.g. by sanding) prior to the application of the next coat. When present on the finish, remove as directed by the Department and apply another coat of finish to the area. Remove all other defective coating to sound material and reapply.

3. Thoroughly coat all surfaces with special attention to hard-to-reach areas, and irregular surfaces such as lacing bars and rivets. When coating configurations such as bolts, apply the material from multiple directions to assure complete coverage.

4. Apply a stripe coat using the intermediate coating material by brush, roll or spray to all edges and outside corners, and by brush to all welds, snipes, crevices, rivets, bolt nuts and threads, bolt heads, and other surface irregularities prior to the application of the full intermediate coat. Apply the stripe coat to ensure complete and uniform coverage, and to build up the thickness of the coating on the irregular surfaces.

3.4.9 Coating Adhesion

1. Apply all coats in such a manner to assure that they are well adherent to each other and to the substrate. If the application of any coat causes lifting of an underlying coat, or there is poor adhesion between coats or to the substrate, remove the coating in the affected area to adjacent sound, adherent, coating, and reapply the material.

2. If adhesion is suspect, conduct adhesion tests in conformance to ASTM D 3359 or ASTM D 4541 as directed by the Department, and repair all test areas. The Department and the coating manufacturer will establish the acceptance criteria for the testing. Replace all defective coating that is revealed by the testing, at no cost to the Department.

3.4.10 Wet Film Thickness. Use wet film thickness gages in conformance to ASTM D4414 to verify the thickness of each coat at the time of application.

3.4.11 Dry Film Thickness and Corrective Action for Thickness Deviations

1. Apply each coat to the thicknesses specified in 2.2 to a dry film thickness as measured <u>above</u> the top surface of the substrate profile peaks per SSPC-PA2, Type 2.

2. Measure the thickness of each coat using nondestructive magnetic dry film thickness gages. Comply with SSPC-PA2 for the calibration and use of gages and the minimum frequency of thickness measurements. QA Inspectors will not be limited by the frequency of thickness measurements of PA2 but will take measurements sufficient to assure that proper thickness is achieved on all surfaces as specified.

3. If there are questions regarding the non-destructive measurements of coating thickness, a Tooke Gage (destructive scratch gage) may be used when authorized by the Department. Conduct measurements in conformance to ASTM D 4138, but limit the use of the gage to a minimum of locations. Mark and repair all damage caused by the destructive testing, whether created by the Department or the Design-Builder at no cost to the Department.

4. Apply additional coating of the same type to areas of insufficient thickness. Use care during application to assure that all repairs blend in with the surrounding material.

5. Unless directed otherwise by the Department in writing, remove excessive coating thickness and reapply the affected coat(s). Coating thickness in excess of that specified, but not exceeding two times the maximum specified thickness, may be acceptable as long as: the coating is free of visible defects prior to applying successive coat; AND the coating manufacturer provides written documentation and test data (if required) to confirm that the thickness will not adversely affect the coating performance for the specific situation.

3.4.12 Bolted Contact Surfaces.

1. Regardless of which paint system is used, the faying surfaces (i.e. contact surfaces internal to the connection) of bolted connections shall be painted with one coat of a zinc-rich primer meeting the AASHTO / RCSC requirements for Class B slip-critical connections. This coat shall not exceed the maximum thickness nor fail to meet the minimum cure time specified on the Certificate of Approval for Class B use.

2. The external surfaces of bolted connections shall be painted with one coat of the primer used on the bridge. Both surfaces of bolted connections shall be masked off within three inches of bolt holes after application of the primer for subsequent coating application.

3.4.13 Non skid walking surfaces.

During the application of the first finish coat the non-skid abrasive shall be immediately broadcast onto the surface over the wet layer of coating to provide a non-slip surface. Vacuum excess granules upon curing of the coating. After the first finish coat has cured, apply one additional encapsulation coat of the finish coat to the non-skid surfaces. The DFT of the encapsulation coat will be 2.5 - 3.5 mils (60-90 microns).

3.5 REPAIR OF FIELD WELDS, DAMAGED AND UNACCEPTABLE NEWLY APPLIED COATINGS

3.5.1 Surface Preparation of Localized Areas

1. Repair field welds, localized handling and erection damage, minor coating defects, corrosion, and unacceptable coatings at no additional cost to the Department.

2. Prepare the surface by solvent cleaning in conformance to SSPC-SP 1 prior to mechanical cleaning.

3. In areas previously blast cleaned, if the damage exposes the substrate, remove all loose material and prepare the steel in conformance to SSPC-SP 11. Follow with solvent cleaning in conformance to SSPC-SP 1 to remove surface contamination.

3.5.2 Surface Preparation of Extensive Areas

1. Repair extensive areas of damage, significant defects, or unacceptable coating only after submitting written repair procedures to the Department for approval and at no additional cost to the Department.

2. The Department will stipulate the degree of cleaning required based on the nature of the defect.

3. Prevent damage to the surrounding coating due to over blast.

3.5.3 Feathering of Repair Areas

1. Feather the existing coating surrounding each repair location for a distance of 1 to 2 inches (25 to 50 mm) to provide a smooth, tapered transition into the surrounding existing intact coating, using a 3-M Clean 'n Strip rotary disc sander (or equal).

2. Verify that the edges of coating around the periphery of the repair areas are tight and intact by probing with a putty knife in conformance to the requirements of SSPC-SP 3. Roughen the existing coating in the feathered area to assure proper adhesion of the repair coats.

3.5.4 Coating Application in Repair Areas

1. When the bare substrate is exposed in the repair area, apply all coats of the system to the specified thicknesses.

2. When the damage does not extend to the bare substrate, apply only the affected coats.

3. Maintain the thickness of the system in overlap areas within the specified total thickness tolerances.

4. Repairs to the finish coat shall result in an acceptable uniform gloss and color on visible members.

3.6 INSPECTION

3.6.1 Quality Control (QC).

1. The applicator (i.e. fabricator or field painting contractor) is required to conduct and document quality control inspection of the cleaning and painting operations (see 3.1.4). QC inspection shall include the components and at the frequency listed in Tables 5.2, 6.1, 6.2, and 6.3 of the AASHTO/NSBA Collaboration S8.1 Standard Specification, and using Appendix 1 forms, or approved equal.

2. The data shall be recorded in a log maintained at the site and available for the Department's review during working hours.

3. Refer to the internet website for Tables and forms (at http://www.steelbridge.org/TG8/S8.1).

3.6.2 Quality Assurance (QA). The Department will perform QA inspection on all phases of the work to verify that it is in conformance to the requirements of this Item.

1. Facilitate QA inspection as required, including proper notification, allowing adequate time for the inspections, and providing lighting and access to the work together with all necessary safety and inspection equipment.

2. QA inspections will include the following minimum hold points to determine specification compliance. Do not proceed with subsequent phases of the work until the preceding phase has been approved by the Department:
   a) prior to the start of work,
   b) immediately following surface preparation,
   c) immediately prior to the application of the first coat,
   d) prior to the application of each additional coat, and
   e) after the final coat is applied and dried.

3. The presence or activity of Department QA inspections in no way relieves the Design-Builder of the responsibility to comply with all requirements of this Item, and to provide adequate inspections of its own to assure compliance with the requirements of this Item.

4. Furnish, until final acceptance of the coating system, all equipment and instrumentation needed to inspect all phases of the work.

3.7 HANDLING

3.7.1 Care shall be exercised in handling coated steel in the shop, during shipping, field erection, and subsequent construction of the bridge. Coated steel shall be insulated from lifting devices and from the scraping and rubbing of parts that would damage the coating by the use of lifting softeners, padded slings, storage pallets, separators, cushioners, tie-downs, and other approved supports.

3.7.2 The fabricator shall be responsible for the condition of the paint until the structural members arrive at the jobsite.

3.7.3 Structural steel material shall not be lifted, placed on supports, or loaded for shipment until the shop coating has been adequately cured and inspected. The steel members will be stamped "Approved" only after the loading has been completed and approved. No structural steel shall be shipped without the prior approval of the Department.

FIELD PAINTING

4.1 GENERAL

4.1.1 All field painting and repairs shall conform to the applicable requirements of this Item for shop painting (including section 3.5 for repairs) and the coating manufacturer's instructions.

4.1.2 Field work shall consist of the following:

1. Repair of damage to the shop applied coats due to handling, shipping, erecting, etc.;

2. The satisfactory cleaning and painting of field welded areas or field bolted connections with appropriate surface preparation and the application of the prime (if required), intermediate, and finish coats to these areas.

3. The finished painted surfaces shall be cleaned of all cement and concrete spatter and drippings to the satisfaction of the Department.

4. At the completion of the work painted surfaces, especially fascia surfaces exposed to public view, shall be clean, neat, undamaged, and present a uniform, acceptable appearance to the satisfaction of the Department.

4.1.3 Contain the surface preparation and painting operations to avoid contamination of surrounding property. Use extreme diligence to assure that vehicles, equipment, hardware, fixtures, surrounding property, and other materials are protected against abrasive impact, paint spillage, overspray, falling objects, and other damage. Make full restitution for damages caused at no additional cost to the Department.

4.1.4 Requirements for containment when removing paints that contain lead or other toxic metals are found in Item 556.

4.1.5 Use protective coverings, shields, or masking as necessary to protect surfaces that are not designated to receive surface preparation or coating, including nameplates, electrical equipment, bridge substructure, highway appurtenances, and slope protection.

4.1.6 Maintain all protective coverings during the entire period the work is being performed, and remove all coverings upon completion of the work.

4.1.7 Erect all scaffolding and staging required for the work and remove it upon project completion. Exercise extreme care in fastening, bracing, and handling the scaffolding and staging to avoid scratching or damaging bridge surfaces and surrounding property and equipment. Repair any damage created at no cost to the Department.

4.1.8 Structural steel surfaces which will be inaccessible for painting after erection, except for bolted connections, shall be inspected, repaired, and coated prior to erection.

4.2 SURFACE PREPARATION.

4.2.1 Removal of Existing Debris. Remove and properly dispose of accumulated pigeon droppings, cinders, dirt, and debris from all areas to be prepared and painted prior to undertaking any surface cleaning or surface preparation operations.

4.2.2 Surface Cleaning Requirements - Bolts

1. Remove machine oil, lubricant or residuals from the surface of new installed black or galvanized bolts by solvent cleaning in conformance to SSPC-SP 1.

2. Supplement the solvent cleaning of <u>galvanized</u> bolts by hand or power tool cleaning in conformance to SSPC-SP 2 or SSPC-SP 3 as needed to remove insoluble contaminants such as white rust and to thoroughly roughen the entire surface without removing the zinc layer. An additional pre-treatment or tie coat may be required if recommended by the paint

manufacturer and approved by the Department. A clean white cloth wipe test may be used to confirm that all lubricant and non-absorbed dye has been removed, leaving only the residual "stain" on the surface.

3. Supplement the solvent cleaning of rusted black bolts by power tool cleaning in conformance to SSPC-SP 3. Use a 2 3/4 inch diameter knot wire cup brush as manufactured by Weiler Corporation and supplied by Grainger Industrial Supply, or 3-M Clean 'n Strip rotary disc sander, unless other methods are approved by the Department.

4.3 HOUSEKEEPING AND WASTE DISPOSAL

4.3.1 Conduct housekeeping daily to maintain the work site in a neat and orderly condition. Do not store any paint or equipment on or below the bridge structure.

4.3.2 Unless directed otherwise by the Department, at the end of each day at a minimum, haul empty paint cans and other debris to the waste storage area.

4.3.3 Remove all paint drips, splashes, and overspray from surfaces not intended to be painted or previously painted work.

4.3.4 Upon project completion, remove all equipment and materials, correct any damage caused by the operation, and leave all surfaces in a clean and acceptable condition, including the revegetation of ground areas defoliated by the work.

4.3.5 Handle, store, transport, and dispose of all hazardous and non-hazardous project waste in strict conformance to Federal and state regulations.

4.4 FINAL ACCEPTANCE

4.4.1 Although the Department's Quality Assurance Inspector may accept the shop painted fabricated items before shipment to the jobsite, final acceptance of the paint system by the Department will occur at the jobsite after erection of the steel, and after all coats and repairs have been completed.

4.5 THREE-YEAR ANNIVERSARY INSPECTION

4.5.1 A three-year anniversary inspection will be conducted after completion of the painting. Participate in this inspection with the Department.

4.5.2 Should the coating system fail within three years after the project has been accepted, the coating shall be repaired by the Design-Builder at no cost to the State. The extent and method of repair must be acceptable to the Department. System failure does not include damage from external agents, such as scraping from snow removal equipment, vandalism, debris impacts, collisions, etc., or normal loss of gloss and color. Once the coating system has been accepted, a failure shall mean any visible corrosion, blistering, checking, cracking, or delamination (peeling) of the paint resulting from the installation of the product or from the performance of the coating. Perform all repairs in accordance with the requirements of this Item and the coating manufacturer's written instructions.

PART III of III -- SECTION 708 PAINTS

SECTION 708 - PAINT SYSTEM A
Inorganic zinc rich / Epoxy / Urethane

NH 1.70 Inorganic Zinc-Rich Primer

1. General. This VOC-compliant inorganic zinc-rich primer is to be used on structural steel cleaned to SP10 and meeting the requirements of NEPCOAT. Water-base systems are not permitted.

(NEPCOAT refers to the qualified products list of coatings approved by the Northeast Protective Coatings Committee and meeting the requirements of the NEPCOAT Specification Criteria for Protective Coatings for Use on New and Bare Existing Steel).

NH 3.21 High-Build Epoxy Polyamide Intermediate

1. General. This specification covers a VOC-compliant epoxy polyamide and is suitable for use on steel surfaces which have been properly cleaned and primed.

2. Composition.
Mixed Epoxy-Polyamide (All parts mixed)

VOC content,	2.8 max. Lb./Gal. (340 g/L)

3. Color.

The color when dry shall	Contrast with primer & topcoat

NH 3.81 Aliphatic Polyurethane Finish

1. General. This specification covers a VOC-compliant, polyurethane having good color retention and weathering resistance and suitable for use over an intermediate coat.

2. Composition.
Mixed Aliphatic Polyurethane Enamel (All parts mixed)

VOC content,	2.8 max. Lb./Gal. (340 g/L)

3. Color.

Color:	See 2.2 (9)
Finish:	Semi-gloss

SECTION 708 - TABLE A
PAINT SYSTEM A - Inorganic zinc rich / Epoxy / Urethane

The following list of paint systems are approved for the painting of structural steel cleaned to SP10. These coatings have been tested and approved by NEPCOAT.

1. Carboline Company (www.carboline.com)
   350 Hanley Industrial Court, St. Louis, MO 63144-1599 — (800) 848-4645
   Local contact: Charles Vaillant — (603) 329-9691

Primer:	Carbozinc 11 HS Inorganic Zinc Rich
Intermediate:	Carboline 893 High Build Epoxy
Finish:	Carboline 133 HB Aliphatic Polyurethane

2. Carboline Company (www.carboline.com)
   350 Hanley Industrial Court, St. Louis, MO 63144-1599 — (800) 848-4645
   Local contact: Charles Vaillant — (603) 329-9691

Primer:	Carbozinc 11 HS Inorganic Zinc Rich
Intermediate:	Carboline 893 High Build Epoxy
Finish:	Carboline 133 LH Aliphatic Polyurethane

3. Sherwin Williams Company (www.sherwin-williams.com)
   101 Prospect Ave, N.W. Cleveland, OH 44115 — (216) 566-2000

Primer:	Zinc Clad DOT Inorganic Zinc Rich Primer
Intermediate:	Steel Spec Epoxy Intermediate
Finish:	High Solids Polyurethane

SECTION 708 - PAINT SYSTEM B
Organic zinc rich / Epoxy / Urethane

NH 1.20 Organic Zinc-Rich (Epoxy or Urethane) Primer

1. General. This VOC-compliant organic zinc-rich primer is to be used on structural steel cleaned to SP10 and meeting the requirements of NEPCOAT. Water-base systems are not permitted.

(NEPCOAT refers to the qualified products list of coatings approved by the Northeast Protective Coatings Committee and meeting the requirements of the NEPCOAT Specification Criteria for Protective Coatings for Use on New and Bare Existing Steel).

NH 3.21 High-Build Epoxy Polyamide Intermediate

1. General. This specification covers a VOC-compliant epoxy polyamide and is suitable for use on steel surfaces which have been properly cleaned and primed.

2. Composition.
Mixed Epoxy-Polyamide (All parts mixed)

VOC content,	2.8 max. Lb./Gal. (340 g/L)

3. Color.

The color when dry shall	Contrast with primer & topcoat

NH 3.81 Aliphatic Polyurethane Finish

1. General. This specification covers a VOC-compliant, polyurethane having good color retention and weathering resistance and suitable for use over an intermediate coat.

2. Composition.
Mixed Aliphatic Polyurethane Enamel (All parts mixed)

VOC content,	2.8 max. Lb./Gal. (340 g/L)

3. Color.

Color:	See 2.2 (9)
Finish:	Semi-gloss

SECTION 708 - TABLE B
PAINT SYSTEM B - Organic zinc rich / Epoxy / Urethane

The following list of paint systems are approved for the painting of structural steel cleaned to SP10. These coatings have been tested and approved by NEPCOAT.

1. Carboline Company (www.carboline.com)
   350 Hanley Industrial Court, St. Louis, MO 63144-1599 (800) 848-4645
   Local contact: Charles Vaillant (603) 329-9691

   Primer: Carboline 859 Organic Zinc Rich primer
   Intermediate: Carboline 888 Epoxy intermediate
   Finish: Carboline 133 HB Aliphatic Polyurethane

2. Carboline Company (www.carboline.com)
   350 Hanley Industrial Court, St. Louis, MO 63144-1599 (800) 848-4645
   Local contact: Charles Vaillant (603) 329-9691

   Primer: Carboline 859 Organic Zinc Rich primer
   Intermediate: Carboline 888 Epoxy intermediate
   Finish: Carboline 133 LH Aliphatic Polyurethane

3. Carboline Company (www.carboline.com)
   350 Hanley Industrial Court, St. Louis, MO 63144-1599 (800) 848-4645
   Local contact: Charles Vaillant (603) 329-9691

   Primer: Carboline 859 Organic Zinc Rich primer
   Intermediate: Carboline 893 Epoxy intermediate
   Finish: Carboline 133 LH Aliphatic Polyurethane

4. Carboline Company (www.carboline.com)
   350 Hanley Industrial Court, St. Louis, MO 63144-1599 (800) 848-4645
   Local contact: Charles Vaillant (603) 329-9691

   Primer: Carboline 859 PRIMER Organic Zinc Rich primer
   Intermediate: Carboline 825 Epoxy intermediate
   Finish: Carboline 133 LH Aliphatic Polyurethane

5. International Protective Coatings (www.international-pc.com)
   6001 Antoine, Houston, Texas, 77091, Dan Griffin (800) 525-6824 x 1289
   Local contact: Mark Ellis (508) 587-8877

   Primer: Interzinc 52 Organic Zinc Rich Primer
   Intermediate: Intergard 475 HS Epoxy
   Finish: Interthane 979 Polysiloxane

6. International Protective Coatings (www.international-pc.com)
6001 Antoine, Houston, Texas, 77091, Dan Griffin (800) 525-6824 x 1289
Local contact: Mark Ellis (508) 587-8877

Primer:	Interzinc 315B Epoxy Zinc Rich Primer
Intermediate:	Intergard 475 HS Epoxy
Finish:	Interthane 870 UHS

7. PPG Protective & Marine Coatings (www.ppgamercoatus.ppgpmc.com)
One PPG Place, Pittsburgh, PA 15272 (412) 434-3131
Local contact: C. G. Edwards & Co. (617) 268-4111

Primer:	Amercoat 68 HS Zinc Rich Epoxy Primer
Intermediate:	Amercoat 399 Fast Drying Epoxy
Finish:	Amercoat 450H Gloss Aliphatic Polyurethane

8. Sherwin Williams Company (www.sherwin-williams.com)
101 Prospect Ave, N.W. Cleveland, OH 44115 (216) 566-2000

Primer:	Zinc Clad III HS Organic Zinc Rich Epoxy Primer
Intermediate:	Macropoxy 646 Fast Cure Epoxy
Finish:	Acrolon 218 HS Acrylic Polyurethane

SECTION 708 - PAINT SYSTEM C
Single-component moisture-cure Zinc urethane / Mio / U

NH 1.40 Single-component moisture-cure zinc-rich polyurethane primer

Generic type:	Zinc-rich, single-component, moisture-cure polyurethane
Vehicle type:	Moisture-cure polyurethane
Volume solids:	60% minimum
Pigment type:	83% min. zinc dust in the dry film by weight
Weight per volume:	22 pounds (2.64 kg/L) minimum
VOC:	2.8 lb./gal. (340 g/L) maximum
Recoat time:	4 to 6 hours minimum
Color:	Tinted to contrast with blasted steel

NH 2.40 Single-component moisture-cure aromatic polyurethane with micaceous iron oxide (MIO) intermediate

Generic type:	MIO, single-component, moisture-cure aromatic polyurethane
Vehicle type:	Moisture-cure polyurethane
Volume solids:	60% minimum
Pigment type:	3.0 pounds/gallon micaceous iron oxide
Weight per volume:	12-14 lb./gal. (1.4-1.68 kg/L) minimum
VOC:	2.8 lb./gal. (340 g/L) maximum
Recoat time:	6 to 8 hours minimum
Color:	To contrast with primer and finish coat

Finish #1 - NH 3.41 Single-component moisture-cure aliphatic polyurethane with micaceous iron oxide (MIO) finish

Generic type:	Single-component, moisture-cure aliphatic polyurethane
Vehicle type:	Moisture-cure polyurethane
Volume solids:	53% minimum
Pigment type:	3.0 pounds/gallon micaceous iron oxide
Weight per gallon:	12-14 pounds/gallon minimum
VOC:	2.8 lb./gal. (340 g/L) maximum
Recoat time:	4 hours minimum
Color:	See 2.2 (9).
Finish:	Semi-gloss

Finish #2 - NH 3.43 Single-component moisture-cure aliphatic polyurethane finish

Generic type:	Single-component, moisture-cure aliphatic polyurethane
Vehicle type:	Moisture-cure polyurethane
Volume solids:	53% minimum
Weight per volume:	11-12 pounds/gallon (1.3-1.4 kg/L) minimum

VOC:	2.8 lb./gal. (340 g/L) maximum
Recoat time:	4 hours minimum
Color:	See 2.2 (9).
Finish:	Semi-gloss

SECTION 708 - TABLE C
PAINT SYSTEM C - SC MC Zinc Urethane/ Mio / Urethane

The following list of paint system(s) are approved for the painting of structural steel cleaned to SP10. These coating(s) have been tested by NEPCOAT.

1. Wasser Corporation (www.wassercoatings.com)
4118 B PL NW-Suite B, Auburn, Washington 98001 (800)-627-2968
Local contact: Ben Forde (508)-930-0330

Primer:	Wasser MC-Zinc (shop applied) or MC-Miozinc (field applied)
Intermediate:	Wasser MC-Ferrox B (shop applied) or MC-Miomastic (field applied)
Finish #1:	Wasser MC-Ferrox A
Finish #3:	Wasser MC-Antigraffiti

2 Xymax Coatings Incorporated
520 Cure Boivin, Boisbriand, PQ J7G2A7 Canada (450)-430-6780
Contact: Marc Schondorf

Primer:	Xymax MonoZinc ME III
Intermediate:	Xymax MonoFerro PUR
Finish #1:	Xymax Bridge Finish (or Mono Brite for aluminum color)
Finish #3:	Xymax Maxcoat Clearcoat

SECTION 708 - PAINT SYSTEM E
Single-component moisture-cure zinc rich urethane / Tar / Tar

NH 1.43 Single-component moisture-cure zinc-rich polyurethane primer

Generic type:	Single-component, moisture-cure zinc rich polyurethane
Vehicle type:	Moisture-cure polyurethane
Volume solids:	60% minimum
Pigment type:	zinc dust
Weight per volume:	20 pounds (2.40 kg/L) minimum
VOC:	2.8 lb./gal. (340 g/L) maximum
Recoat time:	4 to 6 hours minimum
Color:	Tinted to contrast with blasted steel

NH 2.42 Single-component moisture-cure refined coal tar aromatic polyurethane with micaceous iron oxide (MIO)

Generic type:	Refined coal tar / micaceous iron oxide-filled, single-component, moisture-cure polyurethane
Vehicle type:	Moisture-cure polyurethane
Volume solids:	60% minimum
Barrier filler:	3 pounds/gallon micaceous iron oxide
VOC:	2.8 lbs./gallon maximum
Recoat time:	6 minimum
Color:	Red-oxide

NH 3.42 Single-component moisture-cure refined coal tar aromatic polyurethane with micaceous iron oxide (MIO)

Generic type:	Refined coal tar / micaceous iron oxide-filled, single-component, moisture-cure polyurethane
Vehicle type:	Moisture-cure polyurethane
Volume solids:	60% minimum
Barrier filler:	3 pounds/gallon micaceous iron oxide
VOC:	2.8 lbs./gallon maximum
Recoat time:	6 minimum
Color:	Black

SECTION 708 - TABLE E
PAINT SYSTEM E - SC MC Zinc Urethane/ Tar / Tar

The following list of paint systems are approved for the painting of structural steel cleaned to SP11 or better:

1. Wasser Corporation (www.wassercoatings.com)
   4118 B PL NW-Suite B, Auburn, Washington 98001 (800)-627-2968
   Local contact: Ben Forde (508)-930-0330

Primer:	Wasser MC-Zinc (shop applied) or MC-Miozinc (field applied)
Intermediate:	Wasser MC-Tar
Finish:	Wasser MC-Tar

2 Xymax Coatings Incorporated
   520 Cure Boivin, Boisbriand, PQ J7G2A7 Canada (450)-430-6780
   Contact: Marc Schondorf

Primer:	Xymax MonoZinc ME III
Intermediate:	Xymax MonoGuard
Finish:	Xymax MonoGuard

S P E C I A L   P R O V I S I O N

SECTION 592 -- RETAINING WALL

Item 592.1 – Mechanically Stabilized Earth Retaining Wall

Description

1.1 This work consists of designing, furnishing and constructing a mechanically stabilized earth (MSE) retaining wall system in accordance with these specifications and in close conformance with the lines, grades, design and dimensions shown on the plans or established by the Engineer. The MSE wall includes a non-structural cast in place concrete leveling pad, precast concrete facing panels, tensile reinforcement mechanically connected to each facing panel, concrete slip joint posts, reinforced cast-in-place and precast concrete coping, impervious membrane with non-woven geotextile and perforated pipe, and all incidental materials, as detailed on the plans.

1.1.1 Inextensible reinforcement refers to metallic reinforcement, and extensible reinforcement refers to polymeric reinforcement. Approved MSE wall systems based on the wall application are provided in 1.2. The type of reinforcement used for the systems listed in 1.2 shall be as previously approved by the Department for a particular system. More detailed information regarding the Department's approved wall systems with associated applications, requirements and limitations are provided in the following memorandums and letters, which can be obtained through NHDOT Bureau of Bridge Design:

1. Memorandum dated November 30, 2007, entitled "Review and Summary of Recommendations for Additional MSE Retaining Wall Systems"

2. Memorandum dated March 6, 2008 entitled "Review, Summary and Recommendations for T&B Structural MSE Retaining Wall System"

3. Letter dated June 30, 2009 entitled "Tricon MSE Retaining Wall, NHDOT Response to Recent Discussions and Issues with Tricon System"

1.1.2 An impervious membrane with perforated pipe shall be provided above inextensible tensile reinforcement. The MSE wall item includes the requirement to design the rows of inextensible tensile reinforcement located above the impervious membrane for a 125 year design life, as described in this specification, and all other tensile reinforcement for a 100 year design life.

1.1.3 The MSE wall items include the cost of designing the MSE wall, providing design calculations and shop drawings, site visits by the wall supplier's technical representative and concrete and granular backfill testing.

1.1.4 As described in 2.2, the precast concrete facing panels shall be reinforced with steel bars that are galvanized.

1.1.5 The material requirements for Item 209.5 Granular Backfill for MSE Walls are provided in the Special Provision Amendment to Section 209.

1.1.6 As described in 1.4, the MSE Walls shall be designed in accordance with the applicable provisions of the 2007 AASHTO LRFD Bridge Design Specifications as amended through 2010.

1.1.7 Exposed MSE panels shall have an Ashlar Stone form liner pattern that conforms to Ashlar Stone P/C 30664, Symons Dura-Tex as manufactured by Symons Corporation; or Ashlar Stone No. 330 Multi-Cast, as manufactured by Greenstreak; or approved equal. The form liner pattern shall extend to a minimum of 12 inches below the finished grade at the face of the wall.

1.1.8 Item 534.3, Water Repellant (Silane-Siloxane), shall be applied to the entire wall coping, and to exposed MSE panel surfaces to 12 inches below the finished grade at the face of the wall.

1.1.9 All wall systems shall have a precast or cast-in-place concrete coping at the top of wall.

1.2 Approved Wall Systems. The following proprietary MSE wall systems are approved for the following applications for this project.

1.2.1 Walls Supporting Overlying Structures – The following precast concrete panel wall systems are approved for retaining walls that support overlying structures including bridge abutments and soundwalls:

A. Reinforced Earth® by The Reinforced Earth Company
133 Park Street, North Reading, Massachusetts 01864
(978) 664-2830

B. Retained Earth™ by The Reinforced Earth Company
133 Park Street, North Reading, Massachusetts 01864
(978) 664-2830

C. TBSS Permanent MSE Retaining Wall System
T&B Structural Systems LLC
6800 Manhattan Blvd., No. 304, Fort Worth, Texas 76120
(888) 280-9858

1.2.2 Stand Alone Walls With No Overlying Structures – In addition to the wall systems listed in 1.2.1, the following precast concrete panel wall systems are approved for stand alone walls with no overlying structures.

A. Tricon Precast Ltd.
   15055 Henry Road
   Houston, TX 77060
   (281) 931-9832
   (Approved in accordance with the design requirements in the letter from the NHDOT Bridge Design Bureau to Tricon Precast Ltd, dated June 30, 2009)

B. Tensar Ares MSE Retaining Wall System
   Tensar International
   5883 Glenridge Drive, Suite 200
   Atlanta, Georgia 30328
   (404) 250-1290

1.2.3 Stand Alone Walls With No Overlying Structures in Non-Salt Spray Locations – In addition to the wall systems listed in 1.2.1 and 1.2.2, the following dry cast modular concrete block systems are approved for stand alone walls in non-salt spray locations (outside the clear zone).

A. Tensar Mesa MSE Retaining Wall System
   Tensar International
   5883 Glenridge Drive, Suite 200
   Atlanta, Georgia 30328
   (404) 250-1290

B. Keysystem I (with either galvanized steel welded wire, or HDPE geogrid)
   Keystone Retaining Wall Systems
   4444 West 78th Street
   Minneapolis, MN 55435
   (952) 897-1040

C. Keystone Standard (with HDPE geogrid)
   Keystone Retaining Wall Systems
   4444 West 78th Street
   Minneapolis, MN 55435
   (952) 897-1040

1.3 Requirements for Supplier Prepared Design and Plans. The Design-Builder shall submit plans and calculations for the selected MSE wall system for approval in accordance with

Section 105.02, the design criteria in section 1.4 of this specification and the requirements listed below.

1.3.1 The fully detailed plans shall be prepared in ink on permanent, archival quality, 22 inch by 34 inch (559 by 864 mm) double matte mylar (minimum 4 mil thickness) with Project Name, Number and Proprietary Firm Name. All dimensions and elevations shall use the English system of units and the project datum.

1.3.2 The plans and calculations shall be prepared, stamped and signed by a Licensed Professional Engineer in the State of New Hampshire and shall be submitted a minimum of 45 days prior to beginning any wall related construction.

1.3.3 The MSE wall design calculations shall include a complete and thorough set of hand calculations that are specific to this project to support any computer generated calculations. The calculations shall include all applicable references to the LRFD code. A detailed explanation of any symbols and computer programs used in the design shall be provided. The design calculations shall be provided for external stability (sliding, overturning, and maximum bearing pressure) of the final wall configuration, and internal stability within each layer of reinforcement (tensile stress, pullout resistance and tensile stress at the connection with the facing) for the applicable strength and extreme event limit states. Calculations shall be performed in English units, with the final calculation results shown in English units.

1.3.3.1 The design calculations for internal and external stability of the MSE wall shall incorporate the effects of the guardrail system loads, stub abutment spread footing loads, rail support slab/barrier loads and stub abutment pile loads, where applicable.

1.3.3.2 The design calculations and associated design parameters, including the pullout resistance of the tensile reinforcement shall account for the frictional, gradation and strength characteristics of the specific reinforced backfill materials that are provided by the Design-Builder for the project.

1.3.4 Plan and elevation sheets shall be provided and shall contain the following information:

A. Elevation view of the wall that shall indicate the elevation at the top of the wall at all horizontal and vertical break points and at least every 50 feet (20 m) along the wall, elevations at the top of leveling pads, the designation as to the type of panel, the length, size and number of tensile reinforcement strips or grids, and the location of the original and final ground line.

B. Plan view of the wall that shall indicate the offset from the construction centerline to the face of the wall at all changes in horizontal alignment, the limit of the tensile reinforcement, the centerline of any drainage structure or drainage pipe that is behind or passes under or through the wall, and the location of bearing piles.

C. Any general notes required for design and construction of the wall.

D. All horizontal and vertical curve data affecting wall construction.

E. Summary listing of quantities provided on the elevation sheet of each wall for all items including subsidiary items.

F. Cross section showing limits of construction and the limits and extent of the tensile reinforcement and associated granular backfill.

1.3.5 Detail sheets shall be provided and shall contain the following information:

A. All details for foundations and leveling pads, including the maximum calculated bearing pressures (factored).

B. All details for the facing panels including all dimensions necessary to fabricate the panels and all reinforcing steel in the panels and the location of tensile reinforcement connection devices embedded in the panel.

C. All reinforcing bar bending details.

D. All details for construction of the wall around bearing piles, drainage facilities, rail posts, utilities or other items located within the reinforced soil volume.

E. All details for connections to traffic barriers, copings, parapets, attached lighting and other structures.

F. Details for tensile reinforcement connections to stub abutments, if applicable.

1.4 Design Criteria. The MSE wall design shall meet all applicable requirements from the 2007 AASHTO LRFD Bridge Design Specifications as amended through 2010 for the applicable strength and extreme event limit states. Design criteria shall include the following:

A. Traffic loads shall be based on LRFD Section 11.10.10.2 with a soil unit weight of 125 pounds per cubic foot (19.7 kilonewtons per cubic meter).

B. The Extreme Event limit state shall be included in the wall analysis.

C. The reinforced soil shall assume a soil friction angle of 34 degrees and a soil unit weight of 125 pounds per cubic foot (19.7 kilonewtons per cubic meter). The retained soil shall assume a soil friction angle of 30 degrees and a soil unit weight of 120 pounds per cubic foot (18.9 kilonewtons per cubic meter).

D. The design life of the MSE structure based on corrosion shall be 125 years for inextensible tensile reinforcement located above the impervious membrane, and 100 years for all inextensible tensile reinforcement located below the impervious membrane, and all extensible tensile reinforcement.

E. The nominal bearing resistance (q_n) for the MSE walls shall be based on the site specific geotechnical evaluation. The associated resistance factor shall be equal to 0.65 as defined in Table 11.5.6-1 of the LRFD code for the strength limit states and 1.0 for the Extreme Event limit states as defined in Section 11.5.7 of the LRFD code.

F. The coefficient of sliding resistance at the base of the MSE wall shall be based on Sections 11.10.5.3 of the LRFD code using φ_f equal 30 degrees. The associated resistance factor shall be equal to 1.0 as defined in Table 11.5.6-1 of the LRFD code.

G. MSE walls shall be designed so that the tensile reinforcement does not conflict with stub abutment footings, bridge approach slabs, rail support slabs or soundwalls. The contract plans should be referenced for relevant design information for stub abutment footings, approach slabs, rail support slabs or soundwalls. The uppermost level of tensile reinforcement shall be located a minimum of 6 inches below the bottom of an overlying slab or footing. Calculations that demonstrate sufficient structural capacity shall be provided for MSE panels that require an extended cantilevered section above the uppermost row of tensile reinforcement.

H. The MSE wall design shall include any temporary loads or conditions that may occur during the construction phase, including equipment loads, and the effects of any surface or subsurface water infiltration into the MSE wall construction site.

Materials

2.1 The Design-Builder shall make all arrangements to purchase the materials covered by this section of the specifications, including concrete facing panels, concrete coping, concrete cap slab, concrete slip joint posts, tensile reinforcement, connection devices, fasteners, joint materials, impervious membrane, perforated and non-perforated pipe, geotextile and all necessary incidentals from the approved MSE wall system supplier. The Design-Builder shall furnish the Engineer a Certificate of Compliance, meeting the requirements of Section 106.04, certifying that the applicable materials comply with this section of the specifications. Materials not conforming to this section of the specifications shall not be used without the written consent of the Engineer.

2.2 Concrete Facing Panels Precast concrete facing panels shall have a minimum thickness of 5 1/2 inches (140 mm) exclusive of the form liner pattern, and a minimum concrete cover on reinforcing steel of 1-1/2 inches (38 mm). Cement shall be Type II and shall conform to the requirements of AASHTO M 85. Concrete shall have a minimum compressive strength of 5000 psi (35 MPa) at 28 days and meet all other requirements of Concrete Class A as specified in Section 520. A corrosion inhibitor (calcium nitrate) admixture from the Qualified Products List shall be used at the rate recommended by the manufacturer, and as approved. Panels shall be reinforced with steel bars that are galvanized in accordance with AASHTO M111 or ASTM A767/767M. Lifting devices shall be set in place to the dimensions and tolerances shown on the approved shop drawings prior to casting. All concrete components shall meet or exceed specifications listed in Section 520.

2.2.1 Testing and Inspection. Acceptability of the panels shall be determined on the basis of compliance with the properties specified for Class A concrete in Section 520, compliance with the requirements in Section 2.2 of this specification, and visual inspection. The Design-Builder shall furnish all necessary facilities and access for the Engineer to sample, test and inspect the panels in an expeditious and satisfactory manner. The Design-Builder shall furnish all necessary facilities and shall perform sampling and testing to measure the compressive strength of the concrete in an expeditious and satisfactory manner as outlined in Section 2.2.7.

2.2.2 Casting. The concrete in each panel shall be placed without interruption and shall be consolidated by the use of an approved vibrator, supplemented by such hand tamping as may be necessary to force the concrete into the corners of the forms and to prevent the formation of stone pockets or cleavage planes. Clear form oil or release agent shall be used on the forms prior to each casting operation.

2.2.3 Curing. The panels shall be cured as specified in Section 520.3.10, and as approved. Any production lot which does not conform to the strength requirements shall be rejected.

2.2.4 Removal of Forms. The forms shall remain in place until they can be removed without damage to the panel.

2.2.5 Concrete Finish. The front face of the panels shall have a form liner finish as described in 1.1.7. The rear face of the panels shall have an unformed finish and shall be free of open pockets of aggregate and surface distortions in excess of 1/4 inch (6 mm). The front face of the panels shall be coated with water repellent, as described in 1.1.8.

2.2.6 Tolerances. All panels shall be manufactured within the following tolerances with respect to the dimensions shown on the approved shop drawings:

A. Connection Device Locations and Alignment. Individual reinforcing strip connection devices shall be positioned within one inch (25 mm). Multiple connection points for a single reinforcement grid shall be positioned within 1/8 inch (3 mm). Embedment measured from the back face of the panel shall be within + 1/4 inch to –1/2 inch (+6 mm to –12 mm).

B. Panel Dimensions. All panel dimensions shall be within 1/4 inch (6 mm). All hardware embedded in the panel with the exception of connection devices shall be within 1/4 inch (6 mm).

C. Panel Squareness. Squareness, as determined by the difference between the two diagonals, shall not exceed 1/2 inch (12 mm).

D. Panel Surface Finish. Surface defects on smooth-formed surfaces, measured on a length of 5 feet (1.5 m) shall not exceed 1/4 inch (6 mm). Surface defects on textured-finished surfaces, measured on a length of 5 feet (1.5 m) shall not exceed 5/16 inch (8 mm).

2.2.7 Compressive Strength. Acceptance of the panels, with respect to compressive strength, shall be determined on the basis of production lots. A production lot is defined as a group of panels that shall be represented by a single set of compressive strength samples and shall consist of not more than 20 panels or a single day's production, whichever is less.

2.2.7.1 During the production of the panels, the manufacturer shall randomly sample the concrete in accordance with AASHTO T 141. A single set of compressive strength samples, consisting of a minimum of four cylinders, shall be made for every production lot.

2.2.7.2 For every compressive strength sample, a minimum of two cylinders shall be cured in the same manner as the panels and tested at 7 days or less. The average compressive strength of these cylinders, when tested in accordance with AASHTO T 22, will determine the initial strength of the concrete. In addition, a minimum of two cylinders shall be cured in accordance with AASHTO T 23 and tested at 28 days. The average compressive strength of these cylinders, when tested in accordance with AASHTO T 22, will determine the compressive strength of the production lot.

2.2.7.3 If the initial strength test result indicates a compressive strength greater than or equal to the required 28-day strength, then this test result will be utilized as the compressive strength test results for that production lot, and the requirement for testing at 28 days will be waived for that particular production lot.

2.2.7.4 Acceptance of a production lot will be made if the compressive strength test result is greater than or equal to the required 28-day strength. If the compressive strength test results is less than the required 28-day strength, the acceptance of the production lot will be based on its meeting the following acceptance criteria in its entirety:

A. Ninety percent of the compressive strength test results for the overall production shall exceed 1.0375 times the required 28-day strength.

B. The average of any six consecutive compressive strength test results, including the one in question, shall exceed 1.0625 times the required 28-day strength.

C. No individual compressive strength test result shall fall below 0.9 times the required 28-day strength.

2.2.7.5 In the event that a production lot fails to meet the specified compressive strength requirements, the production lot shall be rejected. Such rejection shall prevail unless the Design-Builder, at no cost to the Department, obtains and submits evidence of a type acceptable to the Engineer that the strength and quality of the concrete placed in the panels within a production lot is acceptable. If such evidence consists of tests made on cores taken from the panels within the production lot, the cores shall be obtained and tested in accordance with AASHTO T 24.

2.2.8 Rejection. Panels shall be subject to rejection because of failure to meet any of the requirements specified above. In addition, any or all of the following defects may be sufficient cause for rejection:

A. Defects that indicate imperfect molding.

B. Defects indicating honeycombed or open-texture concrete.

C. Defects in the physical characteristics of the concrete, such as broken or chipped concrete.

2.2.9 The Engineer shall determine whether spalled, honeycombed, chipped or otherwise defective concrete shall be repaired or be cause for rejection. Repair of concrete, if allowed, shall be done in a manner satisfactory to the Engineer. Repair to concrete surfaces which will be exposed to view after completion of construction must be approved by the Engineer.

2.2.10 Marking. The date of manufacture, the production lot number, and the piece-mark shall be clearly scribed on the rear face of each panel.

2.2.11 Handling, Storage and Shipping. All panels shall be handled, stored and shipped in such a manner as to eliminate the potential for chips, cracks, fractures and excessive bending stresses. Panels shall be stored and shipped in stacks, front face down. Firm blocking, of sufficient thickness to prevent the attachment devices from contacting the panel above, shall be located immediately adjacent to the attachment devices. Lifting inserts shall be installed on the top edge of the panels to permit lifting at the project site. Reinforcement connection inserts (tie strips or loop inserts) shall not be used for lifting or handling the panel.

2.3 Tensile Reinforcement and Connection Devices. All tensile reinforcement and panel connection devices shall be carefully inspected to ensure they are true to size and free from defects that may impair their strength and durability.

2.3.1 Ribbed Reinforcing Strips. Ribbed reinforcement strips shall be hot rolled from bars to the required shape and dimensions. Their physical and mechanical properties shall conform to ASTM A 572/A 572M grade 65 (450) or equal. Galvanizing shall conform to the requirements of

AASHTO M 111 (ASTM A 123). The minimum coating thickness shall be 2 ounces per square foot (605 grams per square meter).

2.3.2 Ladder Reinforcing Strips. Ladder reinforcement strips shall be shop fabricated of cold drawn steel wire conforming to the minimum requirements of AASHTO M 32/M 32M (ASTM A 82) and welded into the finished strip configuration in accordance with AASHTO M 55/M 55M (ASTM A 185). The longitudinal and transverse wires shall be of the same size. Galvanizing shall be applied after the ladder strips are fabricated and shall conform to the minimum requirements of AASHTO M 111 (ASTM A 123). The minimum coating thickness shall be 2 ounces per square foot (605 grams per square meter).

2.3.3 Wire Grid Reinforcement. Wire grid reinforcement shall be shop fabricated of cold drawn steel wire conforming to the minimum requirements of AASHTO M 32/M 32M (ASTM A 82) and welded into the finished grid in accordance with AASHTO M 55/M 55M (ASTM A 185). The longitudinal and transverse wires shall be of the same size. The maximum spacing between longitudinal wires shall be 6 inches (150 mm) and the maximum spacing between transverse wires shall be 24 inches (600 mm). A minimum of 4 longitudinal wires shall be provided for each grid, unless otherwise approved for unique panel locations that cannot accommodate a 4 wire configuration. For grids with less than 4 longitudinal wires, the tensile load calculated using the methods defined in 1.4 shall be multiplied by the ratio of 4 divided by the number of provided longitudinal wires to determine the tensile load used for the internal stability analysis. Galvanizing shall be applied after the grid is fabricated and shall conform to the minimum requirements of AASHTO M 111 (ASTM A 123). The minimum coating thickness shall be 2 ounces per square foot (605 grams per square meter).

2.3.4 Tie Strips. Tie strips shall be shop fabricated of hot rolled steel conforming to the minimum requirements of ASTM A 1011/A 1011M SS, Grade 50 or equivalent. Galvanizing shall conform to the minimum requirements of AASHTO M 111 (ASTM A 123), or AASHTO M 232 (ASTM A 153). The minimum coating thickness shall be 2 ounces per square foot (605 grams per square meter).

2.3.5 Wire Tie Strips and Loop Inserts. Wire tie strips and loop inserts shall be shop fabricated of cold drawn steel wire conforming to the minimum requirements of AASHTO M 32/M 32M (ASTM A 82). Galvanizing shall conform to the minimum requirements of AASHTO M 111 (ASTM A 123). The minimum coating thickness shall be 2 ounces per square foot (605 grams per square meter).

2.3.6 Fasteners. Fasteners shall consist of ½-inch (12 mm) minimum diameter hexagonal cap screw bolts and nuts conforming to the minimum requirements of AASHTO M 164 (ASTM A 325) or equivalent. Galvanizing shall conform to the minimum requirements of AASHTO M 232 (ASTM A 153).

2.3.7 Connector Bars and Pins. Connector bars and pins shall be fabricated from cold drawn steel wire conforming to the minimum requirements of AASHTO M 32/M 32M (ASTM A 82) and shall be galvanized in accordance with the requirements of AASHTO M 111 (ASTM A 123). The minimum coating thickness shall be 2 ounces per square foot (605 grams per square meter).

2.3.8 Structural Connectors. Structural plate connectors and fasteners used for yokes to connect soil reinforcing to facing panels around pile or utility conflicts shall conform to the material requirements of 2.3.4 Tie Strips and 2.3.6 Fasteners, stated above.

2.4 Joint Materials. Joint materials shall be as specified by the wall supplier subject to the following requirements:

2.4.1 Bearing Pads. Bearing pads shall be preformed rubber pads having a durometer hardness of 80 ± 5.

2.4.2 Joint Cover. Horizontal and vertical joints between panels shall be covered by a geotextile. The geotextile may be either a non-woven needle punched polyester geotextile or a woven monofilament polypropylene geotextile as approved by the wall supplier. Adhesive used to hold the geotextile filter fabric material to the rear of the panels prior to backfill placement shall be approved by the wall supplier.

2.5 Granular Backfill for MSE Walls (Item 209.5). Material used for Item 209.5 within the reinforced soil volume or within other areas as detailed on the plans shall conform to the material requirements contained in the Special Provision Amendment to Sections 209 for Item 209.5. Construction requirements for Item 209.5 are provided below in 3.6.

2.6 Clean Stone for Structural Fill (Item 508). Material used within MSE structures for Clean Stone for Structural Fill below the stub abutment footing shall conform to applicable requirements of Section 508 and to the plasticity, soundness and electrochemical requirements defined in the Special Provision Amendment to Section 209 for Item 209.5.

2.7 Concrete for Leveling Pads. Concrete for cast in place leveling pad shall conform to the requirements of Concrete Class B as specified in Section 520.

2.8 Non-Woven Geotextile. Geotextile used directly above the impervious membrane shall be a medium strength, non-woven geotextile that meets the property requirements of Item 593.1.2.1.

2.8.1 At least two weeks prior to installation of the geotextile, the Design-Builder shall submit a certificate of compliance in accordance with 106.04. Each roll shall be clearly labeled so as to easily identify the product in the field. The label shall include as a minimum, the manufacturer's name, product name and number and the contract item name and number.

2.9 Impervious Membrane. The impervious membrane shall be a 0.75 mm (30 mil) PVC sheet, compounded from first quality domestic virgin material of single ply construction, having polyvinyl chloride as its principal polymer. The membrane shall be produced so as to be free of holes, undispersed raw materials or blisters and shall meet the following physical requirements:

Property	Test Method	Property Requirements
Thickness [mil (mm)]	ASTM D 1593	30 (0.75) ± 5% min.
Specific Gravity	ASTM D 792	1.20 min.
Dimensional Stability (% change)	ASTM D1204	5 max.
Tensile Strength [pounds per square inch (kPa)]	ASTM D 882	2300 (16,000) min.
Tear Resistance [pounds (N)]	ASTM D 1004 Die C	8 (35) min.
Low Temperature Brittleness [°F (°C)]	ASTM D 1790	-20 (-30) min.
Resistance to Soil Burial (% strength retained)	ASTM D 3083	95 min.
Hydrostatic Resistance [pounds per square inch (kPa)]	ASTM D 751 Method A	75 (520) min.

2.9.1 At least two weeks prior to installation of the impervious membrane, the Design-Builder shall submit a certificate of compliance in accordance with 106.04. The membrane shall be clearly labeled so as to easily identify the product in the field. The label shall include as a minimum, the manufacturer's name, product name and number and the contract item name and number.

2.9.2 All factory seams and field seams shall have a strength at least equal to the specified sheet strength. The factory fabricated panels shall be a size that can be easily handled on the job site with conventional construction equipment. The panels should be as large and as square as possible to minimize the amount of field seaming required.

2.10 Perforated and Non-Perforated Pipe. Perforated pipe shall be smooth-wall polyvinyl chloride (PVC) conforming to AASHTO M 278, profile-wall PVC conforming to AASHTO M 304 or corrugated polyethylene drainage tubing conforming to AASHTO M 252, with Class 2 perforations, except that the required pipe stiffness shall be a minimum of 60 psi (400 kPa). Individual pipe lengths shall not exceed 20 ft (6 m). The non-perforated pipe shall be the same as the perforated pipe, without perforations.

2.11 Wall Coping. Concrete for cast-in-place wall coping shall conform to the requirements of Concrete Class AA as specified in Section 520. Concrete for precast wall coping shall conform to 2.2. The wall coping shall be coated with water repellent, as described in 1.1.8.

2.12 Reinforcing Steel. Reinforcing steel shall conform to Section 544. Reinforcing steel in the precast concrete facing panels shall be galvanized as described in 2.2. Reinforcing steel in the wall copings shall be epoxy coated.

Construction Requirements

3.1 Coordination Meeting. A coordination meeting shall be held prior to initiating the MSE wall construction and related work. The purpose of the meeting shall be to review all aspects of the MSE wall construction and to facilitate coordination between all parties involved. The coordination meeting shall not take place until the Design-Builder has submitted and received approval for the MSE wall design. Individuals attending the meeting shall include the Engineer, the Design-Builder, the MSE wall Technical Representative, the Bridge Engineer and the Geotechnical Engineer from the Materials and Research Bureau and all other personnel deemed appropriate by the previously mentioned personnel. The Bridge Engineer and the Geotechnical Engineer shall be notified at least 7 days in advance of the meeting.

3.2 Wall Supplier's Representative. The Design-Builder shall make the necessary arrangements with the wall supplier to have a Technical Representative on the project to supervise the initial construction of the wall. The Technical Representative shall also be required to be on-site at any time during wall construction as requested by the Engineer. When a Technical Representative has been requested by the Engineer, no wall construction shall be allowed until the Technical Representative has arrived at the project site.

3.3 Foundation Preparation. The foundation for the structure shall be graded level for a width equal to or exceeding the length of the tensile reinforcement, or as shown on the plans. Prior to wall construction, the foundation, if not in rock, shall be compacted with approved compaction equipment. Any foundation soils found to be unsuitable shall be removed and replaced as directed by the Engineer. At each panel foundation level, an unreinforced concrete leveling pad shall be provided as shown on the plans. The leveling pad shall have minimum nominal dimensions of 6 inches by 12 inches (150 mm thick by 300 mm wide). The leveling pad shall be cast to the design elevations as shown on the plans. Allowable elevation tolerances are plus 1/8 inch (3 mm) and minus 1/4 inch (6 mm) from the design elevation. The leveling pad shall be cured in accordance with 520.3.10. The requirements of 520.3.11 shall be followed before placement of wall panels.

3.4 Wall Erection. Precast concrete facing panels may be placed in the wall when the initial strength of the panels equals or exceeds 85 percent of the 28-day requirement. Panels shall be placed vertically with the aid of a light crane. For erection, panels shall be handled by means of lifting devices set into the upper edge of the panels. Panels shall be placed in successive horizontal lifts in the sequence shown on the approved shop drawings as backfill placement proceeds. A geotextile shall be placed along each panel joint as indicated on the approved shop drawings. As backfill material is placed and compacted behind the panels, the panels shall be maintained in a vertical position by means of shoulder clamps to adjacent panels and temporary wooden wedges placed in the joint at the junction of the two adjacent panels on the external side of the wall. External bracing is required for the initial lift.

3.4.1 The maximum allowable offset in any panel joint shall be 3/4 inch (19 mm). Vertical and horizontal alignment tolerances shall not exceed 3/4 inch in 10 feet (19 mm in 3 m). The overall vertical tolerance of the wall (plumbness from top to bottom) shall not exceed 1/2 inch per 10 feet (12 mm per 3 m) of wall height.

3.4.2 Joint materials and bearing pads shall be installed in accordance with the wall supplier's requirements and the details shown on the approved shop drawings.

3.5 Placement of Tensile Reinforcement. Prior to placing the first layer of tensile reinforcement, backfill shall be placed and compacted in accordance with Section 3.6.

3.5.1 Bending of tensile reinforcement in the horizontal plane that results in a kink in the reinforcement shall not be allowed. Gradual bending in the vertical direction that does not kink the reinforcement is allowable.

3.5.2 Connection of tensile reinforcement to bearing piles, or bending of reinforcement around piles will not be allowed. A minimum 3 inch (75 mm) clearance shall be provided between tensile reinforcement and adjacent steel bearing piles. Cutting of tensile reinforcement longitudinal wires to avoid conflicts with piles or utility obstructions will not be allowed. A structural connection (yoke) from the wall panel to the tensile reinforcement shall be used whenever it is necessary to avoid cutting or excessive skewing of reinforcement due to pile or other conflicts.

3.5.3 Tensile reinforcement shall be placed normal to the face of the wall, unless otherwise shown on the approved shop drawings, or directed by the Engineer. If skewing of the reinforcement is required due to obstructions in the reinforced fill, rotatable connections shall be used. The maximum skew angle shall not exceed 15 degrees from the normal position unless specifically addressed in design calculations that support the adequacy of the skewed reinforcement.

3.5.4 The tensile reinforcement shall be placed so as to not conflict with the subsequent installation of any driven guardrail systems located within the reinforced zone.

3.6 Granular Backfill Placement. The placement of granular backfill shall closely follow erection of each course of panels. Backfill shall be placed in such a manner as to avoid any damage or disturbance to the wall materials or misalignment of the facing panels. Any wall materials which become damaged or disturbed during backfill placement shall be either removed and replaced at the Design-Builder's expense or corrected, as directed by the Engineer. Any backfill material placed within the reinforced soil volume that does not meet the requirements of this specification shall be corrected or removed and replaced at the Design-Builder's expense, as directed by the Engineer.

3.6.1 Testing Requirements. The maximum dry density and optimum moisture content shall be determined in accordance with AASHTO T 99, Method C or D (with oversize correction, as outlined in Note 7 of AASHTO T 99). The in-place density determination shall be made in accordance with 304.3.7.

3.6.1.1 The frequency of sampling of select granular backfill material necessary to assure gradation control throughout construction shall be as directed by the Engineer. If 30 percent or more of the select granular backfill material is greater than 3/4 inch (19 mm) in size, AASHTO T 99 is not applicable. For such a material, the acceptance criteria for control of compaction shall be either a minimum of 70 percent of the relative density of the material as determined by ASTM D 4253 and D 4254, or a method specification, based on a test compaction section, which defines the type of equipment, lift thickness, number of passes of the specified equipment, and placement moisture content.

3.6.2 Density Requirements. Granular backfill shall be compacted to 95 percent of maximum dry density as defined in 3.6.1.

3.6.2.1 Compaction within 3 feet (900 mm) of the back face of the panels shall be achieved by at least three passes of a lightweight mechanical tamper, roller or vibratory system. The specified lift thickness shall be adjusted as warranted by the type of compaction equipment actually used, but no soil density tests need be taken within this area. Care shall be exercised in the compaction process to avoid misalignment of the panels or damage to the connection devices. Heavy compaction equipment shall not be used to compact backfill within 3 feet (900 mm) of the wall face.

3.6.3 Lift Thickness and Placement Requirements. The maximum loose lift thickness shall not exceed 12 inches (300 mm), regardless of the vertical spacing between layers of tensile reinforcement. The Design-Builder shall decrease this lift thickness, if necessary to obtain the specified density. Prior to placement of the tensile reinforcement, the backfill elevation after compaction shall be 2 inches (50 mm) above the connection device elevation from a point approximately 12 inches (300 mm) behind the back face of the panels to the free end of the reinforcement, unless otherwise shown on the plans.

3.6.3.1 At the end of each day's operation, the Design-Builder shall slope the last lift of backfill away from the wall facing to direct runoff of rainwater away from the wall face. In addition, the Design-Builder shall not allow surface runoff from adjacent areas to enter the wall construction site. The Design-Builder shall be responsible for the repair of any damage to the MSE wall that results from surface or subsurface flow of water into the MSE wall construction site in accordance with 3.7.

3.7 Wall Repair. Any portion of a fully or partially constructed MSE wall that is damaged, or that does not meet the required construction tolerances shall be repaired by the Design-Builder to the satisfaction of the Engineer at no cost to the Department.

Method of Measurement

4.1 The accepted quantity of mechanically stabilized earth retaining wall will be measured by the square foot of wall surface area. The wall surface area shall be taken as the surface area measured from the top of the leveling pad to the top of the concrete wall coping, including the surface area of nominal panel joint openings and wall penetrations such as pipes and other utilities.

4.1.1 Mechanically stabilized earth retaining wall shall include designing and constructing the MSE wall, providing design calculations and shop drawings, and shall include precast concrete facing panels, precast or cast-in-place concrete wall copings, precast concrete slip joint posts, tensile reinforcement, connection devices, fasteners, bearing pads and shims, joint materials, concrete leveling pad, non-woven geotextile, impervious membrane, perforated pipe, wall supplier site visits, concrete and granular backfill testing and incidentals.

4.2 Excavation will be measured in accordance with sections 203 and 504, and as indicated on the plans.

4.3 Backfill will be measured in accordance with Sections 209 and 508, and as indicated on the plans.

Basis of Payment

5.1 The accepted quantity of mechanically stabilized earth retaining wall will be paid for at the contract price per square foot complete and in place.

5.1.1 Payment shall be considered full compensation for all engineering calculations, shop drawings and plans associated with the design of the MSE wall, and for all labor, materials, and equipment to install precast concrete facing panels, precast or cast-in-place concrete wall copings, precast concrete slip joint posts, tensile reinforcement, connection devices, fasteners, bearing pads and shims, joint materials, concrete leveling pad, non-woven geotextile, impervious membrane, perforated pipe, cleanup, wall supplier site visits, and concrete and granular backfill testing.

5.2 Excavation will be paid for under the appropriate items of Sections 203 and 504, and as indicated on the plans.

5.3 Backfill will be paid for under the appropriate items of Section 209 and 508, and as indicated on the plans.

Pay Item and Unit

592.1	Mechanically Stabilized Earth Retaining Wall	Square Foot

S P E C I A L P R O V I S I O N

SECTION 592 – PRECAST CONCRETE MODULAR WALL

Item 592.31 – Precast Concrete Modular Wall

Description

1.1 This work shall consist of designing, furnishing and constructing a precast concrete modular (PCM) retaining wall system in accordance with these specifications and in close conformance with the lines, grades, design and dimensions shown on the plans or established by the Engineer. The PCM wall consists of a concrete leveling pad, precast concrete modules, reinforced precast or cast-in-place concrete coping, granular backfill within the wall limits indicated in the plan sheets, and other items as defined in these specifications or on the plans.

1.1.1 As described in 2.2, the PCM modules shall be reinforced with steel bars that are galvanized, and the concrete mix shall include a corrosion inhibitor (calcium nitrate) admixture from the Qualified Products List.

1.1.2 The exposed PCM face shall have an Ashlar Stone form liner pattern that conforms to Ashlar Stone P/C 30664, Symons Dura-Tex as manufactured by Symons Corporation; or Ashlar Stone No. 330 Multi-Cast, as manufactured by Greenstreak; or approved equal. The form liner pattern shall extend to a minimum of 12 inches below the finished grade at the face of the wall.

1.1.3 Item 534.3, Water Repellant (Silane-Siloxane), shall be applied to the entire wall coping, and to the exposed PCM face to 12 inches below the finished grade at the face of the wall.

1.1.4 All wall systems shall have a precast or cast-in-place concrete coping at the top of wall.

1.2 (Not used)

1.3 Approved Wall Systems. The following proprietary PCM wall systems are approved for this project for stand alone retaining walls with no overlying structures:

A. Doublewal
Doublewal Corporation
7 West Main Street
Plainsville, CT 06062
(860) 793-0295

B. T-Wall
The Neel Company
6520 Deepford Street
Springfield, VA 22150
(703) 922-6778

1.4 Requirements for Supplier Prepared Design and Plans. The Design-Builder shall submit plans and calculations for the wall in conformance with Section 105.02, the design criteria in sections 1.5 through 1.7 of this specification and the requirements listed below.

1.4.1 The fully detailed plans shall be prepared in ink on permanent, archival quality, 22 inch by 34 inch (559 by 864 mm) double matte mylar (minimum 4 mil thickness) with Project Name, Number and Proprietary Firm Name. All dimensions and elevations shall use the English system of units and the project datum.

1.4.2 The plans and calculations shall be prepared, stamped and signed by a Licensed Professional Engineer in the State of New Hampshire and shall be submitted a minimum of 45 days prior to beginning any wall related construction or module fabrication.

1.4.3 The PCM wall design calculations shall include a complete and thorough set of hand calculations that are specific to this project to support any computer generated calculations. The calculations shall include all applicable references to the LRFD code. A detailed explanation of any symbols and computer programs used in the design shall be provided. The design calculations shall be provided for external stability (sliding, overturning, and maximum bearing pressure) of the final wall configuration, and internal stability (sliding, overturning and stem pullout) for each module layer for the applicable strength and extreme event limit states. Calculations shall be performed in English units, with the final calculation results shown in English units.

1.4.4 Plan and elevation sheets shall be provided and shall contain the following information:

A. An elevation view of the wall that indicates the elevation at the top of the wall at all horizontal and vertical break points and at least every 50 feet (15 m) along the wall, elevations at the top of the concrete leveling pads, the designation as to the type and size of all modules and the location of the original and final ground line.

B. A plan view of the wall that indicates the offset from the construction centerline to the face of the wall at all changes in horizontal alignment, the limit of the widest module and the centerline of any drainage structure or drainage pipe that is behind or passes under or through the wall.

C. Any general notes required for design and construction of the wall.

D. All horizontal and vertical curve data affecting wall construction.

E. A summary listing of quantities provided on the elevation sheet for all items including subsidiary items.

F. Cross section showing limits of construction and the limits and extent of select granular backfill.

1.4.5 Detail sheets shall be provided and shall contain the following information:

A. All details for foundations and concrete leveling pads, including the maximum bearing pressures (factored).

B. All details for the precast concrete module including all dimensions to construct the module and all reinforcement steel within the module structure.

C. All reinforcing bar bending details.

D. All details for construction of the wall around drainage facilities and utilities, including details for any cast-in-place concrete headwall designs, and for any required end closures.

1.4.6 The submittal shall include the manufacturer's installation manual for the PCM system.

1.5 General Design Criteria. The PCM wall design shall meet all applicable requirements from the 2007 AASHTO LRFD Bridge Design Specifications as amended through 2010 for the applicable strength and extreme event limit states, including Sections 10.5, 10.6 and 11.11. General design criteria which is applicable to both wall systems shall include the following:

A. Traffic loads and impact loads shall be based on LRFD Section 11.10.10.2 with a soil unit weight of 125 pounds per cubic foot (19.7 kilonewtons per cubic meter).

B. The Extreme Event limit state shall be included in the wall analysis.

C. The soil retained by the wall shall be assumed to have a soil friction angle of 30 degrees and a soil unit weight of 120 pounds per cubic foot (18.9 kilonewtons per cubic meter).

D. The nominal bearing resistance (qn) for the PCM wall shall conform to Section 11.11.4.3 of the LRFD code and shall be based on the site specific geotechnical evaluation. The associated resistance factor shall be as defined in Table 11.5.6-1 of the LRFD code for the strength limit states, and 1.0 for the Extreme Event limit states as defined in Section 11.5.7 of the LRFD code.

E. The sliding resistance of the PCM wall shall conform to Section 11.11.4.2 of the LRFD code.

F. Design calculations shall be provided that verify conformance of the module structural design with the requirements of Section 11.11.5 of the LRFD code, and which also verify that the module is designed to accept all lifting and installation stresses.

1.6 T-Wall Design Criteria. The soil within and vertically above the modules shall be assumed to have the following design values:

A. Shear strength of 32 degrees and unit weight of 120 pounds per cubic foot.

B. fs (soil on soil friction) equal to 0.67

C. Ko (at-rest earth pressure coefficient) equal to 0.47

D. fj (precast concrete on joint material friction) equal to manufacturer's recommendations

E. Stem pullout resistance factor less than or equal to 0.9

1.7 Doublewal Design Criteria. The design of the Doublewal system shall meet the requirements of the referenced AASHTO Specification. The soil within the modules shall be assumed to have design values of 30 degrees for shear strength and 110 pounds per cubic foot (17.3 kilonewtons per cubic meter) for unit weight.

Materials

2.1 The Design-Builder shall make arrangements to purchase the materials covered by this section of the specifications, including concrete modules, lifting devices, joint materials and all necessary incidentals from one of the approved wall system suppliers. The Design-Builder, or the supplier as his agent, shall furnish the Engineer a Certificate of Compliance meeting the requirements of Section 106.04, certifying that the applicable materials comply with this section of the specifications. Materials not conforming to this section of the specifications shall not be used without the written consent of the Engineer.

2.2 Concrete Modules. Concrete modules shall have a minimum concrete cover on reinforcing steel of 1-1/2 inches (38 mm). Cement shall be Type II and shall conform to the requirements of AASHTO M 85. Concrete shall have a minimum compressive strength of 5000 psi (35 Mpa) at 28 days, and shall meet all other requirements of Concrete Class A as specified in Section 520. A corrosion inhibitor (calcium nitrate) admixture from the Qualified Products List shall be used at the rate recommended by the manufacturer, and as approved. Modules shall be reinforced with steel bars that are galvanized in accordance with AASHTO M111 or ASTM A767/767M. Lifting devices shall be set in place to the dimensions and tolerances shown on the plans prior to casting. All concrete components shall meet or exceed specifications listed in Section 520.

2.2.1 Testing and Inspection. Acceptability of the precast modules shall be determined on the basis of compliance with the properties specified for Class A concrete in Section 520, compliance with the requirements in Section 2.2 of this specification, and visual inspection. The Design-Builder shall furnish all necessary facilities and access for the Engineer to sample, test and inspect the modules in an expeditious and satisfactory manner. The Design-Builder shall furnish all necessary facilities and shall perform sampling and testing to measure the compressive strength of the concrete in an expeditious and satisfactory manner as outlined in Section 2.2.7.

2.2.2 Casting. The concrete in each module shall be placed without interruption and shall be consolidated by the use of an approved vibrator, supplemented by such hand tamping as may be necessary to force the concrete into the corners of the forms and to prevent the formation of stone pockets or cleavage planes. Clear form oil or release agent shall be used throughout the casting operation.

2.2.3 Curing. The modules shall be cured as specified in Section 520.3.10, and as approved. Any production lot which does not conform to the strength requirements shall be rejected.

2.2.4 Removal of Forms. The forms shall remain in place until they can be removed without damage to the module.

2.2.5 Concrete Finish. The front face of the panels shall have a form liner finish as described in 1.1.2. The rear face of the panels shall have an unformed finish and shall be free of open pockets of aggregate and surface distortions in excess of 1/4 inch (6 mm). The front face of the panels shall be coated with water repellent, as described in 1.1.3.

2.2.6 Tolerances. All modules shall be manufactured within the following tolerances with respect to the dimensions shown on the shop drawings:

A. Module Dimensions – All module dimensions shall be within 1/4 inch (6 mm).

B. Module Squareness – The module stems or sidewalls shall be perpendicular with respect to the module face in both the horizontal and vertical planes. The acceptable horizontal tolerance shall not exceed 1 inch (25 mm) measured at the end of the stem or sidewalls at its furthest location from the module face. The acceptable vertical tolerance shall not exceed 1/4 inch (6 mm) measured at the end of the stem or sidewalls at its furthest location from the module face.

C. Module Face Squareness – Squareness, as determined by the difference between the two diagonals, shall not exceed 1/2 inch (12 mm) for modules up to 10 feet (3 m) in width and 3/4 inch (19 mm) for modules wider than 10 feet (3 m).

D. Module Face Surface Finish – Surface defects on smooth-formed surfaces, measured on a length of 5 feet (1.5 m), shall not exceed 1/4 inch (6 mm). Surface defects on textured-finished surfaces, measured on a length of 5 feet (1.5 m), shall not exceed 5/16 inch (8 mm).

2.2.7 Compressive Strength. Acceptance of the concrete modules, with respect to compressive strength, shall be determined on the basis of production lots. A production lot is defined as a group of modules that shall be represented by a single set of compressive strength samples and shall consist of not more than 20 modules or a single day's production, whichever is less.

2.2.7.1 During the production of the modules, the manufacturer shall randomly sample the concrete in accordance with AASHTO T 141. A single set of compressive strength samples, consisting of a minimum of four cylinders, shall be made for every production lot.

2.2.7.2 For every compressive strength sample, a minimum of two cylinders shall be cured in the same manner as the modules and tested at 7 days or less. The average compressive strength of these cylinders, when tested in accordance with AASHTO T 22, will determine the initial strength of the concrete. In addition, a minimum of two cylinders shall be cured in accordance with AASHTO T 23 and tested at 28 days. The average compressive strength of these cylinders, when tested in accordance with AASHTO T 22, will determine the compressive strength of the production lot.

2.2.7.3 If the initial strength test result indicates a compressive strength greater than or equal to the required 28-day strength, then this test result will be utilized as the compressive strength test results for that production lot, and the requirement for testing at 28 days will be waived for that particular production lot.

2.2.7.4 Acceptance of a production lot will be made if the compressive strength test result is greater than or equal to the required 28-day strength. If the compressive strength test results is less than the required 28-day strength, the acceptance of the production lot will be based on its meeting the following acceptance criteria in its entirety:

A. Ninety percent of the compressive strength test results for the overall production shall exceed 1.0375 times the required 28-day strength.

B. The average of any six consecutive compressive strength test results, including the one in question, shall exceed 1.0625 times the required 28-day strength.

C. No individual compressive strength test result shall fall below 0.9 times the required 28-day strength.

2.2.7.5 In the event that a production lot fails to meet the specified compressive strength requirements, the production lot shall be rejected. Such rejection shall prevail unless the Design-Builder, at no cost to the Department, obtains and submits evidence of a type acceptable to the Engineer that the strength and quality of the concrete placed in the modules within a production lot is acceptable. If such evidence consists of tests made on cores taken from the modules within the production lot, the cores shall be obtained and tested in accordance with AASHTO T 24.

2.2.8 Rejection. Modules shall be subject to rejection because of failure to meet any of the requirements specified above. In addition, any or all of the following defects may be sufficient cause for rejection:

A. Defects that indicate imperfect molding.

B. Defects indicating honeycombed or open-texture concrete.

C. Defects in the physical characteristics of the concrete, such as broken or chipped concrete.

2.2.9 The Engineer shall determine whether spalled, honeycombed, chipped or otherwise defective concrete shall be repaired or be cause for rejection. Repair of concrete, if allowed, shall be done in a manner satisfactory to the Engineer. Repair to concrete surfaces which will be exposed to view after completion of construction must be approved by the Engineer.

2.2.10 Marking. The date of manufacture, the production lot number, and the piece-mark shall be clearly marked on the back side of each module.

2.2.11 Handling, Storage and Shipping. All modules shall be handled, stored and shipped in such a manner as to minimize the danger of shipping, cracks, fractures and excessive bending stresses.

2.3 Reinforcing Steel. Reinforcing steel within the PCM panels shall conform to Section 544 and shall be galvanized as described in 2.2.

2.4 Joint Materials. Joint materials shall be as specified by the wall supplier, subject to the following requirements:

2.4.1 Bearing Pads. Bearing pads shall be approved by the wall supplier.

2.4.2 Joint Cover. Horizontal and vertical joints between modules shall be covered by a geotextile. The geotextile may be either a non-woven needle punched polyester geotextile or a woven monofilament polypropylene geotextile as approved by the wall supplier. Adhesive used to hold the geotextile filter fabric material to the rear of the front module face prior to backfill shall be approved by the wall supplier.

2.5 Concrete Leveling Pad. Concrete for cast in place leveling pad shall conform to the requirements of Concrete Class B as specified in Section 520.

2.6 Module Backfill. The material used to backfill within, above and behind the modules within the limits indicated in the plans or in this specification shall conform to Granular Backfill (Gravel).

2.7 Wall Coping. Concrete for cast-in-place wall coping shall conform to the requirements of Concrete Class AA as specified in Section 520. Concrete for precast wall coping shall conform to 2.2. The wall coping shall be coated with water repellent, as described in 1.1.3. Reinforcing steel in the wall copings shall conform to Section 544 and shall be epoxy coated.

Construction Requirements

3.1 Coordination Meeting. A coordination meeting shall be held prior to initiating the PCM wall construction and related work. The purpose of the meeting shall be to review all aspects of the PCM wall construction and to facilitate coordination between all parties involved. The coordination meeting shall not take place until the Design-Builder has submitted and received approval for the PCM wall design. Individuals attending the meeting shall include the Engineer, the Design-Builder, the PCM wall Technical Representative, the Project Engineers from Highway Design, Bridge Design and the Geotechnical Section, and all other personnel deemed appropriate by the previously mentioned personnel. The Project Engineers shall be notified at least 7 days in advance of the meeting.

3.2 Wall Supplier's Representative. The Design-Builder shall make the necessary arrangements with the wall supplier to have a technical representative on the project to supervise the initial construction of the wall. The technical representative shall also be required to be on-site at any time during wall construction as requested by the Engineer. When a technical representative has been requested, no wall construction shall be allowed until the technical representative has arrived at the project site.

3.3 Foundation Preparation. The foundation for the structure shall be graded level for a width as shown on the plans. Prior to wall construction, the foundation, if not in rock, shall be compacted as directed by the Engineer. Any foundation soils found to be unsuitable shall be removed and replaced as directed by the Engineer. At each module foundation level, the concrete leveling pad shall be provided as shown on the approved plans. The leveling pad shall have minimum nominal dimensions of 6 inches by 12 inches (150 mm thick by 300 mm wide). The leveling pad shall be cast to the design elevations as shown on the plans. Allowable elevation tolerances are plus 1/8 inch (3 mm) and minus 1/4 inch (6 mm) from the design elevation. The leveling pad shall be cured in accordance with 520.3.10. The requirements of 520.3.11 shall be followed before placement of wall modules.

3.4 Wall Erection.

3.4.1 The modules shall be erected in accordance with the wall supplier's recommendations. Special care shall be taken in setting the bottom course of modules to true line and grade. Assembly of the various components shall be performed in such a manner that no undue strain or stress is placed on the structure. Shims shall not be permitted without prior approval of the Engineer.

3.4.2 The vertical joint opening on the front face of the wall shall not exceed 3/4 inch (19 mm). Vertical tolerances and horizontal alignment tolerances measured from the face line shown on the plans shall not exceed 3/4 inch (19 mm) when measured along an 8-foot (2.4 meter) straightedge. The overall tolerance of the wall from top to bottom shall not exceed 1/2 inch (12 mm) per 8 feet (2.4 meter) of wall height or 1 inch (25 mm) total, whichever is less, measured from the face line shown on the plans.

3.4.3 Joint materials and bearing pads shall be installed in accordance with the wall supplier's requirements and the details shown on the plans.

3.4.4 For T-Wall modules, vertical steps shall be designed and constructed so that horizontal joints between modules consist of continuous horizontal rows along the entire length of the wall.

3.4.5 For Doublewal modules, all modules above the first course shall interlock with the lower courses and vertical joints shall be staggered with each successive course.

3.5 Soil Backfill Placement. Soil backfill materials placed within, behind and above the modules shall be as detailed on the plans. Backfill placement shall closely follow erection of each course of wall modules. Backfill shall be placed in such a manner as to avoid any damage to the wall materials or misalignment of the modules. Any wall components that become damaged or disturbed shall be either removed and replaced at the Design-Builder's expense or corrected, as directed by the Engineer. Any backfill material placed within the soil mass which does not meet the requirements of this specification shall be corrected or removed and replaced at the Design-Builder's expense, as directed by the Engineer.

3.5.1 Testing Requirements. The maximum dry density and optimum moisture content shall be determined in accordance with AASHTO T 99, Method C or D (with oversize correction, as outlined in Note 7 of AASHTO T 99). The in-place density determination shall be made in accordance with 304.3.7.

3.5.1.1 The frequency of sampling of select granular backfill material necessary to assure gradation control throughout construction shall be as directed by the Engineer. If 30 percent or more of the select granular backfill material is greater than 3/4 inch (19 mm) in size, AASHTO T 99 is not applicable. For such a material, the acceptance criteria for control of compaction shall be either a minimum of 70 percent of the relative density of the material as determined by ASTM

D 4253 and D 4254, or a method specification, based on a test compaction section that defines the type of equipment, lift thickness, number of passes of the specified equipment, and placement moisture content.

3.5.2 T-Wall Lift Thickness and Density Requirements. Material placed within the T-Wall modules and behind the T-Wall structure shall be placed in maximum 12 inch (300 mm) thick lifts measured before compaction, and shall be compacted to 95 percent of the maximum dry density.

3.5.3 Doublewal Lift Thickness and Density Requirements. Material placed within the Doublewal module shall be placed in maximum 24 inch (600 mm) thick lifts measured before compaction and shall be compacted to 90 percent of the maximum dry density. Material placed behind the Doublewal structure shall meet the same requirements as in 3.5.2. At no time shall the difference in backfill elevation between the interior and exterior of the wall module exceed 6 feet (1.8 m).

3.5.4 Compaction within 3 feet (0.9 m) of the back face of the modules shall be achieved by at least three passes of a lightweight mechanical tamper, roller or vibratory system. The specified lift thickness shall be adjusted as warranted by the type of compaction equipment actually used, but no soil density tests need be taken within this area. Care shall be exercised in the compaction process to avoid misalignment of or damage to the wall modules. Heavy compaction equipment shall not be used to compact backfill within 3 feet (0.9 m) feet of the wall face.

3.5.5 At the end of each day's operation, the Design-Builder shall slope the last level of backfill to direct runoff of rainwater away from the wall face. In addition, the Design-Builder shall not allow surface runoff from adjacent areas to enter the wall construction site. The Design-Builder shall be responsible for the repair of any damage to the PCM wall that results from surface or subsurface flow of water into the PCM wall construction site in accordance with 3.6.

3.6 Wall Repair. Any portion of a fully or partially constructed PCM wall that is damaged, or that does not meet the required construction tolerances shall be repaired by the Design-Builder to the satisfaction of the Engineer at no cost to the Department.

Method of Measurement

4.1 The accepted quantity of precast concrete modular retaining wall will be measured by the square foot of wall surface area. The wall surface area shall be the surface area measured from the top of the leveling pad to the top of the wall coping, including the surface area of nominal module joint openings and wall penetrations such as pipes and other utilities.

4.1.1 Precast concrete modular wall shall include designing and constructing the PCM wall, providing design calculations and shop drawings, and shall include precast concrete modules and end closure units, precast or cast-in-place concrete wall copings, granular backfill within, above, behind and in front of the modules within the limits indicated in the plans or in this specification, cast-in-place concrete leveling pads, joint materials, geotextile at wall joints, wall suppliers technical representative visits, concrete and granular backfill testing and incidentals.

4.2 Excavation will be measured in accordance with sections 203 and 504, and as indicated on the plans.

4.3 Structural fill (Item 508) placed below the wall modules will be measured in accordance with Section 508, and as indicated on the plans.

Basis of Payment

5.1 The accepted quantity of precast concrete modular retaining wall will be paid for at the contract price per square foot complete and in place.

5.1.1 Payment shall be considered full compensation for all engineering calculations, shop drawings and plans associated with the design of the PCM wall, and for all labor, materials, and equipment to install precast concrete modules and end closure units, precast or cast-in-place concrete wall copings, granular backfill within, above, behind and in front of the modules within the limits indicated in the plans or in this specification, cast-in-place concrete leveling pads, joint materials, geotextile at wall joints, wall suppliers technical representative visits, concrete and granular backfill testing, and incidentals.

5.2 Excavation will be paid for under the appropriate items of Sections 203 and 504, and as indicated on the plans.

5.3 Structural fill (Item 508) placed below the wall modules as indicated on the plans will be paid for under Item 508.

Pay Item and Unit

592.31	Precast Concrete Modular Wall	Square Foot

S P E C I A L   P R O V I S I O N

AMENDMENT TO SECTION 708 -- PAINTS

Amend Appendix B to read:

APPENDIX B

DUPLEX COATINGS - POWDER COATING OVER GALVANIZING

Highlight these requirements:

- Apply galvanizing and powder coating within the same facility (see 1.2);
- Apply first powder coating over galvanizing within a maximum 12-hour window (see 3.4.1).

DESCRIPTION

1.1 GENERAL. This appendix specifies a duplex coating, consisting of hot dip galvanizing and high-performance, shop-applied, thermosetting-based, super-durable powder coatings, for fabricated steel products for exterior use, as shown on the plans or as directed.

1.2 DUPLEX COATING FACILITY. The galvanizer shall be qualified and have demonstrated a minimum of ten years experience in the successful application of hot dip galvanizing using the dry kettle process, and a minimum of five years experience in the successful application of powder coatings over galvanizing within the same facility.

1.3 SCOPE OF WORK. All fabricated products and components, as shown on the plans or as directed, shall be furnished with a duplex coating color finish as described. See Summary Table 1.3.

MATERIALS

2.1 GALVANIZING. Hot dip galvanizing shall conform to AASHTO M111 (ASTM A123) and utilize the dry kettle process in a bath of molten zinc. The galvanizing kettle shall contain special high grade zinc, nickel, and other earthly materials. The galvanizing process shall not include quenching with water or treatment with a chromate conversion coating. Provide thickness of galvanizing specified in the reference standards. Hardware shall be hot dip galvanized in conformance with AASHTO M232 (ASTM A153).

2.2 ABRASIVES. Provide abrasives that are dry and free of oil, grease, and corrosion-producing, or other deleterious contaminants. Provide an abrasive that is sized to produce a dense, consistent, sharp, angular, uniform anchor pattern with a profile height of 1.0-1.5 mils, unless the requirements of the coating manufacturer are more restrictive. The use of iron shot, steel shot, aluminum oxide grit, sand, or coal slag products as blast abrasives, and power wire brushes are NOT permitted. Use approved abrasives [e.g. garnet, stainless steel grit, Dupont StarBlast® XL (fractured), etc.] that will not leave a residue on the galvanized surface after blowing down with compressed air.

2.3 POWDER COATING. The duplex coating shall be a three-coat, shop-applied, oven-cured, high performance, exterior thermosetting powder coating consisting of a durable zinc-rich powder coating primer, a super-durable powder coating topcoat, and a clearcoat applied over hot dipped galvanized (HDG) steel substrates.

Scope of Work - Summary Table 1.3		
Surfaces to be powder coated As shown on the plans (e.g. Item No's) *	Duplex System (2.3)	Final Color (satin)
563.2208, Bridge Rail T2 (Galv-Powder Coat) 563.5208, Bridge Pedestrian Rail (Galv-Powder Coat)	Hot Dip Galvanizing, plus 3 powder coats (i.e. durable primer, super durable topcoat, and clearcoat)	Dark Green Fed # 24109

2.3.1 Furnish powder coating materials from one of the following approved suppliers:

1. AkzoNobel
2. PPG
3. Sherwin Williams
4. TIGER Drylac

2.3.2 The powder coating manufacturer shall certify in writing that:

1. The duplex coating facility applying the powder coating is certified to apply the powder by the coating manufacturer;
2. The powder coating meets or exceeds the following minimum performance requirements for use over hot dip galvanized surfaces:

A. Powder Coat PRIMER;

	Test	Results
1.	Thickness (SSPC PA2)	3 mils (min.)
2.	Abrasion Resistance (ASTM D4060 CS17 Wheel, 1 kg load)	200 mg loss (max)
3.	Adhesion (ASTM D4541)	1050 psi (min)
4.	Corrosion Weathering (ASTM D5894, 13 cycles, 4368 hours)	
	(per ASTM D714 blistering)	Rating: 10
	(per ASTM D610 rusting)	Rating: 7
5.	Impact Resistance (ASTM D2794 Direct)	160 in. lbs.
6.	Flexibility (ASTM D522, 180º bend, 1" mandrel)	Passes
7.	Pencil Hardness (ASTM D3363)	3B
8.	Moisture Condensation Resistance (ASTM D4585, 100º F, 2000 hrs)	Passes, no cracking or delamination
9.	Dry Heat Resistance (ASTM D2485)	250º F

B. Powder Coat TOPCOAT;

	Test	Results
1.	Thickness (SSPC PA2)	5 mils (min.)
2.	Adhesion (ASTM D4541)	1050 psi (min)
3.	Flexibility (ASTM D522, cylindrical mandrel)	Passes
4.	Pencil Hardness (ASTM D3363)	2H
5.	Salt Spray (ASTM B117) 2000 hrs	Passes
6.	Humidity (ASTM D4585) 100º F, 2000 hrs	Passes, no cracking or delamination
7.	Impact Resistance (ASTM D2794 Direct)	160 in. lbs.
8.	Color Retention (ASTM D2244) 10 years	3ΔE (based on inorganic resins)
9.	Chalk Resistance (ASTM D4214)	none
10.	Gloss Retention (ASTM D523) 10 years	45% loss (max)
11.	Xenon Arc Test (ASTM D 4798) 400 hrs	Passes

2.3.3 Provide each coat of powder coating in sufficiently contrasting color to facilitate proper coverage and to distinguish it from previously applied coatings. The previous coat shall be hidden by application of each coat at the specified minimum thickness.

2.3.4 Provide all powder coating materials in sealed, original, containers that are properly marked to allow verification, with applicable material safety data sheets, application instructions and precautions, including the manufacturer's name, type of material, brand name, color, shelf life, purchase order number, lot and batch numbers, and quantity.

2.3.5 Color. The final color of the painted product shall be (see Table 1.3) (satin) unless specified otherwise, closely matching the Federal Standard 595B or RAL Color Standard number, as follows:

Description	Fed Color #	RAL Color Standard
Dark Green	24109	
Black	27038	

2.3.6 Touchup materials. Repair and touch-up materials shall be supplied by the powder coating applicator and applied in accordance with the powder coating manufacturer's recommendations.

2.4 EQUIPMENT.

2.4.1 Inspection Equipment. Provide inspection equipment needed to verify the quality of the entire galvanizing, surface preparation, and powder coating processes, including a Type II dry film thickness gage that can be calibrated, calibration standards, and a mirror for use by the Department.

DUPLEX COATINGS - POWDER COATING OVER GALVANIZING

3.1 GENERAL

3.1.1 Provide all materials, equipment, and labor necessary to perform the scope of work whether or not the material or equipment is specifically identified in this Item. Conduct all galvanizing, surface preparation, powder coating operations, handling, shipment, and installation in a workmanlike manner in conformance with SSPC-PA1, these requirements, and to the reasonable satisfaction of the Department.

3.1.2 [blank]

3.1.3 Specifications. Perform the work in conformance to the Contract requirements, the reference standards, and the coating manufacturer's instructions, respectively.

3.1.3.1 Reference Standards. The latest edition of the following standards and regulations in effect at the time of the Bid form a part of this Specification. A copy of the reference standards applicable to the work shall be available at the shop facility for use by the Department’s representative.

a. American Society for Testing and Materials (ASTM)

1. ASTM A123, Standard Specification for Zinc (Hot Dip Galvanized) Coatings on Iron and Steel Products
2. ASTM A153, Standard Specification for Zinc Coating (Hot Dip) on Iron and Steel Hardware
3. ASTM A385, Standard Practice for Providing High-Quality Zinc Coatings (Hot Dip)
4. ASTM A780, Standard Practice for Repair of Damaged and Uncoated Areas of Hot Dip Galvanized Coatings
5. ASTM D610, Standard Test Method for Evaluating Degree of Rusting on Painted Steel Surfaces
6. ASTM D6386, Standard Practice for Preparation of Zinc (Hot Dip Galvanized) Coated Iron and Steel Product and Hardware Surfaces for Painting.

b. American Association of State Highway & Transportation Officials (AASHTO)

1. AASHTO M111, Zinc (Hot Dip Galvanized) Coatings on Iron and Steel Products
2. AASHTO M232, Zinc Coating (Hot Dip) on Iron and Steel Hardware

c. American Galvanizers Association (AGA)

1. The Inspection of Products Hot Dip Galvanized After Fabrication
2. *Powder Coating over Hot Dip Galvanized Steel*, Powder Coating Journal, Feb 2004, Philip Rahrig, AGA Executive Director
3. *Powder Coating over Galvanized Steel*, Tom Langill, AGA Technical Director

d. Society for Protective Coatings (SSPC)

1. SSPC-SP 1, Solvent Cleaning
2. SSPC-SP 7 / NACE No. 4, Brush Off Blast Cleaning
3. SSPC-PA 1, Shop, Field, and Maintenance Painting

4. SSPC-PA 2, Measurement of Dry Film Thickness with Magnetic Gages

3.1.4 Submittals.

3.1.4.1 Surface Preparation and Powder Coating Plan.

1. Provide a written plan to the Department for applying duplex coatings. Identify the manner of surface preparation, the powder coat system to be applied, film thickness, cure time between coats, repair materials and procedures of typical damage and defects in the duplex coating, and other information needed to successfully apply all coats of the duplex system.

2. Provide material product literature and MSD sheets for the coatings specified, along with test data indicating conformance to the performance criteria required.

3. Verification samples. Submit six 3-inch by 6-inch samples of the full shop-applied duplex coating system and color proposed for use for approval to the Department (Bureau of Bridge Design, Tel. 603-271-2731) a minimum four weeks prior to production coating application. Samples shall be made of the same or comparable material and thickness as production pieces.

4. Submit a Certificate of Compliance stating that the requirements of the contract specifications have been met, in conformance to 106.04.

3.1.4.2 Substitutions or Approved Equals.

1. Substitutions or 'Approved Equals' are defined as meeting the aesthetic, durability, and all other performance criteria described in this specification, and shall be accompanied by proof that the Substitution or 'Approved Equal' meets or exceeds these criteria. Approval is the discretion of the Department. Coatings or processes not matching or exceeding the approved specified process and aesthetic, durablility, and performance criteria shall be removed and replaced at the expense of the Design-Builder and all subcontractors that were involved with the supply of and application of the non-conforming product.

3.1.5 Supplier Coordination.

1. **Fabricator-Galvanizer Coordination**. Prior to fabrication and final submittal of shop drawings to the Department, fabricators shall submit shop drawings to the galvanizer for all metal fabrications to receive shop-applied duplex coatings, to review fabricator's shop drawings for suitability of materials for galvanizing and coatings, and to coordinate any required modifications to fabrications required to be performed by the fabricator.

2. The supplier of steel products shall notify the galvanizer if the chemical composition of the steel to be galvanized exceeds the following limits in order to determine its suitability for processing: 0.25% carbon, 0.22% silicon, 0.04% phosphorous, and 1.3% manganese.

3.2 HOT DIP GALVANIZING (HDG)

3.2.1 Fabricated products shall meet the requirements of ASTM A385 (for material composition, cleanliness, drainage vents, etc.) prior to galvanizing, and galvanized surfaces shall meet the requirements of ASTM D6386 (preparing zinc surfaces for painting), as applicable and as stated herein.

1. Galvanizing: Galvanize materials in accordance with specified standards and this specification. Galvanizing shall provide an acceptable substrate for applied coatings. The dry kettle process shall be used to eliminate any flux inclusions on the surface of the galvanized material.

2. Prior to galvanizing, the steel shall be immersed in a preflux solution (zinc ammonium chloride). The preflux tank shall be 12-14 Baumé and contain less than 0.4 percent iron. The wet kettle process is prohibited.

3. Implement the following procedures to provide the appropriate surface for the material to be galvanized:

   a) Utilize and regularly inspect a monitoring recorder to observe any variances in the galvanizing bath temperature.

   b) The pickling tanks shall contain hydrochloric acid with an iron content less than 8 percent and zinc content less than 3 percent. Titrations shall be taken weekly at a minimum.

   c) All chemicals and zinc content will be tested at least once a week to determine compliance with ASTM standards. All testing will be done using atomic absorption spectrometry or x-ray fluorescence (XRF) equipment at a lab in the galvanizing plant.

3.2.2 Surface Preparation of Hot Dip Galvanizing (HDG)

1. Prepare all surfaces in conformance to the requirements of this Item, and the approved Surface Preparation/Powder coating Plan provided under 3.1.4, Submittals.

2. Prior to powder coating, clean and prepare galvanized surfaces as necessary to remove detrimental contaminants. (See *Powder Coating over Galvanized Steel*, Feb 2010 Tom Langill) for cautions regarding cleaning. If applicable apply cleaning materials with clean lint-free rags or soft bristle brushes frequently changed to prevent reapplying contaminants. After cleaning, rinse thoroughly with hot water and allow the part to dry completely.

3. Prepare galvanized surfaces with SSPC-SP7, Brush-Off Blast Cleaning, using non-metallic abrasives at a reduced nozzle pressure as recommended by the equipment manufacturer, or abraded by approved mechanical means using sanding disks with appropriate abrasive, to thoroughly roughen the entire surface and produce a dense, consistent, sharp, angular, uniform anchor pattern with a profile height of 1.0-1.5 mils, exhibiting a uniform gray color free of any bright, shiny spangles and to an appearance and feel similar to sandpaper.

4. The required thickness of the zinc coating shall be maintained and checked prior to powder coating. Surface preparation shall be acceptable to the powder coating manufacturer's requirements. Additional surface preparation or a tie coat may be considered if required by the powder coating manufacturer and approved by the Department.

5. The substrate surface shall be dry and free from dust, dirt, oil, grease or other contaminants.

3.2.3. Discontinuities. All visually evident detrimental surface imperfections (e.g. flux inclusions, dross inclusions, oil) that are present on galvanized surfaces shall be cleaned, and any high spots, rough areas and edges, spikes, and sharp protrusions shall be removed by grinding to produce a smooth surface. Disbondment (peeling) of galvanizing is not acceptable and the piece shall be regalvanized, or investigated for extent and severity and a repair solution proposed to the Department for approval before corrective action is taken.

3.2.4 Surface profiling shall be performed prior to the formation of "white rust" on the galvanized surface. If any "white rust" is detected by visual means, the galvanizing shall be stripped off and the steel re-galvanized in conformance with these specifications. "White rust" shall be as defined in the Inspection of Products Hot Dip Galvanized After Fabrication, Table IV, by the American Galvanizers Association.

3.2.5 Prior to powder coating galvanized products shall not be nested, stacked or stored with adjacent surfaces touching but shall be kept separated to be remain dry and permit the circulation of air between products.

3.3 GALVANIZED STEEL OUTGASSING.

3.3.1 The galvanized parts shall be subjected to a thermal cycle (i.e. outgassing) after surface profiling and before powder coating application. The thermal cycle should be set at the appropriate temperature and duration for the thickness of the product recommended by the powder coating manufacturer.

3.4 POWDER COAT APPLICATION.

3.4.1 Time limits. The first coat of powder coating shall be applied within twelve (12) hours of galvanizing and within one hour of surface preparation of the galvanized surface and outgassing, at the galvanizer's facility, and in a controlled environment meeting applicable atmospheric requirements, as recommended by the coating manufacturer.

3.4.2 Powder coating application. Pretreatment and powder coating application and curing shall be performed after galvanizing in conformance with the powder coating manufacturer's recommendations and shall consist of the following, unless approved otherwise:

1. Verify that the galvanized surface exhibits the specified degree of cleaning immediately prior to powder coating.

2. The coating and curing facility shall be maintained free of airborne dust and dirt until coatings are completely cured.

3. The powder coating shall be electostatically applied according to the coating manufacturer's written specifications, maintaining even coverage on all parts. The powder shall only be applied when both the ambient temperature is 65º F. or above, and the part surface temperature is between 60º and 95º F., and is (min.) 5º F. higher than the dew point. Relative humidity shall be less than 85 percent (max.).

4. After applying the powder, all parts shall be placed in an oven, cured and bonded at the manufacturer's recommended levels (e.g. approximately 392º F. for 25 minutes). The Design-Builder shall ensure that a stable transfer exists between the powder application system and the curing oven to prevent the loss of powder from the parts.

5. The powder coating shall be applied to a minimum dry film thickness of 3 mils primer and 5 mils topcoat, and in a manner that will ensure a uniform coating without holidays, runs, or detrimental build at edges. A clear coat shall be applied at the manufacturer's recommended thickness.

6. Each coated part shall be visually inspected. Measure the coating thickness with a thickness gauge. Any part that does meet the specified coating thickness may be recoated immediately after lightly abrading (sanding) the surface. Once cured, all parts shall be allowed to cool sufficiently before further handling.

3.4.3 Surface smoothness - Duplex coatings shall exhibit a smoothness (i.e. rugosity) not greater than 4 rug (16-20 microns of variation) when measured by a profilometer over a 1-inch straight line on the surface of metal products less than 24 lbs/ linear foot. The profilometer shall be capable of operating in 1 micron increments.

3.4.4 All fasteners shall be galvanized and fastener components visible to view shall be powder coated. Furnish an application procedure to the Department including which fastener components are to be powder coated. Coating procedures for fasteners are not restricted to the same-facility (1.2) and 12-hour maximum window (3.4.1) restrictions, due to the nature of fastener supply.

1. Bolts - Powder coat bolt heads visible to view. Minor overspray is permitted on the threads.
2. Nuts - Powder coat the exterior surfaces of nuts visible to view and mask off interior surfaces. Nuts not visible to view (e.g. W-beam splice bolts) need not be powder coated.
3. Washers - Powder coat all washers visible to view. Minor overspray is permitted on washer surfaces that are not required to be powder coated.

3.5 INSPECTION.

3.5.1 Quality Control (QC). The applicator is required to conduct and document quality control inspection of the cleaning and powder coating operations including at a minimum, measurements of surface profile, surface cleanliness, dry film coating thickness, and visual inspection for coating defects.

The data shall be recorded in a log maintained at the site and available for the Department's review during working hours.

3.5.2 Quality Assurance (QA). The work is subject to QA inspection by the Department.

1. Facilitate QA inspection as required, including proper notification, allowing adequate time for inspections, and providing access to the work. Furnish, until final acceptance of the coating system, all equipment, reference documents, and instrumentation needed to inspect all phases of the work.

2. Measure the thickness of each coat using nondestructive magnetic dry film thickness gages. Comply with SSPC-PA2 for the calibration and use of gages and the minimum frequency of thickness measurements. QA Inspectors will not be limited by the frequency of thickness measurements of PA2 but will take measurements sufficient to assure that proper thickness is achieved on all surfaces as specified.

3. The presence or activity of Department QA inspections in no way relieves the Design-Builder of the responsibility to comply with all requirements of this Item, and to provide adequate inspections of its own to assure compliance with the requirements of this Item.

4. Finished products will be stamped "Approved" only after the loading has been completed and approved. No material shall be shipped without the prior approval of the Department.

3.6 HANDLING / SHIPPING / INSTALLATION.

3.6.1. **Cure**. Duplex-coated materials shall not be lifted, placed on supports, or loaded for shipment until the shop coating has been adequately cured and inspected.

3.6.2. Protective measures. Exercise care in handling shop-coated materials in the shop, and during storage, shipping, field installation, and subsequent construction to protect the coating from any scraping, marring, or other damage to the surface finish. Coated material shall be insulated from lifting devices and from the scraping and rubbing of parts that would damage the coating, by the use of lifting softeners, nylon slings, padded cables, storage pallets, separators, cushioners, tie-downs, and other approved supports. Individual parts shall be wrapped or padded with effective protective material (e.g. foam, not paper or cardboard).

3.6.3. **Mechanical damage.** Installation operations involve tasks which may damage the finish coating on some areas of the finished product, such as from driving posts, overlapping sections of rail, and installing fasteners. The Design-Builder shall exercise reasonable care to minimize damage to the coating during installation.

3.7 TOUCH-UP AND REPAIRS.

3.7.1 The total repair area shall be less than <u>one quarter of one percent</u> (<u>0.25%</u>) of the area of an individual member*, or the member shall be rejected and regalvanized and recoated with the duplex coating. [The repair area definition is comparable to <u>Rust Grade 7</u> in ASTM D610, *Standard Test*

Method for Evaluating Degree of Rusting on Painted Steel Surfaces.] [*Note - The areas listed in Section 3.6.3 subject to mechanical damage during installation shall be repaired as required but are excluded from the total repair area calculation.]

3.7.2 HDG- Repair damaged galvanizing and bare steel surfaces in accordance with ASTM A780, Standard Practice for Repair of Damaged Hot Dipped Galvanized Coatings, Annex A2. Thoroughly clean damaged areas to produce a clean, bare and dry bright metal surface with a roughened profile and feather into the edges of adjacent undamaged galvanizing. Use a power sanding disk per SSPC-SP3. For bolts use a thorough hand wire brushing and SP1 cleaning as a minimum.

3.7.3 Apply an approved organic zinc-rich repair paint containing 95 percent (min.) zinc by weight in the dry film, according to the manufacturer's recommendations, in two to four coats to a thickness equivalent to the surrounding galvanizing. Silver paint, brite paint, or aluminum paint is not acceptable.

3.7.4 Powder coating - The repair to the powder coat may be a liquid and brushed on or an aerosol and sprayed, whichever is appropriate to achieve an aesthetic finish and as long as the coats, cure, and minimum thickness of the original system are achieved. The Design-Builder shall provide a dry film thickness gage and check the thickness of the repair areas. Touch-ups shall be such that the repair is not noticeably visible from a distance of six feet.

1. The field-touch-up of shop-applied finish coatings shall be performed or supervised by personnel from the duplex coating facility for the warranty to apply.

2. Touch up fasteners in the field after installation, assuming there may be mechanical damage to nuts during tensioning fasteners.

3. Touch-up repair kits in sufficient quantity and touchup instructions shall be provided to the field for each type of shop-applied finish. Additional touchup repair kits and instructions shall be furnished to the Department for use after project acceptance for maintenance repairs.

3.8 FINAL ACCEPTANCE.

Although the Department's QA Inspector may accept the finished duplex coated fabricated products before shipment to the jobsite, final acceptance of the duplex coat system by the Department will occur at the jobsite after installation of the product, and after all coats and repairs have been completed.

3.9 FIVE-YEAR WARRANTY.

Should the duplex system fail within five years after the project has been accepted, the coating shall be repaired or replaced by the Design-Builder at no cost to the State. The extent and method of repair must be acceptable to the Department. System failure does not include damage from external agents, such as scraping from snow removal equipment, vandalism, debris impacts, collisions, etc., or normal loss of gloss and color. Once the duplex system has been accepted, a failure shall mean any visible corrosion, blistering, checking, cracking, or delamination (peeling) of the galvanizing or powder coating resulting from the installation of the product or from the performance of the duplex coating.

POWDER COATING OVER GALVANIZED STEEL

Thomas J. Langill, Ph.D., Technical Director

American Galvanizers Association
Centennial, CO

Abstract: Powder coating over hot dip galvanized steel is an extremely effective corrosion protection system. However, careful surface preparation techniques need to be used to alleviate potential coating failures. The age and characteristics of the galvanized coating should be used to determine what type of surface preparation is needed.

INTRODUCTION

Hot dip galvanized steel parts or assemblies are often required to be painted or powder coated. The reason for powder coating can be to identify the particular structure, for architectural reasons, to provide a particular type of protection, or to extend the service life of an existing structure. The combination of a powder coating system with a hot dip galvanized coating is often referred to as a "duplex system" (1). When powder coating and galvanized steel are used together, the corrosion protection is superior to either protection system used alone (2).

The application of a powder coating system onto a hot dip galvanized surface requires careful surface preparation and a good understanding of both corrosion protection systems. The margin for error is very small when dealing with newly galvanized steel surface preparation. However, there have been many examples of powder coating adhesion problems on older or more moderately aged galvanized steel surfaces, and the most common cause is improper or incomplete surface cleaning and preparation (3). When the surface is cleaned and prepared correctly the combined powder coating and galvanized steel corrosion protection system gives extremely long lifetimes (4). If the powder coating is properly maintained on the galvanized surface there is practically no limit on the life of the structure in terms of corrosion attack.

The adhesion of powder coating onto galvanized steel becomes a very small problem when the galvanized coating has weathered for at least a one-year period. The zinc corrosion products form a very dense, insoluble protective layer that accepts a powder coat readily. A brand new galvanized coating also experiences few adhesion problems within the first 24 to 48 hours after coating. The intermediate period from 24 hours to one year can present some challenges to surface preparation but the corrosion products that are formed on the galvanized surface can be cleaned and the surface can be successfully powder coated.

GALVANIZED COATING

Hot dip galvanized coatings can be applied in two different ways. The parts can be fed into a liquid zinc bath in a continuous roller process where the coating characteristics are highly dependent on the speed of the steel through the liquid zinc bath. The two most common steel products that are hot dip galvanized using the continuous process are sheet and wire. The objective of the continuous process is to deposit a zinc coating that is smooth, thin and composed of nearly all zinc bath metal with very little zinc-iron intermetallic. The coating can be alloyed to form a dull gray intermetallic coating which has a good surface profile and can be easily powder coated.

The second type of hot dip galvanizing process is often called the "batch" process since individual steel pieces or assemblies are dipped in a molten zinc bath as individuals or as groups. The coating is formed by the interdiffusion of zinc and iron. The coating forms four distinct layers or intermetallics. During the batch hot dip galvanizing process, a number of process variables can affect the coating thickness. The primary determiner of coating thickness is the steel chemistry, with the most influential elements being silicon and phosphorous. These two elements promote the interdiffusion of zinc and iron and cause the hot dip galvanized coating to become thick and filled with intermetallic. The coating produced when the steel is reactive contains mainly intermetallics of iron and zinc. This means that the surface will not be bright and shiny, but rather dull gray and slightly rough. This intermetallic surface makes a very good anchor for powder coating systems. The main concern with reactive steel galvanized coatings is the thickness of the coating. If the coating is too thick it may become brittle and will be susceptible to applied stresses that may separate the galvanized coating from the steel underneath. Knowing the silicon and phosphorous content is very important to producing a quality galvanized coating.

GALVANIZED STEEL SURFACE PREPARATION

Successful surface preparation is the key to producing adherent powder coatings and realizing the benefits of a duplex system. There are three basic steps to preparing galvanized surfaces for powder coating: surface cleaning, surface profiling, and out-gassing of the coating.

Surface Cleaning

When cleaning a galvanized surface prior to powder coating, the goal is to remove any dirt, grease or oils. At the same time, care must be taken not to remove too much of the galvanized coating. Alkaline cleaning, ammonia cleaning and solvent cleaning are the most common ways of removing dirt from a galvanized surface. As some cleaners may react differently with different powder coating systems, the powder manufacturer should be consulted for specific reaction problems.

Oil, grease and dirt can be removed by using an alkaline solution in the pH range of 11 to 12, but not greater than 13 as this will damage the zinc coating. Most alkaline cleaning solutions are nominally 2 to 5 percent sodium compounds with small additions of emulsifying or chelating agents. The solution can be applied through dipping, spraying or brushing. If brushing is used, apply the solution with a soft bristle brush, preferably of nylon, definitely not copper or steel bristle brushes. If dipping or spraying the solution, the temperature range that works best is between 140^{o} and 185^{o} F. For newly galvanized steel, a water-based emulsifier can be used to remove contaminants. After cleaning, thoroughly rinse the surface with hot water and allow the part to dry.

Mineral spirits, turpentine, high flash naphtha, and other typical cleaning solvents can be used to clean galvanized surfaces provided they are applied with lint-free rags or soft bristle brushes. The rags and brushes must be changed often to prevent reapplying the contaminants. After cleaning, rinse thoroughly with hot water and allow the part to dry completely.

A solution of 1 to 2 percent ammonia applied with a soft bristle brush can also be used to clean galvanized surfaces, although this method is typically reserved for cleaning parts with zinc skimmings residue. As a piece of steel is removed from the galvanizing kettle, it may pick up particles of oxidized zinc from the bath surface, otherwise known as zinc skimmings. Skimmings residue must be removed prior to painting. After cleaning, thoroughly rinse the surface with hot water and allow the part to dry completely.

Surface Profiling.

In order to provide a good adhesion profile for the powder coating, the galvanized surface must be flat with no protrusions and slightly roughened to provide an anchor profile. During the removal of the galvanized article from the zinc bath, the excess zinc runs down the edges of the part and can sometimes build up at a protrusion or irregular edge. The zinc can also form tears at the edge where it drains off the part. These high spots and tears must be removed before powder coating as they will be very difficult to coat. The high spots and tears are usually ground off with hand tools or power grinders. Care must be taken when performing this operation to insure that the galvanized coating is not removed below the specified thickness.

In order to roughen the typically smooth galvanized surface after cleaning, an abrasive sweep or brush blast may be used. Care should be taken to prevent removing too much of the zinc coating. Particle size for a sweep blast of galvanized steel should range between 200 and 500 microns. Aluminum/magnesium silicate has been used successfully in the sweep blasting of galvanized steel as seen in Fig. 1. Organic media such as corn cobs and walnut shells or minerals such as corundum, limestone and sands with a Mhos hardness of five or less may also be used.

The temperature of the galvanized part when blasting can have a significant affect on the finished surface profile. Sweep blasting while the galvanized part is still warm from the galvanizing process, 175^{o} to 390^{o} F, provides an excellent profile for powder coating. Ambient conditions for sweep blasting are recommended to be less than 50 percent relative humidity and a minimum temperature of 70^{o} F.

The process of sweep blasting should not be confused with the near-white blasting that is used to clean uncoated steel before applying powder coating systems. This near-white blasting will remove the galvanized coating and negate the corrosion protection afforded by the zinc. The process of sweep blasting is best performed by an experienced applicator. If the sweep angle becomes near perpendicular to the galvanized part, the blasting can quickly remove the protective zinc rather than the zinc oxide particle on the surface of the coating.

Galvanized Steel Outgassing

The removal of surface entrapped water and solutions is accomplished by a thermal cycle of the hot-dip galvanized part. Zinc on the surface of the coating can potentially retain air or moisture. Upon heating during the curing stage of the powder coating process the entrapped air or water can release causing pinholes of blisters in the powder coating. The thermal cycle should take place after surface profiling and before the actual powder coating. The thermal cycle should be 25^{o} F or 14^{o} C above the curing temperature of the particular powder coating system. This removal of trapped air or water will significantly lower the potential of pinholes or blisters in the powder coating. For some surface treatments on the galvanized coating there will be a maximum temperature for the thermal cycle since the surface treatments may be adversely affected by higher temperatures.

POWDER COATING SELECTION

The proper selection of a powder coating system for a certain engineering need is the province of the architect and the engineer. There are many options depending on the intended use of the duplex coated part, the application method and place for the powder coating system, environmental concerns, and aesthetics of the total system. Many powder coating companies offer good powder coating systems that are designed to work with galvanized steel. Consult your powder coating manufacturer for the proper powder coating selection.

DUPLEX SYSTEM PERFORMANCE

When hot dip galvanized steel is powder coated, the duplex system provides a more sophisticated manner of corrosion protection. The galvanized coating protects the base steel by providing both cathodic and barrier protection. The powder coating acts as a barrier protection for the hot dip galvanized coating and significantly reduces the corrosion rate of the zinc. The overall affect on the base steel is that the duplex system not only provides hot dip galvanized life plus the paint life but also provides a multiplication factor of 1.5 to 2.3 on the sum of these two lifetimes. This means that a galvanized coating with a lifetime of 75 years and a powder coating system with a lifetime of 30 years together would have a lifetime of 157 to 240 years as a Duplex System. The increased lifetime that can be provided with a combination of powder coating over galvanized steel makes this type of corrosion protection system very attractive for structures designed to last a long time in aggressive atmospheres.

SUMMARY

The powder coating of galvanized steel has been a difficult task for many people. The secret of good powder coating on galvanized steel is the surface preparation of the galvanized surface. If the surface is newly galvanized, that is less than 48 hours out of the zinc kettle, the surface can be powder coated after a surface roughening procedure and a thermal outgassing cycle. If the surface of the galvanized part has been exposed to the environment for more than one year then the surface can be powder coated after the dirt, grease and oils have been removed and the part has been thermal cycled. The most difficult time to powder coat galvanized steel is between one day and one year after it has been galvanized. Following the correct surface preparation procedures can give a satisfactory duplex system.

REFERENCES

(1) J.F.H. van Eijnsbergen, Duplex Systems, Elsevier Science, New York (1994).
(2) F. Porter, Zinc Handbook, Marcel Dekker, Inc., New York (1991).
(3) J.F. Malone, “Painting Hot Dip Galvanized Steel”, Materials Performance, Vol. 31, No. 5, pp. 3942 (1992).

S P E C I A L   P R O V I S I O N

SECTION 801 – BRIDGE MACHINERY

Description

1.1 General

1.1.1 Scope of Work. Sub-sections 7.1, 7.2, 7.3, 7.3, 7.4, 7.5 and 7.6 shall give the general requirements which apply to all machinery. Section 7.1 also applies to the installation of electric motors, brakes, limit switches and position transmitters to be mounted with the machinery but supplied under the Electrical Work. Section 7.1 shall also apply to the installation of the span and counterweight guides but supplied under Structural Work.

1.1.2 All apparatus for controlling the operation of the span drives and all conduits, boxes, wiring, cables and other equipment required to extend the necessary circuits from the control house to the respective components shall be furnished and installed under Division 800 Electrical Pay Items.

1.2 Specifications

The design, workmanship and erection of all machinery components shall meet the applicable requirements of AASHTO 2007 LRFD Design Specifications for Movable Highway Bridges, with subsequent interim revisions, hereinafter referred to as the AASHTO Specifications. In addition, wire ropes shall meet the requirements of AASHTO M 277-06 “Standard Specification for Wire Rope and Sockets for Movable Bridges”.

1.3 Required Drawings and Data

1.3.1 The Design-Builder shall furnish data and drawings on the mechanical equipment as listed below and as required elsewhere in these specifications. Data and charts shall be submitted, or installed on the job, as called for.

1.3.2 The reducer manufacturer shall furnish calculations demonstrating reducers supplied meet requirements as specified by AASHTO and herein. Calculations shall be submitted to the Engineer for approval.

1.3.3 The rope manufacturer shall test the required number of rope assemblies of each type, as assembled with their sockets, to a point of destruction and shall furnish test data to the engineer for review. Rope assemblies that do not meet the required standards for strength shall be replaced in accordance with AASHTO 3.2.8 and 3.2.11.

1.4 Working Drawings

1.4.1 Prepare working drawings in accordance with Section E, in addition to meeting the following requirements:

1. Submit manufacturer's data and/or working drawings for all manufactured and purchased items of machinery for approval.
2. Coordinate the work of the machinery component manufacturers where components interface. Review and approve all shop and working drawings prepared by those Manufacturers for coordination prior to submittal of working drawings to the Department for approval.
3. Ensure working drawings show all parts and that they are completely detailed and dimensioned. Do not use reproductions of plans as base sheets for assembly or erection drawings.
4. List materials and material specifications for each part. Where ASTM or any other standard specifications are used, give the applicable numbers of such specifications.
5. Show required finish machining, including grade of finish in accordance with ANSI B46.1, Surface Texture, and dimensional tolerances and allowances for specific fits in accordance with ANSI B4.1, Preferred Limits and Fits for Cylindrical Parts.
6. Ensure working drawings are prepared according to the provisions of the general requirements of the Standard Specifications as supplemented and amended herein and to the special requirements specified hereinafter. Also, ensure all drawings are prepared according to NHDOT Standards, latest revision.
7. Submittals for each manufactured item must be manufacturer's descriptive literature, drawings, diagrams, performance and characteristic curves, and catalog cuts, and must include the manufacturer's name, trade name, catalog model or number, nameplate data, size, certified layout dimensions, capacity, specification reference, including ASTM, ANSI, Federal Military Specification and any other applicable references, and all other information necessary to establish Contract compliance.
8. Ensure the fits and finishes used are according to any other requirements given hereinafter in this General Specification.
9. Show all external dimensions and clearances necessary for installation and operation of all new machinery components on working drawings.
10. Furnish complete assembly drawings or diagrams for all assemblies and parts, showing each part contained therein and the manufacturer's part number assigned to each part. Ensure the drawings or diagrams are sufficient to enable complete disassembly and reassembly of the assemblies covered. In the event that any part is modified in any manner from the way it is described or delivered

by its original manufacturer, furnish a drawing which details each modification and assign a unique part number to assure the furnishing of replacement parts modified in similar fashion.

11. Furnish certified prints of each manufactured assembly. Certified prints are manufacturer's drawings of proprietary products on which the manufacturer or supplier states mounting dimensions, ratios, speeds, ratings, and any other correctness for use on this specific project. In addition to identifying and describing each part, ensure the certified prints show:
    1. Dimensions of all principal parts comprising the assembly.
    2. Certified external dimensions affecting clearances and required for installation.
    3. Capacity and normal operating ratings.
    4. Recommended lubrication, including location, lubrication fittings and provisions for adding, draining and checking the level of lubricants.
    5. Inspection openings, seals and vents.
    6. Details or description of all fasteners required to mount the assembly.
    7. Gross weight.
    8. Provide certified prints signed by an officer of the manufacturing company.
12. Show in outline on working drawings, all proprietary items and also indicate the method and sequence employed in assembly of bridge machinery and installation of necessary utilities support and service facilities. In addition to identifying and describing each internal part, the assembly drawings of each item must contain dimensions of all principal elements within the item; certified external dimensions affecting interfaces or installations; gross weight capacity and normal operating ratings; method and recommended type of lubrication, including location and type of fittings and provisions for adding, draining, and checking the level of each lubricant employed; inspection openings, seals, and vents; and details of all fasteners used to mount the equipment to its foundation.
13. Create complete shop bills of materials for all machinery parts. If the bills are not shown on the working drawings, furnish prints of the bills in the same manner as specified for the working drawings.
14. State the weight of each piece of machinery on the working drawing upon which it is detailed or billed.
15. Furnish complete assembly and erection drawings. These drawings must give part numbers, match marks, and essential dimensions for locating each part or assembled unit with respect to the bridge structure or foundation.
16. Clearly show and detail all marks or indentations of any type. In general, avoid die-stamping or scoring. Detail all components and assemblies separately to assure correct fabrication, assembly, and erection. Do not use mirror image or opposite hand erection drawings.

17. Provide a suitable title on each working drawing such that it describes the parts detailed thereon and indicate who makes the shop inspection.
18. Submit proof of conformance where equipment or materials are specified conform to requirements of the standards of an organization, such as American Society for Mechanical Engineers (ASME), Underwriters Laboratories (UL), American Gas Association (AGA), and American Refrigeration Institute (ARI), that use a label or listing as method of indicating compliance. The label or listing of the specified organization is acceptable evidence. In lieu of the label or listing, submit a certificate from an independent testing organization adequately equipped and competent to perform such services and approved by the Contracting Officer, stating that the item has been tested in accordance with the specified organization's test methods and that the item conforms to the specified organization's standard or code.
19. As used herein, certified test reports refer to reports of tests conducted on previously manufactured materials or equipment identical to that proposed for use.
20. As used herein, factory tests refer to tests required to be performed on the actual materials or equipment proposed for use. Submit test results according to the provisions of this Contract for laboratory test results.
21. Prepare a list of all machinery items that require lubrication and their recommended cycle for lubrication. Prior to the start up and testing of the machinery, provide the Department a list containing the types of lubricant used and the date it was lubricated.
22. Prepare and submit lubrication charts prepared as working drawings. After final approval, furnish one lubrication chart for each machinery room. Lubrication charts are to be 17” x 24” and framed with durable translucent plastic cover, to be mounted in location approved by the Department. Lubrication charts are to include all machinery items clearly identified that require lubrication, their recommended cycle for lubrication, type of lubricant, and method of application.
23. Submit any departures from the Contract Drawings or these Specifications for approval by the Department. Provide details of such departures and the reasons as soon as practicable in writing. Make no departures from Contract drawings without approval by the Department. Any departure from the Contract documents that are made without this approval, risk being required to remove the equipment, correct any modifications, and replace with approved equipment, components, etc., at no additional cost to the owner..
24. It is the Design-Builder's responsibility to manufacture and install suitable functioning machinery. Review and approval of working drawings by the Department does not relieve the Design-Builder of this responsibility.

1.5 Quality Assurance

1.5.1 Qualifications, Personnel and Facilities

1. Use only products produced by manufacturers regularly engaged in the manufacture of the specified products.
2. Ensure adequate numbers of skilled, trained, and experienced mechanics and millwrights are thoroughly familiar with the requirements and methods specified for the proper execution of the specified work for the fabrication, installation, cleaning, aligning, testing and all other work required. Provide supervisory personnel with a minimum of 2 movable bridge jobs as previous experience in the installation of bridge machinery.
3. Provide adequate plant and all necessary tools and instruments required for the proper performance of the personnel engaged in the execution of the specified work.

1.5.2 2. Codes and Standards

Work under machinery pay items must comply with, but not be limited to, all applicable requirements of the following codes and standards and their abbreviations used in this Specification are as shown:

1. American Association of State Highway and Transportation Officials	AASHTO
2. American Gear Manufacturers Association	AGMA
3. American Iron and Steel Institute	AISI
4. American National Standards Institute	ANSI
5. American Society for Testing and Materials	ASTM
6. American Welding Society	AWS
7. Anti-Friction Bearing Manufacturers Association	AFBMA
8. National Lubricating Grease Institute	NLGI
9. Society of Automotive Engineers	SAE
10. Steel Structures Painting Council	SSPC
11. New Hampshire Standard Specifications	-

1.5.3 Ensure the work meets the requirements of all other codes and standards as specified elsewhere in these Specifications. Where codes and standards are mentioned for any pay item, it is intended to call particular attention to them; it is not intended that any other codes and standards are not applicable if not mentioned.

1.5.4 Rules, Regulations and Ordinances

1. Work must comply with all applicable Federal, State and local rules, regulations, and ordinances.
2. In the event of a conflict between these Specifications and the above-mentioned codes, standards, rules, regulations, and ordinances, the most stringent requirement applies.

1.5.5 Measurements and Verification

1. Dimensions indicated on the Contract Drawings are nominal and are intended for guidance only. Note all variations from the nominal dimensions on the Contract Drawings on the shop drawings.

1.5.6 Substitutions

1. The terms "approved equal", "of equal quality" and "or equal" which appear on the Contract Drawings and in these Specifications are intended to allow the Design-Builder to substitute other manufacturers and model numbers of products of equal quality and rating for those specified.
2. Prior to the ordering of any substitute product, obtain in writing the Department's approval of the equivalence the substitute product. The acceptance of the substitute products is at the sole discretion of the Department who will establish the basis for equivalence and will review the quality of the materials and products described in detail on the submitted working drawings and product data.
3. The Department will review and stamp substitute material either "Approved" or "Revise and Resubmit". Upon return of a working drawing showing rejection, resubmit the working drawing showing the specified product. Rejection shall not in any way result in any extra cost.
4. Approval by the Department of any substitute products does not relieve the Design-Builder of responsibility for the proper operation, performance, or functioning of that product.
5. Where a particular product is specified by a manufacturer's name and catalog or part number in this Specification or on the Contract Drawings, it is specified to establish quality, configuration, and arrangement of parts. An equivalent products made by another manufacturer may be substituted for the specified product subject to the approval of the Department; however, all necessary changes required by the substitution to related machinery, structural, architectural and electrical parts, will be made at no additional cost to the owner.
6. Submit any departures from the Contract Drawings or these Specifications for approval by the Department. Provide details of such departures and the reasons as soon as practicable. Make no departures without approval by the Department. Any departure from the Contract documents that are made without this approval, risk being required to remove the equipment, correct any modifications, and replace with approved equipment, components, etc., at no additional cost to the owner.

1.5.7 Shop Assembly

1. Shop assembly of machinery is covered under Section 7.2 – "Span Operating Machinery".

1.5.8 Specialized Machinery Components Field Installation, Adjustment, and Inspection

1. Furnish manufacturers' service personnel skilled in these specialties during the installation, adjustment, and alignment of all specialized machinery components. Ensure service personnel are properly equipped with all necessary instruments to assure that related components are within acceptable tolerances and to make all necessary adjustments for attaining the specified ratings.

1.5.9 Inspection and Testing

1. Provide no less than 10 working days notice to the Department of the beginning of work at foundries, forge, and machine shops so that inspection may be provided. No materials must be cast, forged, or machined before the Department has been notified where the orders have been placed.
2. Furnish all facilities for the inspection of material and workmanship in the foundries, forge, and machine shops and allow the Inspector designated by the Department free access to necessary parts of the premises. Work done while the Inspector has been refused access or presented in a manner that prevents adequate inspection will automatically be rejected.
3. The Department's Inspector will reject materials or workmanship that does not fulfill the requirements of these Specifications.
4. Inspection at the foundries, forge, and machine shops is intended as a means of facilitating the work and responsibility in regard to imperfect material or workmanship and to avoid the necessity of replacing defective materials or workmanship which are delivered to the job site.
5. Furnish the Department with a copy of all orders covering work performed by subcontractors or suppliers.
6. Furnish, without additional charge, test specimens as required, and all labor, testing machines, tools, and equipment necessary to prepare the specimens and to make the physical tests and chemical analyses required by material specifications. Furnish a copy of all test reports and chemical analyses to the Department.
7. Engineer acceptance is not a bar to their subsequent rejection if materials and parts are later found defective. Replace or make acceptable all rejected material and workmanship at no additional cost to the State – NHDOT.

1.5.10 Defective Materials and Workmanship

1. Remove all machinery rejected during inspection and testing and replace without additional cost.
2. Make no claims on delays resulting from the rejection of material, equipment or work.
3. At no additional cost, correct all defects found during the guarantee period resulting from faulty material, components, workmanship, or installation. The NHDOT reserves the right to make necessary correction with its own forces and charge the resulting costs to the Design-Builder.

1.5.11 Training

1. Provide 3 days of instruction to NHDOT Maintenance personnel. The instruction will include but not be limited to the following with respect to all machinery components.
    1. Brake adjustment and operation
    2. Checking, adding, and purging lubricants to newly installed components
    3. Auxiliary drive operation
    4. Instrument drive and limit switch adjustments

1.6 Delivery and Storage and Protection for Shipment.

A. Machinery parts shall be cleaned of dirt, chips, grit, and all other injurious materials prior to shipping and shall be given a coat of corrosion-inhibiting preservative.

B. Finished metal surfaces and unpainted metal surfaces that would be damaged by corrosion shall be coated as soon as practicable after finishing with a rust-inhibiting preservative. Excepting unfinished metal surfaces inside of gear reducers, this coating shall be removed from operation and from all surfaces prior to painting after erection.

C. Any interface between stainless steel or aluminum and Structural Steel shall receive an Engineer approval coat of zinc-chromate primer prior to assembly.

D. Shims shall be coated prior to shipment with a rust-inhibiting preservative, and before erection, this coating shall be removed from the shims that are used.

E. Machinery parts shall be completely protected from weather, dirt, and all other injurious conditions during manufacture, shipment, and storage.

F. Shaft journals that are shipped disassembled from their bearings shall be protected during shipment and before erection by a packing of oil-soaked waste secured in place by burlap and covered with heavy metal thimbles or heavy timber lagging securely attached. Every precaution shall be taken to ensure that the bearing surfaces are not damaged and that all parts arrive at their destination in satisfactory condition.

G. Assembled units shall be mounted on skids or otherwise crated for protection during handling and shipment.

2. **Packaging and Delivery of Spare Parts**. Spare parts shall be protected for shipment and prolonged storage by coating, wrapping, and boxing.

All spare parts shall be durably tagged or marked with a clear identification showing the designation used on the approved shop drawing.

Boxes for spare parts shall be clearly marked on the outside to show their contents. Spare parts shall be delivered to a location designated by the NHDOT.

3. **Guarantee and Warranties**. Manufacturer's warranties or guarantees on equipment, materials or products purchased for use on the Contract which are consistent with those provided as customary trade practice, shall be obtained by the Design-Builder and, upon acceptance of the Contract, the Design-Builder shall assign to the New Hampshire Department of Transportation, all manufacturer's warranties or guarantees on all such equipment, material or products furnished for or installed as part of the Work.

The Design-Builder shall warrant the satisfactory in-service operation of the mechanical equipment, material, products, and related components. This warranty shall extend for a period of one year following the date of final acceptance of the Project.

1.7 Components Having Extensive Delivery Periods

The Design-Builder's attention is called to the fact that certain mechanical components may normally require long delivery times that could affect the schedule if not proactively addressed. These include but may not be limited to the tower sheave assemblies, the operating drum assemblies, and the speed reducers for operating machinery. The Design-Builder shall obtain all delivery times necessary to meet the schedule; shall expedite the production, submission and resubmission of shop and working drawings for these items, including assembly drawings; and shall expedite the manufacture of these items so that the schedule does not slip.

Materials

2.1 General

2.1.1 The materials shall meet the minimum requirements specified herein. Materials and equipment shall be essentially the standard catalogued products of manufacturers regularly engaged in production of such materials or equipment and shall be manufacturer's latest standard design that complies with the specification requirements. Materials and equipment shall essentially duplicate items that have been in satisfactory commercial or industrial use at least two years prior to bid opening. Where two units of the same class of equipment are required, these units shall be products of a single manufacturer; however, the component parts of the system need not be the products of the same manufacturer. Each major component of equipment shall have the manufacturer's name and address and the model and serial number on a nameplate, securely affixed in a conspicuous place. The name plate of the distributing agent will not be acceptable

2.1.2 All equipment and materials furnished under the items specified herein shall be brand-new. All new equipment, materials and workmanship shall be first class in every particular, and shall be manufactured and installed to the satisfaction of the Engineer and be in accordance with the recommendations of the manufacturer of the material being installed, printed copies of these recommendations shall be furnished to the Engineer prior to installation.

2.1.3 Portions or all of certain recognized industry or association standards or specifications referred to herein as being a requirement of these Special Provisions shall be considered as binding as though reproduced in full herein unless supplemented and/or modified by more stringent requirements of the Contract Documents. Unless otherwise stated the reference standard or specification which is current as of the date of issuance of these Special Provisions.

2.2 Steel Castings

2.2.1 Steel castings shall conform to the requirements of ASTM A27 and/or ASTM A148.

2.2.2 All steel castings shall be fully annealed. Castings shall be true to pattern in form and dimensions, free from pouring faults, sponginess, cracks, blow holes, and other defects in positions affecting their strength and value for the service intended. All castings shall be sandblasted or otherwise effectively cleaned of scale and sand, to present a smooth, clean, and uniform surface. All unfinished edges of castings shall be neatly cast with rounded corners, and all inside angles shall have ample fillets. All surfaces requiring finish shall have adequate material allowance for machining to finish dimensions. Machined bosses shall be provided on cast steel machinery parts to give proper seats for bolt heads and nuts.

2.2.3 Blow holes appearing upon finished castings shall be so located that a straight line laid in any direction will not cut a total length of cavity greater than one inch in any one foot, nor shall any single blow hole exceed one inch in any dimension or have an area greater than one-half square inch. Blow holes shall not have a depth injuriously affecting the strength of the casting. Minor defects, which do not impair the strength may, with the approval of the Engineer, be welded by an approved process and be inspected by magnetic particle examination. The defects shall be removed to solid metal by chipping, drilling, or other satisfactory method, and, after welding, the castings shall be annealed, if required by the Engineer. Castings which have been welded without the Engineer's permission will be rejected.

2.2.4 All castings that have solid sections 100 millimeters thick or greater shall be ultrasonically tested in accordance with ASTM A609, Method A, Quality Level 3. Castings that do not pass this test may be rejected. Test results, whether positive or negative, shall be submitted to the Engineer.

2.2.5 Carbon Steel and Alloy Steel Forgings shall meet the requirements of AASHTO Specification M102 (ASTM A668M) unless as otherwise approved by the Department.

2.3 Steel Castings and Forgings

2.3.1 All necessary precautions shall be taken to fabricate the castings free of cracks, cold shuts, shrink holes, blowholes, and porosity.

2.3.2 All castings shall be cleaned free of loose scale and sand; all fins, seams, gates, risers, and other irregularities shall be removed. All unfinished edges of castings shall be neatly cast with rounded corners, and all inside angles shall have ample fillets.

2.3.3 All castings shall be ultrasonically tested in accordance with ASTM A609, Method A, Quality Level 3. Castings that do not pass this test may be rejected. Test results, whether positive or negative, shall be submitted to the Engineer. Test records meeting Quality Level 4 may be considered for weld repaired, provided the fabricator submits a procedure to the Engineer for review and approval. All repair procedures shall include a means to qualify the repair. Test records meeting Quality Level 5 or higher shall be cause for rejection, and not be allowed for weld repair. Rejection shall result in the Design-Builder providing a new casting meeting the acceptance criteria.

2.3.4 All castings shall be visually inspected in accordance with ASTM A 802, Level II. Castings that do not pass this test may be rejected. Test results, whether positive or negative, shall be submitted to the Engineer. Test records meeting Level III may be considered for weld repair, provided the fabricator submits a procedure to the Engineer for review and approval. All repair procedures shall include a means to qualify the repair.

2.3.5 All castings shall be magnetic particle examined in accordance with ASTM E125. The following level of discontinuities will be acceptable.

Type I	Cracks/Hot Tears	¼" max
Type II	Shrink	Degree 3
Type III	Inclusions	Degree 3
Type IV	Chaplets	Degree 2
Type V	Porosity	Degree 1

2.3.6 Test results, whether positive or negative, shall be submitted to the Engineer. All surface discontinuities may be considered for weld repaired, provided the fabricator submits a procedure to the Engineer for review and approval. All repair procedures shall include a means to qualify the repair.

2.3.7 All proposed weld repairs shall be performed prior to all heat treatment so that no weld repairs will be necessary after machining. In addition, all surface defects removed by machining shall be performed prior to heat treatment.

2.3.8 Carbon Steel and Alloy Steel Forgings shall meet the requirements of AASHTO Specification M102 (ASTM A668) unless as otherwise approved by the owner. The main pinion shafts shall conform to the requirements of ASTM A291. Other shafts and trunnions shall conform to the requirements of ASTM A668.

2.4 Bearings and Bushings

2.4.1 Anti-friction bearings shall be selected for B-10 life of 40,000 hours.

2.4.2 Pillow block and flange-mounted roller bearings shall be, adapter mounting, self-aligning expansion and non-expansion types as called for on the drawings. Housings shall be cast steel and capable of withstanding the design radial load in any direction, including uplift. Bases shall be cast without mounting holes. Undersized mounting holes shall be drilled from the solid in the shop to ensure perpendicularity and location. Seals shall retain the lubricant and exclude water and debris. Cap bolts on pillow blocks shall be high-strength steel. The cap and cap bolts shall be capable of resisting the rated bearing load as an uplift force.

2.4.3 All grease-lubricated bronze bushings 8 inch diameter or less shall have grease grooves cut in a spiral pattern for the full length of the bearing. All grease grooves shall be machine-cut and smooth. The corners of all grooves shall be rounded to a radius of not more than half the width of the groove. The grooves shall be 3/8 inch wide at the bearing surface and be rounded to a 1/8 inch radius.

2.4.4 Laminated bearing liners shall be surface-bonded, laminated brass or bronze shim stock. The laminations shall be peelable by knife for reductions of 0.003 inch in thickness of the laminated stack. Laminated shims shall be as manufactured by one of the following companies, or approved equal.

1. Ohio Gasket & Shim Company, Akron, OH
2. Metallo Gasket Co., New Brunswick, NJ
3. Allinabal, Milford, CT
4. Spirol International Corp., Danielson, CT
5. Laminated Shim Company, Orange, CA

2.4.5 Pillow blocks shall be as manufactured by one of the following companies, or approved equal:

1. The Timken Company, Torrington, CT
2. Meither Bearing Products, Inc., Odessa, TX
3. SKF Bearing Industries, Inc., King of Prussia, PA

2.5 Open Gears

2.5.1 All open gears shall have 20-degree full-depth involute cut teeth with tooth proportions in accordance with the ISO (International Organization for Standardization) Standard No. 53 and conform to the requirements of AASHTO Specifications and the requirements for accuracy of the AGMA Standard 2001-D04, Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth, except as otherwise provided herein. The open gears shall conform to AGMA Quality No. 7 or higher. The AGMA quality number shall be stated on the applicable shop drawings.

2.5.2 The teeth of all gears shall be cut from solid rims or blanks. The teeth shall be provided with the appropriate root radius to limit stress concentration, but still allow for proper operation. The sides and peripheries of all gears and pinions shall be finished and the pitch circle shall be scribed on both sides not less than 0.020 inch deep with a V-pointed tool. The working surfaces of all gear teeth shall be true to the proper outline, accurately spaced on the true pitch circle, exceptionally smooth and free from planning or milling cutter ridges. Cutter burrs shall be removed from all edges of the teeth and the top edges of all teeth shall be rounded to a 1/32 inch radius.

2.6 Speed Reducers

2.6.1 Speed reducers with minimum requirements shall conform to the requirements of AASHTO and shall also conform to AGMA Product Standard 6010-F97, Standard for Spur, Helical, Herringbone, and Bevel Enclosed Drives, and shall carry the AGMA symbol on the nameplate. In addition, no component or element of the speed reducer shall be stressed to more than 75 percent of the material yield strength at 300 percent of the required nameplate output torque rating.

2.6.2 Gears and shafts shall be heat-treated alloy steel suitable for the intended service. Casehardened gears shall not be used in speed reducers of the span drive. Gearing in enclosed reducers shall conform to AGMA Quality No. 8 or higher.

2.6.3 Housings shall be of cast steel or welded plate construction. Inspection covers shall be provided to permit inspection of the gearing inside.

2.6.4 Provisions shall be made for filling, draining, and ventilating the housings; and a sight gauge shall be mounted on each unit to read the recommended lubricant level. Ventilation opening shall come equipped with a moisture (hygroscopic) and particle filtration unit.

2.6.5 The drain provisions shall include a shut-off valve between a drain pipe cap and each reducer. A hose bib or other device suitable for connecting a 1" drain hose shall be provided for the reducer.

2.6.6 A drain hose shall be provided for use when oil must be drained from the reducer. The hose shall be a minimum of 50 feet long. The hose shall be provided with a storage reel and shall be permanently stored where directed by the Engineer.

2.6.7 The inside of the housings shall be sandblast cleaned prior to assembly and be protected from rusting.

2.6.8 Speed reducers shall be provided with continuous oil bath lubrication. The lubricant level shall be such that all shaft bearings are submerged or to such higher level as recommended by the reducer manufacturer. The reducer shall be provided with effective seals to retain the lubricant.

2.6.9 The reducers shall be rated for a service factor of 1.0 at 150% horsepower rating of the main motors. The AASHTO requirements for peak or breakdown torque shall be construed to mean that the stress levels may be a maximum of 50 percent higher than normal. Additional testing requirements are included in this Specification under Construction Details.

2.7 Shafts

2.7.1 All shafts and pins shall be accurately finished, round, smooth and straight and, when turned to different diameters, shall have rounded fillets at the shoulders. Each shaft or pin having a uniform diameter of 8 inches or more and each shaft or pin having several diameters, of which the smallest is 8 inches or more, shall be bored lengthwise through the center to a diameter approximately one-fifth the smallest body diameter.

2.7.2 All shafts shall conform to tolerances in ASTM A29 unless otherwise indicated. Turned, ground and polished shafting straightness tolerances shall be 0.002 inches per foot for shafts up to and including 1-½ inches in diameter and 0.005 inches per foot for shafts over 1-½ inches in diameter.

2.7.3 Each end of all shafts, when finished to the required lengths shall have a 60-degree lathe center, with clearance hole, at the exact center of the shaft. Shafts that are bored with an inspection hole shall have the ends prepared for the attachment of a centering device equivalent to the lathe center. All such devices shall be furnished as part of the work.

2.7.4 Where shown on the drawings, stepped shafts shall have fillets blended in smoothly to adjacent surfaces without tool marks or scratches. Unless otherwise required herein or on the drawings to have a finer finish, the surfaces shall have an ANSI maximum roughness of 63 micro inches. Fatigue calculations for all stepped shafting, including counterweight trunnion shafts and main pinion shafts, shall be performed.

2.7.5 All cold-finished shafting shall be steel of the type and grade shown on the drawings and shall be tested for its mechanical properties, and a test certificate shall be furnished to the Engineer. Each cold-finished shaft shall be free from camber and shall run without vibration, noise, or chatter at all speeds up to and including the maximum rated speed.

2.7.6 All hubs mounted on the ends of cold-finished shafts shall have the fit specified herein or on the drawings. To obtain the required fit between hub and shaft, the Design-Builder shall furnish the cold-finished shaft 1/16 inch larger than the nominal diameter specified and shall turn the ends to the required dimension for the hub. The Design-Builder may, at his option, furnish any cold-finished shaft of one diameter end to end; but such a shaft shall have tolerances selected from the normal manufacturing range to provide the specified fit. The selected tolerances shall be shown on the shop drawings.

2.8 Couplings

2.8.1 Couplings shall include grid type or gear type.

2.8.2 All couplings and shaft fits and finishes shall meet the requirements of AASHTO for hubs on shafts. Couplings shall, in general, be finish-bored and have keyways cut by the Coupling Manufacturer to dimensions and tolerances established on the working drawings and then shipped to the manufacturers of the various components for shop installation on the shafts.

2.8.3 The couplings shall have provisions for lubricating all contact surfaces and the housings shall be oil-tight under all operating conditions.

2.9 Fasteners

2.9.1 Unfinished bolts shall conform to the requirements of ASTM A325, Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105ksi Minimum Tensile Strength. Turned bolts shall conform to ASTM A449, Standard Specification for Hex Cap Screws, Bolts and Studs, Steel, Heat Treated, 120/105/90 ksi Minimum Tensile Strength, General Use. Bolts shall have single self-locking nuts or double nuts. Beveled washers shall be used where bearing faces have a slope of more than 1:20 with respect to a plane normal to the bolt axis. Except as otherwise provided in this article, bolted construction shall conform to applicable specifications.

2.9.2 Unfinished Bolts

Unfinished bolts shall be furnished unless other types are specified. The bolts shall be of such length that they will extend entirely through their nuts, but not more than 1/4 inch beyond them. Bolts shall conform to the requirements of Section 2.6.18 Fasteners and Section 3.3.15 Bolt Holes and Bolts, of the AASHTO Specifications.

2.9.3 Turned Bolts

The surface of the body of turned bolts shall have a surface finish roughness height of 63 microinches. Heads and nuts shall be hexagonal with standard dimensions for bolts of the nominal size specified or the next larger nominal size. Diameter of shanks shall be 1/16" greater than the threaded portion of the bolt. Holes for turned bolts shall be carefully reamed with bolts furnished to provide for a LC6 fit. Threads shall be entirely outside of the holes. An extra thick washer shall be provided under the nut. Turned bolts shall conform to the requirements of Section 2.6.18 Fasteners and Section 3.3.15 Bolt Holes and Bolts, of the AASHTO Specifications.

2.9.4 High Strength Bolts

Where noted on the Drawings, bolts shall be ASTM A 325 Type 1 or ASTM A449 with heavy hex suitable nuts and washers. Where connecting galvanized parts galvanized bolts shall be used. SAE J429 Grade 5 bolts will be considered as an equivalent product for interconnecting machinery components. Rolled or pressed threads will not be accepted for galvanized bolts. Galvanizing, where required, shall conform to the requirements of ASTM A 153 or B 695.

2.10 Keys and Keyways

Keys and keyways shall be provided between open gears, couplings, clutches and their respective shafts. Keys and keyways shall conform to the dimensions and tolerances for square and flat keys of ANSI B17.1. All keys shall be effectively held in place, preferably by setting them into closed-end keyways milled into the shaft. The ends of all such keys shall be rounded to a half circle equal to the width of the key. Subject to the Engineers approval, keys that are not set into the closed-end keyways shall be held by safety set screws, or other effective means. Keyways shall not extend into any bearing.

2.11 Shims

2.11.1 All machinery shims required for leveling and alignment of equipment shall be neatly trimmed to the dimensions of the assembled parts and drilled for all bolts that pass through the shims. Holes for bolts shall be oversized by 1/16-inch. In general, sufficient thickness shall be furnished to secure 1/64-inch variations of the shim allowance plus one shim equal to the full allowance. Shimming of equipment shall be performed with the least amount of shims needed to fill space. No more than five (5) shims shall be used unless approved by the Engineer. Shims shall conform to the requirements of ASTM A709, Grade 36, except that thickness less than ¼-inch shall be stainless steel. Corrosion resistant precision thickness shims will be permitted if desired by the Design-Builder.

2.11.2 Shims with open side or U-shaped holes for bolts will not be permitted. No shims shall have less than two holes for bolts.

2.11.3 The use of peelable laminated shims with solder or resin bonding will be permitted as previously specified. Plastic or other non-metallic shims will not be permitted.

2.12 Structural Steel

2.12.1 Structural steel for machinery base supports and counterweight sheave covers shall conform to the requirements of the Standard Specification, ASTM A709, Grade 50. Steel components of manufactured items shall conform to the materials recommended by the manufacturer.

2.12.2 The Design-Builder shall provide suitable supports that are structurally adequate. The material thickness should be increased if appropriate for the application.

2.12.3 Top surfaces of all new supports shall be milled after fabrication to provide a uniform surface. All surfaces requiring milling shall have adequate material allowance for milling to the minimum finish dimensions as required by AASHTO section 2.5.17 “Fits and Surface Finishes”.

2.12.4 Weldments for machinery base supports shall be neat and shall have all exposed sharp corners and edges removed. Mounting surfaces of the frames shall be straight and flat such that full contact with the equipment being supported or retained is obtained. Mounting surfaces shall be of sufficient size for mounting of magnetic drills and other field installation tools.

2.12.5 All welding required herein shall be done in accordance with the requirements of AWS D1.5. Weldments shall be stress relieved by heat prior to final machining. The fitting up and welding procedure shall be such that distortion of the work will be a minimum. If necessary to obtain this result, suitable welding fixtures shall be used. The Design-Builder shall submit welding procedures, together with the working drawings, to the Engineer for approval.

2.12.6 All fillet welds and partial penetration groove welds shall be tested by the magnetic-particle method in accordance with the requirements of Section 6 of AASHTO/AWS D1.5. Radiographic testing shall be used for examination of complete joint penetration groove welds in butt joints. Complete penetration groove welds in T-joints and corner joints shall be tested by ultrasonic testing.

2.12.7 All complete joint penetration welds shall be tested in accordance with the requirements of Section 6 of AASHTO/AWS D1.5 for each size and type weld. Inspection and testing of welds and basis of acceptance shall be in accordance with the requirements of Section 6 of AASHTO/AWS D1.5.

2.12.8 All field welds shall be stress relieved by peening unless otherwise indicated within these Special Provisions or unless specific written permission is granted to omit the peening process for each particular weld. The Design-Builder shall submit his proposed weld procedures for all field welds. Proposed peening procedures will be required to be included in the weld procedures before approval will be granted. In addition, any existing structural steel being field welded shall be tested to determine its chemical composition. The actual chemistry of the existing steel shall be considered when developing the proposed field welding procedures. The chemistry of each and every existing plate or shape shall be determined. No field welding shall begin until the approved weld procedures are available. All field welding shall be in accordance with requirements of the Standard Specifications.

2.13 Weldments

2.13.1 The fabrication of steel weldments shall conform to the requirements of the AASHTO Specifications and the following:

2.13.2 The circumferential welded joints in each counterweight sheave connecting web plates to the rim and hub shall be inspected by ultrasonic testing 100% of each weld length. Welds shall meet the minimum acceptance levels in AWS D1.5. Where the joint detail prevents the use of ultrasonic tests, magnetic particle tests may be used.

2.13.3 Butt welds in plates making up counterweight sheaves shall be radiograph inspected 100 percent.

2.13.4 All other welds on machinery parts shall be inspected by magnetic particle tests on at least 10% of the length of each size and type of weld. Location of tests shall be selected at random so as to be typical for each size and type of weld.

2.13.5 Inspection of welds and basis of acceptance shall be in accordance with the requirements of Section 6 of American Welding Society (AWS) Welding Code D1.5.

2.13.6 Welded steel machinery parts shall be given a stress relief heat treatment. The Design-Builder shall submit a schedule of the proposed stress relief heat treatment to the Engineer for his approval. The schedule shall include a description of the part and an explanation of the proposed heat treatment, including the rate of heating, the soaking temperature, the time at the soaking temperature, the rate of cooling, and the temperature at which the part is to be withdrawn from the chamber. Soaking times less than one hour will not be approved.

2.14 Lubrication

2.14.1 Standard grease fittings for a pressure system of lubrication shall be provided for all bearings and surfaces requiring external lubrication. Not more than two sizes of fittings shall be used. The large size shall be used wherever possible and the smaller size shall be used for motor bearings and other small devices. The large fitting shall be equal to Alemite part number 1823-1 with associated adapters. Pressure fittings shall be rated at a minimum of 10,000 psi. Fittings shall contain a steel check valve that will receive grease and close against backpressure.

2.14.2 The large fittings shall be connected directly into the bushings by 1/4-inch minimum size, extra strong, threaded steel pipe and forged threaded fittings. The smaller fittings shall be connected with 1/4-inch pipe where pipe extensions are required or by the size pipe thread furnished with the device to be lubricated.

2.14.3 Pipe extensions shall be provided to facilitate access for lubrication but shall be kept as short as practical and shall be rigidly supported at the fittings and at intermediate points.

2.14.4 Immediately after the completion of fabrication, all grease fittings shall be plugged until components are installed and regular lubrication is started. The plugs will then be replaced with the proper grease fittings.

2.14.5 The Design-Builder shall furnish full size lubrication charts and the component manufacturer's lubrication literature for every machinery component, which requires lubrication.

The charts shall consist of:

1. A schematic diagram of all machinery showing the location of all lubrication fittings and other points of mechanical and electrical equipment that require lubrication of any kind. These diagrams shall indicate the type of lubrication to be used at each point, the method of application at each point and the frequency of lubrication at each point.

2. A table chart listing each machinery component that requires lubrication, the minimum frequency of inspection, the minimum lubrication frequency, the minimum lubrication change frequency instructions, standards, guidelines and a history of most recent service.

2.14.6 A Phenolic nameplate matching the number designation shown on the lubrication chart shall be mounted at each lubrication point. Characters on the plates shall be a minimum of 1” high. Plates shall be fastened with stainless steel screws.

2.14.7 Maintenance and lubrication manuals for each machinery component shall be kept in the machinery room in a heavy bound binder.

2.14.8 The bridge shall be furnished with an amount of lubricants as specified for each lubricant. The amount shall be in addition to the lubricant required for initial lubrication. The lubricant shall be stored in steel containers in each machinery room.

2.14.9 The lubricant for each type of machinery component shall be kept separately in clearly marked containers. All measures shall be taken to prevent lubricant contamination.

2.14.10 During installation, the Design-Builder shall lubricate all rotating and sliding parts of the machinery and fill all gear reducers and pillow block housings and flexible couplings with lubricants indicated on the approved charts.

2.14.11 Lubrication fittings shall be as manufactured by one of the following companies, or approved equal:

1. Stewart Warner Alemite Corp., Charlotte, NC
2. Lincoln, Inc., St. Louis, MO

2.15 Lubricants

2.15.1 General

The Design-Builder shall coordinate all lubricants to be used for bridge machinery with the owner's maintenance forces and than submit selections to Engineer for approval.

2.15.2 Enclosed Gear Reducers

Enclosed gear reducer lubricant shall meet the requirements of the American Gear Manufacturers Association (AGMA) Standard 9005-D94 "Industrial Gear Lubrication".

The lubricant shall be manufactured by a reputable and knowledgeable supplier of lubrication and all lubricant shall be recommended for use in each application by the lubricant manufacturer.

The lubricant shall be recommended for use by the reducer manufacturer.

The lubricant should contain oxidation inhibitors, rust inhibitors, anti-foaming agents and anti wear additives.

Enclosed Gear Reducer Lubricant specification to be used in conjunction with AGMA Standard 9005-D94.

The maintenance of the lubricant, method of application and re-lubrication intervals, shall be recommended by both the reducer manufacturer and the lubricant manufacturer and meet the requirements of the AGMA Standard 9005-D94, unless otherwise stated herein.

2.15.3 Open Gears

The open gear lubricant utilized must bond strongly to gear teeth to maintain a continuous film on bearing surfaces despite high loading and high load repetition, contain an EP additive, repel water, resist throw off and dripping, maintain consistency over wide temperature variations and allow for ease in application and removal.

The lubricant shall have an operating range of (-18 to 94)°C and shall be considered a heavy bodied, adhesive type open gear lubricant by a reputable lubricant manufacturer.

Some adhesive lubricants are available in a diluted form for ease of application. This type of lubricant is diluted with solvent that quickly evaporates after application leaving behind an adhesive tacky film. If such a lubricant is desired, the solvent must be non-flammable and the mixture must not pose any hazard to health.

The detailed specifications for open gear lubrications that will satisfy the above requirements do vary. The lubricant chosen shall be comparable to the following lubricants:

1. Mobil Mobiltac LL
2. Exxon Dynagear

2.15.4 Roller Bearings

The roller bearing lubricant, the maintenance of the lubricant, method of application and re-lubrication intervals shall be recommended or approved by the manufacturer unless otherwise stated herein.

2.15.5 Sleeve Bearings

The lubricant shall be comparable to the following:

1. Mobil Mobilux EP-2
2. Exxon Lidok EP-2

2.15.6 Couplings

Coupling lubricant and its maintenance shall be specified by the manufacturer. The lubricant chosen shall be approved for use in sleeve bearings by the lubricant manufacturer.

2.16 Machinery Guarding

All driving mechanisms and power transmission apparatus shall be guarded. Guards and shields must meet the full intent of requirements outlined in OSHA 1910.219. Guards shall be fabricated from expanded steel mesh size 3/4”-9 gauge. Guard supports shall be standard structural shapes fabricated from ASTM A709 Grade 50. Guards shall be secured to supports utilizing tack welded bolts and wing nuts, suitable for hand tightening. Bolt holes shall be oversized such that assembly and disassembly can be accomplished without interference. Guard supports shall be anchored to the machinery floor utilizing steel anchors. Supports and guarding shall be painted, complying with the requirements of this specification. All hardware shall be galvanized conforming to the requirements of ASTM A 153. Alternative guarding materials and designs may be utilized, subject to the approval of the Engineer. Guards shall be designed with access hatches to allow lubrication of couplings or any other rotating components.

2.17 Tools

2.17.1 A complete set of tools, each set located in a lockable steel cabinet, shall be furnished. The Design-Builder shall provide one set of wrenches suitable for machinery maintenance and to fit all nuts and bolt heads in the machinery installation. Wrenches shall be drop-forged steel with chrome plating. In addition, a full set of square-shank flat head and Phillips head screwdrivers shall be furnished which will fit all machinery and electrical components together with an assortment of punches, files, chisels and a 32 oz. ball peen hammer. Punches and chisels shall be forged, hardened and tempered chrome vanadium steel.

2.17.2 The miscellaneous tools, grease, and grease guns shall be stored in a location approved by the Engineer in a cabinet or toolbox made of galvanized steel and having provisions for a padlock. Cabinet or toolbox shall be constructed of 24 Ga. Material minimum.

2.17.3 Spare parts shall be provided in sealed, uniform-sized cartons with clearly typed labels indicating their contents. Spare parts shall be delivered to the site and stored where ordered by the Engineer. The spare parts shall also be marked to correspond with their respective item numbers, as indicated on the machinery schedule.

2.18 Warranty and Quality Control

2.18.1 The Owner reserves the right to receive on demand a test report from an independent laboratory certifying that the equipment furnished meets these specifications. The cost of the testing will be paid for by NHDOT if the material is found to be in compliance with the specifications, but shall be paid by the Design-Builder if the material is non-compliant.

2.18.2 The Owner reserves the right to reject an entire shipment of material covered by this specification if an item or items are found to be defective within a 30-day period following receipt of materials.

Construction Details

3.1 General

3.1.1 The machinery specified and as approved on the shop drawings and related electrical equipment shall be installed according to best millwright practice. Millwrights shall provide documentation that they have performed installations on heavy machinery of a similar character to that required within this project. The millwright foreman shall have successfully installed movable bridge machinery on a previous project.

3.1.2 In addition to the mechanical equipment, electrical equipment including the main drive motors, brakes, limit switches and the auxiliary motors shall be installed as a part of this specification. The Design-Builder shall coordinate the work with subcontractors to provide for the necessary shop assembly and field installation of all of the equipment.

3.1.3 Machinery manufacture and installation shall conform to all applicable requirements in AASHTO Specifications and all applicable requirements with special requirements and additions as specified herein.

3.2 Service Engineer

The Design-Builder shall be required to have a qualified service engineer from the manufacturer of the bearings present on the job at the time that the bearings are installed, aligned and tested. In addition, the service engineer shall be available for consultation as needed until final acceptance of the work. Such consultation shall, if considered necessary by the Engineer, be at the job site.

3.3 Inspection and Testing

3.3.1 The Design-Builder shall give two weeks notice to the owner prior to the beginning of work at the foundries, forge, and machine shops so that inspection may be provided. No materials shall be cast, forged, or machined before the owner has been notified where the orders have been placed.

3.3.2 The Design-Builder shall furnish all facilities for the inspection of material and workmanship in the foundries, forge, and machine shops; and the Engineer shall be allowed free access to necessary parts of the premises. Work done while the Inspector has been refused access will automatically be rejected.

3.3.3 The Inspector shall have the power to reject materials or workmanship, which do not fulfill the requirements of these Specifications.

3.3.4 Inspection at the foundries, forge and machine shops is intended as a means of facilitating the work and avoiding errors; and it is expressly understood that it will not relieve the Design-Builder from any responsibility in regard to imperfect material or workmanship and the necessity for replacing the defective materials or workmanship.

3.3.5 The Design-Builder shall furnish the owner with as many copies of orders covering work as the owner may direct.

3.3.6 Unless otherwise provided, the Design-Builder shall furnish test specimens, as specified herein, and all labor, testing machines, tools, and equipment necessary to prepare the specimens and to make the physical tests and chemical analyses. Copies of all test reports and chemical analyses shall be furnished to the Engineer.

3.3.7 The proper operation of the lubricating system shall be demonstrated during the shop test. In addition to the test specified above, the proper distribution of load on the gear teeth shall be demonstrated by the application of tooth contact tape applied to each gear and these tapes shall be preserved in the records to be submitted with the Certificate of Compliance.

3.4 Field Assembly

Each assembly shall be operated continuously for a period of not less than four hours in the shop before shipment. The operating machinery shall then be completely assembled, aligned and adjusted in the field in the machinery house and tested by operation at the erection site prior to the float-in of the span. The speed of operation shall be not less than that of the assembly under normal bridge operation and testing in the field at the erection site shall be performed for 4 hours to fully demonstrate operation to the satisfaction of the Engineer prior to float-in.

3.5 Paint and Protection for Machinery

3.5.1 All surfaces of the operating machinery shall be painted using a three-coat system conforming to all requirements stated elsewhere for Painting New Structural Steel [Item 550] except for the following:

3.5.2 The surfaces of commercially manufactured machinery components shall be prepared for painting using the three-coat system being used for the new structural steel as described above. If manufacturer's standard paint is already applied to such a commercial machinery component, it shall be coated with a primer both suitable for covering any paint or primer applied previously, and compatible with (or as part of) the three-coat system for new structural steel described above. The commercial manufacturer's warranty for any materials provided by them shall not be affected.

3.5.3 All finished contact surfaces which are not finally assembled in the shop shall be coated with waterproof National Lubricating Grease Institute No. 3 Multipurpose grease or cosmoline as soon as possible after being accepted and before removal from the shop, and shall be adequately protected during shipment by wrapping with burlap or canvas held by wooden bats securely wired together. During erection these surfaces shall be thoroughly cleaned and a field coat of this grease applied.

3.5.4 All unfinished machinery surfaces shall be made free of all chips, dirt, rust, scale, sand, grease, and other foreign matter by sandblasting, wire brushing, or other approved means as stated elsewhere. Sandblasting shall not be permitted when machined surfaces are present.

3.5.5 After installation is complete, all machinery surfaces remaining exposed, except rubbing surfaces, shall be thoroughly cleaned and given two field coats of paint prepared as specified elsewhere for intermediate and finish coat. Cleaning and any required re-priming of the components shall conform to the requirements of the paint manufacturer. The color of paint for machinery enclosed in the machinery room, lifting girders and tower hoods, and for machinery exposed to weather, shall be approved by the Engineer and/or Owner.

3.5.6 After completion of the operating tests and acceptance of the machinery in the shop, all accumulated oil, grease, dirt, and other foreign matter shall be solvent cleaned in accordance with SSPC-SP1 from exposed machinery surfaces, except rubbing surfaces.

3.5.7 Cleaning of surfaces preparatory to shop painting shall not be by sand blast as specified for structural metal, but shall be by means of wire brushes, scrapers and other suitable hand tools and solvents.

3.5.8 All grease holes shall be adequately plugged for painting and shipment. Careful attention shall be given to the protection of all machinery parts during shipment and while stored before erection.

3.6 Installation of Machinery

3.6.1 The machinery frames carrying machinery assemblies and all individual bearings and machinery parts of the electrical equipment, which connect to the machinery, shall be adjusted to proper elevation and alignment on the supporting steel parts, by the use of full length steel shims, and the holes for connection to the steel work shall be drilled while the parts are thus assembled. The thickness of shimming under bearings, motors, line shafts, and reducers, shall be varied as required to place centerline of shafts truly horizontal at proper elevation over their full length.

3.6.2 Installation, alignment and adjustment of all mechanically connected machinery and electrical equipment shall be made only under the supervision of the machinery manufacturer's field engineers.

3.7 Operation

After float-in, and after all dead load has been placed on the lift span, prior to placing ropes on the operating drums, operating machinery and electrical equipment alignment shall be re-verified and adjusted if necessary. The machinery shall then be tested and operated continuously for an additional period not less than one hour to assure that all parts are in satisfactory working condition, as determined by the Engineer, before the ropes are connected.

3.8 Installation of Electrical Items

3.8.1 General. The Design-Builder shall coordinate the work of the subcontractors supplying and installing components under electrical and machinery as well as structural items of the contract. The Design-Builder will be held fully responsible for supplying all work necessary to provide a complete installation, properly fitted together, adjusted and satisfactorily operating as one unit.

3.9 Tests and Preliminary Operation

3.9.1 The lift span, counterweight sheave assemblies, span guides and operating machinery, comprise an operating machine. The Design-Builder shall construct, erect and adjust every part so that the machine will function and operate satisfactorily. The Design-Builder shall make all necessary tests of the completed structure and all trial operations so that the completed structure, ready for acceptance, shall be acceptable to the Engineer and in accordance with design. During testing and adjustment of the span, representatives of the manufacturer of major mechanical and electrical components shall be present at the bridge site and available for consultation as may be required.

3.9.2 The Design-Builder shall supply without charge all grease, oil, fuel, maintenance, and other incidentals necessary for testing, adjustments, and preliminary operation. Until final acceptance, the Design-Builder shall operate the span if and as required for navigation and highway traffic.

S P E C I A L   P R O V I S I O N

SECTION 801.1 – SPAN OPERATING MACHINERY

Description

1.1 General

1.1.1 Under this item, the Design-Builder shall furnish, install, adjust, paint, test and place in operation the new Operating Machinery. This will include all machinery parts from the motor couplings through the counterweight sheaves on the towers. The components include but are not limited to:

1. Counterweight Sheaves (4)
2. Trunnion Bearings (8)
3. Counterweight Ropes & Sockets (48)
4. Operating Drums (4)
5. Operating Ropes (8)
6. Deflector Sheaves (4)
7. Guide Rollers (8)
8. Ring Gears (4)
9. Pinions (2)
10. Reducer (1)
11. Floating Drive Shafts (2)
12. Motor Brakes (2)
13. Machinery Brakes (2)
14. Gearmotor (1)
15. Bronze Bushed Bearings (as listed in Bearing Table)
16. Couplings (as listed in the Coupling Table)

1.1.2 Details and arrangements of all Operating Machinery systems are specified herein.

1.1.3 The work shall also include installing and aligning the drive motors and brakes, as well as control instrumentation that is to be supplied under the Electrical Work. The work shall be in accordance with the requirements specified in “Common Machinery Provisions”.

1.1.4 The Design-Builder shall coordinate the installation of the Operating Machinery with all other bridge machinery items, electrical work and structural work, as well as navigational and vehicular traffic closures and restrictions.

Materials

2.1 General

2.1.1 The materials shall meet the minimum requirements specified herein.

2.1.2 All equipment and materials furnished under the items specified herein shall be brand-new. All new equipment, materials and workmanship shall be first class in every particular, and shall be manufactured and installed to the satisfaction of the Engineer.

2.2 Open Gearing

2.2.1 Rack segments and main pinions-P1 shall have 20-degree stub, involute, cut teeth in accordance with the proportions of the ANSI/AGMA 201.02, Tooth Proportions for Coarse-Pitch Involute Spur Gears.

2.3 Enclosed Speed Reducers

2.3.1 Speed reducers for the Operating Machinery shall be special models from one manufacturer, with sizes, ratios, ratings, and construction details as specified herein. Speed reducers shall have mounting holes located such that final field drilling and reaming for permanent fasteners is feasible.

2.3.2 Speed Reducers for the Operating Machinery shall be as manufactured by one of the following companies or approved equal:

Earle Gear by Steward Machine Co., Birmingham, AL.

Horsburgh & Scott, Cleveland, OH

Prager, Inc., New Orleans, LA

2.4 Lubrication

2.4.1 Upon approval, the Design-Builder shall provide the following quantities of additional lubricants for the Operating Machinery after all components have been lubricated per manufacturer's recommendations, which shall be stored at the site:

1. Gear Reducer Oil 110 gal (416 liters)

2.	Open Gear Grease	50 # (23 kg)
3.	Bearing Grease	50 # (23 kg)
4.	Grid Coupling Lubricant	25 # (12 kg)
5.	Gear Coupling Lubricant	25 # (12 kg)

2.4.2 The lubricant for each type of machinery component shall be kept separately in clearly marked containers. All measures shall be taken to prevent lubricant contamination.

2.5 Spare Parts

2.5.1 Upon approval, the Contractor shall provide the following spare parts for the Operating Machinery, which shall be delivered to a location designated by the NHDOT:

- 1 main motor coupling – flex grid type
- 1 auxiliary gearmotor coupling – flex grid type
- 1 primary reducer output coupling – gear type
- 1 complete set of seals - main motor coupling
- 1 complete set of seals – auxiliary motor coupling
- 1 complete set of seals – reducer output coupling
- 1 complete set of seals – auxiliary drive input coupling
- 2 complete sets of brake pads – machinery brake
- 2 complete sets of brake pads – motor brake
- 1 complete set of bearing seals and inspection portal gaskets – reducer
- 1 operating rope assembly for each length of uphaul and downhaul ropes

2.5.2 Spare parts shall be provided in sealed, uniform-sized cartons with clearly typed labels indicating their contents. Spare parts shall be delivered to the site and stored where ordered by the Engineer. The spare parts shall also be marked to correspond with their respective item numbers, as indicated on the machinery schedule.

Construction Details

3.1 Shop Inspection and Testing

3.1.1 All Operating Machinery components shall be assembled to assure proper fits and verify tolerances specified. Assemblies requiring disassembly shall be match marked and documented so that the machinery can be reassembled at the bridge site.

3.2 Reducer Testing

3.2.1 The reducer manufacturer shall shop test each reducer by running it at the normal operating speed at no load for at least four hours and at 150% full load torque of the main motor for 1 hour in the presence of the Engineer or his duly appointed representative. These tests shall be run with the reducer filled to the recommended mark with new oil of the viscosity the manufacturer recommends on his lubrication chart for normal operation. Half of the run shall be in one direction and the other half in the opposite direction. Immediately before the start of the test, at half-hour intervals for no load and at ten-minute intervals for 150% full-load motor torque thereafter, the following measurements shall be made and recorded and the records shall be submitted with the Certificate of Compliance:

1. Temperature of ambient air
2. Temperature of oil near bottom of housing (not to exceed 135°F)
3. Surface temperature of each shaft extension adjacent to shaft seal (not to exceed 135°F)
4. Sound level at point above and 60 inches distant from center of unit (not to exceed 98 dB)

3.2.2 During testing the speed reducer shall be checked for unusual noise (thumping or any non-uniformity), excessive bearing clearance, and any other unusual operating characteristics. The units shall operate smoothly, and without excessive vibration or temperature rise. All malfunctions shall be recorded and corrected, and the units retested if necessary before release from the manufacturer's shop. After the unit has passed the test, a Certificate of Compliance shall be submitted by the Design-Builder to the Engineer.

3.3 Field Testing

3.3.1 When the mechanical machinery and electrical equipment are ready for final testing, the Design-Builder shall submit to the Engineer a testing procedure and schedule in accordance with the requirements specified.

3.3.1 After installation is complete prior to operation, the Design-Builder shall make a thorough inspection to ensure that all gears are clean and free of obstruction, that all parts are aligned and adjusted as closely as practicable without actual operation, and that all bolts are properly tightened. All gear housings shall be filled with lubricant to the proper level, and all rotating and sliding parts shall be supplied with lubricants recommended by the suppliers of the units.

3.3.2 Each test run shall verify that the Operating Machinery is in proper working order and fully meets the requirements of the Specifications. If any tests show that the Operating Machinery components are defective or inadequate, or function improperly, the Design-Builder shall make all corrections, adjustments, or replacements required before final acceptance at no additional cost.

S P E C I A L   P R O V I S I O N

SECTION 801.2 – COUNTERWEIGHT SHEAVES, TRUNNIONS, AND BEARINGS

Description

1.1 Counterweight Sheave and Operating Drum Assemblies

1.1.1 Sheaves and Drums

The counterweight sheaves and operating rope drums shall be steel weldments, fabricated from material as specified. Rims shall be welded into a complete ring, the welds ground flush on all four sides, and be radiograph inspected 100 percent before being welded into the sheave or drum assembly. The four circumferential welded joints connecting web plates to the rim and hub shall be inspected by ultrasonic testing 100 percent of each weld length. Welds shall meet the minimum acceptance levels in AWS D1.5. Where the joint detail prevents the use of ultrasonic tests, magnetic particle tests may be used. Each web shall be fabricated from not more than two pieces of plate. Web welds, if used, shall be full penetration welds made with low-hydrogen procedure. Automatic submerged-arc welding shall be used to the greatest extent practical. Butt welds in plates making up counterweight sheave webs shall be radiograph inspected 100 percent. After completion of the weldment and before final machining, the sheaves and drums shall be stress relieved. The grooves in the sheaves and drums shall be turned. The variation of the grooves from the required diameter in the sheaves on one tower shall not exceed plus or minus 0.010 inch.

1.1.2 Drum Shafts and Counterweight Sheave Trunnions

Shafts and trunnions shall be of forged steel fabricated from ASTM A668, class as required. The journals of these shafts shall be finished as required. The shafts shall have a shop shrinkage fit in the sheaves which may be made by cooling the shafts to the required temperature by packing in dry ice and then inserting them in the sheaves or by other approved means. Each shaft shall have crossed centerlines scribed at right angles to each other, on each end of the shaft, as a guide in aligning the sheaves and drums. All sheaves and drums shall be shop inspected for runout.

1.1.3 Bearings

The counterweight sheave and operating drum bearings, together with those of the pinion shafts, shall be plain bronze-bushed bearings and dimensioned as required. Complete details of bearing assemblies shall be submitted for approval by the Engineer.

1.2 Intermediate Deflector Sheaves and Bearings

The intermediate deflector sheaves shall be fabricated from ASTM A27 Grade 70-30 of the grade required. At the Design-Builder's option, suitable steel weldments may be provided. Rope grooves shall be finished to a 63 microinch roughness surface texture. Intermediate deflector sheave bearings shall be of the plain bronze-bushed type, mounted within the hub of the sheave.

1.3 End Deflector Sheaves and Bearings

The end deflector sheaves shall be fabricated from ASTM A27 Grade 70-30 of the grade required. At the Design-Builder's option, suitable steel weldments may be provided. Rope grooves shall be finished to a 63 microinch roughness surface texture. End deflector sheave shafts shall have a shop shrinkage fit in the sheaves which may be made by cooling the shafts to the required temperature by packing in dry ice and then inserting them in the sheaves or by other approved means. End deflector sheave bearings shall be plain bronze-bushed bearings mounted in pillow block housings as required.

1.4 Operating Rope Support Rollers and Bearings

Operating rope support rollers shall be provided between the operating drums and intermediate deflector sheaves, and between the intermediate deflector sheaves and end deflector sheaves as required. Rollers shall be fabricated from ASTM A36 steel, and of welded construction. The outside diameter of the rollers shall be turned. Rollers shall be straight and true, and rotate concentric within the bearings. Mounting flanges shall be cast steel. Setscrew locking collars shall be provided with the bearings. Seals appropriate for outdoor application shall be provided as part of the bearing unit.

Construction Details

2.1 Sheave and Drum Assembly

After lining up and bolting in place, before the ropes are placed over the sheave or drum, the sheave or drum shall be tested to see that the shaft or trunnion turns freely in the bearings. If the shaft does not turn freely, the alignment of bearings must be corrected as may be necessary to accomplish this. Before the sheaves or drums are put in service, bearings shall be checked for proper lubrication by the Design-Builder and bearing manufacturer, subject to approval by the Engineer.

2.2 Alignment

2.2.1 Each counterweight sheave, shaft and bearing shall be carefully aligned and installed to proper elevation. Each end of each sheave shaft shall be within 0.020 inches from a common transverse centerline on each tower in the combined horizontal and vertical directions. When determining the alignment, due consideration of the expected deflection of the supporting structural steel shall be considered.

2.2.2 The centerline used for alignment of the counterweight sheaves shall be determined by the Design-Builder and approved by the Engineer. The centerline shall be at right angles to the bridge centerline and at proper elevation without respect to the actual centerline of the front tower columns and the proper distance from the centerline of bearing of the lift span. If the centerline is more than 1/4 inch from the average centerline of the front tower columns, the work shall be halted and the reason for the apparent discrepancy determined. The Design-Builder shall readjust the centerline as directed by the Engineer if such discrepancy occurs at no additional cost to the Owner. The Design-Builder shall also readjust alignment of sheaves, if necessary, after weight of the span and counterweight have been applied to the ropes.

S P E C I A L P R O V I S I O N

SECTION 801.3 – COUNTERWEIGHT AND OPERATING ROPES

Description

1.1 Wire Rope and Sockets

1.1.1 Wire rope and sockets shall conform to the requirements of Section 3.2.11 Sockets of the AASHTO specifications, as well as AASHTO M 277-06, "Standard Specification for Wire Rope and Sockets for Movable Bridges". Wire ropes shall be uncoated and shall not be galvanized. Every possible effort shall be made to fabricate wire ropes of uniform physical properties and all similar ropes shall be cut from a minimum number of reels.

1.1.2 Counterweight ropes shall be 2" diameter, preformed, of 6x19 classification, 6x25 filler wire construction, extra-extra improved plow steel (EEIPS) with independent wire rope core (IWRC). The minimum breaking strength shall be 217 tons.

1.1.3 Operating ropes shall be 1-1/2" diameter, preformed, of 6x19 classification, extra-extra improved plow steel (EEIPS) with independent wire rope core (IWRC). The minimum breaking strength shall be 125 tons.

1.1.4 Rope and rope assemblies shall be tested in accordance with the procedure prescribed in Section 3.2.7 Wire-Physical Properties and Section 3.2.8 Ultimate Strength of the AASHTO Specifications.

1.1.5 Rope sockets shall be steel castings conforming to ASTM A148 Standard Specification for Steel Castings, High Strength, for Structural Purposes, and shall be of the Grade required. During testing of wire rope assemblies per AASHTO 3.2.8, socket performance shall be as specified in AASHTO 3.8.11.

1.1.6 After erection of counterweight suspending ropes, the free ends shall be temporarily held in position by approved means until lift span is in place and ready to receive the ropes.

1.2 Wire Ropes

1.2.1 When erecting counterweight rope and operating wire ropes, care shall be taken to see that each rope has no twist, but that it has exactly the same number of turns and that the strands and sockets occupy exactly the same relation to each other, which existed when the rope was measured. Twisted counterweight ropes are not acceptable and shall be cause for removal and reinstallation of the ropes.

1.2.2 It is important to note that the wire ropes will be pre-stretched by the manufacturer prior to placing the completed rope on the spool. Once the rope has been placed on the spool, the rope will relax and shorten. The amount of relaxation and shrinking varies depending on the length of rope and the time the rope is kept on the spool. This information is provided to advise the Design-Builder that it may be necessary to pre-stretch the ropes in the field to a lesser degree in order to ensure the counterweight suspending ropes can be properly attached to the lift span. It may also be necessary to readjust the operating ropes after initial installation and adjustment. All shall be done at no additional cost to the Owner.

1.2.3 Counterweight ropes shall be adjusted such that the tension in each rope is within 1,500 lbs., or approximately 5%, of the average tension of the group of ropes in that corner of the lift span. The anticipated average tension in each counterweight rope is approximately 45,000 lbs., which could vary somewhat due to variation in the as-built weight of the span, and variations between quadrants. The stripe painted on the rope in the shop shall be straight after the rope is erected. The tension in the operating ropes shall be equal at all four corners of the lift span. The anticipated tension in each operating rope is approximately 23,000 lbs. per uphaul rope when the span is held by the brakes just above the seated position, and approximately 23,000 lbs. per downhaul rope when the span is held by the brakes just below the full open position, based solely on the unbalance of the span with respect to the counterweight in each position. The slack side of the operating rope shall have only slight tension, in each case.

1.2.4 After the lift span is in operating condition, the Design-Builder shall properly clean all ropes of foreign material and shall furnish and apply, in an approved manner, and when weather conditions are suitably dry and warm, one coat of Wire Rope Dressing. Rope dressing shall be as recommended by Wire Rope manufacturer.

SPECIAL PROVISION

SECTION 802 – SPAN LOCK MACHINERY

Description

1.1 General

1.1.1 Under this item, the Design-Builder shall furnish, install, adjust, paint, test and place in operation the new Lock Machinery. This work consists of installing the span lock machinery (2 locations), including the following:

1. Furnish, install and align new lift span lock machinery
2. Furnish, install and align new span lock machinery actuators and proximity switches
3. Survey and align lock bar and centering device (2 locations)
4. Lubricate span lock machinery
5. Perform field acceptance testing

1.1.2 Details and arrangements of all Lock Machinery systems are specified herein.

1.1.3 The Design-Builder shall coordinate the installation of the Lock Machinery with all other bridge machinery items, electrical work and structural work.

Materials

2.1 General

2.1.1 The materials shall meet the minimum requirements specified herein.

2.1.2 All equipment and materials furnished under the items specified herein shall be brand-new. All new equipment, materials and workmanship shall be first class in every particular, and shall be manufactured and installed to the satisfaction of the Engineer.

2.2 Lock Bar Actuator. Use Acme screw type linear actuators for all lock bar operators meeting the following operational requirements:

Thrust Capacity:	8,800 lbs
Stroke:	16 inches
Speed:	1.5 inches/sec

Power consumption:	5 hp
Operating voltage	240/480V @ 60 Hz

2.2.1 Equip each lock bar actuator with a disengaging manual hand crank and disengaging mechanism with an electrical interlock switch.

2.2.2 Ensure lock bar operator travel is controlled by 2 pairs of single pole, double throw internal limit switches. Ensure limit switch contacts are rated for 120 VAC, 10 Amps.

2.2.3 Ensure drive motors are the marine duty rated, NEMA Design “D”, weatherproof, totally enclosed, non-ventilated type, ball bearing, squirrel cage motor capable of withstanding instant reversal when running at full speed. Provide each motor with a 15-minute duty rating and equip with a 3 ft-lb marine duty brake with manual release and electronic safety interlock switch. Ensure Lock limit switch meets the requirements as specified under the Electrical Work item. Use high starting torque drive motors.

2.2.4 Provide each motor with a single-phase, 120-volt, space heater installed in the lower frame beneath the windings. Ensure the manufacturer will determine the wattage of the heater.

2.2.5 Provide brakes for the lock motors with a motor-mounted, totally enclosed, spring-set, 480-volt, magnetically released disc brake with rated torque approximately equal to, but not less than, motor full-load torque. Each brake must be dust-tight, self-adjusting, weatherproof, cast-iron construction, except modified for marine duty to comply with IEEE Standard 45, "Recommended Practice for Electrical Installations on Shipboard". The marine duty modification includes the use of brass internal parts.

2.2.6 Provide each brake with a 120-volt, 15-watt internal strip heater and a single-voltage operating coil. Use brakes equal to the Stearns 87,000 Series brake with M-Mod for marine duty, equivalent as manufactured by Harnischfeger or Dings, or approved equal.

2.2.7 Size all anti-friction bearings for a B-10 life of 10,000 hours as defined by ABMA for the loads and ratings established by the lock bar operator manufacturer.

2.2.8 Use weatherproof lock bar operator cylinder.

2.2.9 Ensure all lock bar operators are identical and from the same manufacturer

2.2.10 Use lock bar operators manufactured by Steward Machine Co., Inc., Raco, Inc., or approved equal.

2.2.11 The lock bar actuator, receivers, and guides shall be easily accessed for inspection and maintenance.

Construction Details

3.1 Shop Inspection and Testing

3.1.1 All Lock Machinery components shall be assembled to assure proper fits and verify tolerances. Assemblies requiring disassembly shall be match marked and documented so that the machinery can be reassembled at the bridge site.

3.1.2 **Shop Testing.** Shop assemble and test each span lock machinery assembly. After all components are in proper initial alignment, manually operate the span lock machinery by rotating the actuator hand crank input shaft. Care must be taken to insure that the input shafts are not damaged. Report any damage to the Department. Operate each assembly 10 full cycles. During this time inspect the components for proper operation, alignment and overheating. If any defects are identified, stop the test and fix the cause of the problem. Restart the test until all components perform satisfactorily.

3.2 Field Testing

3.2.1 Install the new span lock machinery components, starting at the lock bar guides and sockets and working back to the actuator.

3.2.2 Shim the live load shoes according to the tolerances required and with an owner approved procedure.

3.2.3 Install and align new proximity switches within the limit recommended by the manufacturer.

3.2.4 Field test machinery according to Common Machinery Provisions.

3.2.5 After final alignment, test operate the machinery a minimum of ten cycles, to the satisfaction of the Department.

S P E C I A L   P R O V I S I O N

SECTION 803 – SPAN BALANCE

Description

1.1 General

1.1.1 This Section describes the requirements for balancing and balance testing the movable span to ensure compliance with the design criteria and as listed elsewhere herein. Perform balance testing using dynamic strain gage procedure as described herein. This item includes the calculation and documentation of the span balance procedure and methods. All work required to complete the span balance, including furnishing, placing, removing and adjusting the location of the balance blocks is included in this item. Keep the span operable in accordance with the provisions for construction over or adjacent to navigable waters.

1.1.2 Prepare balance calculations prior to perform any work potentially affecting the span balance. Base calculations on approved shop drawings and material tests, and submit to the owner for review and approval.

1.1.3 In all cases above, prior to performing balance testing, submit balance calculations and summary tables to the owner for review. Perform span balance calculations of the movable span for the removal of existing movable span components and installation of the new components to determine the interim and final balance of the span. Format the calculations such that each removal and installation is in sequential order according to the Design-Builder's planned schedule. Do not exceed the maximum calculated span imbalance.

1.1.4 The Design-Builder shall coordinate the installation of the Operating Machinery with all other bridge machinery items, electrical work and structural work, as well as navigational and vehicular traffic closures and restrictions.

1.2 Lift Span Balance

1.2.1 **During Construction**: Balance the lift span to provide the required reactions at the four lift span bearings. Adjust the balance of the movable span as the existing lift span components are removed and new components are installed. This work consist of balancing the span by adding, removing, or shifting new balance blocks in the counterweights to obtain interim balance of the lift span during the various stages of construction. Perform the installation of additional balance blocks and the removal of existing balance blocks as necessary so that the lift span is balanced at all times. A maximum (span heavy condition) of 2700 pounds at each corner of the lift span will be permitted during construction. At the completion of the work on the lift span, the final balance must be such that the lift span is within 5% of 2200 lbs span heavy per corner. Schedule this work after the installation of the strain gages to assist in maintaining the draw span balancing. Measure the imbalance moment, specifying friction values, and determine the location of the leaf center of gravity a minimum of 3 times or as required by the Engineer.

1.2.2 **Final**: After construction completion, balance block adjustments to determine if the revised imbalance is within the limits specified and as described herein. Perform leaf operation for final balance testing with the span drive machinery. If the second balance testing indicates that the revised imbalance is not within acceptable limits, perform further balance block adjustments and imbalance measurements until the criteria specified herein are met.

Materials

2.1 General

2.1.1 The materials shall meet the minimum requirements specified herein.

2.1.2 Balance material to be cast iron balance blocks, 50 pounds each, and painted to match color of bridge.

Construction Details

3.1 Calculation of Leaf Balance during Construction.

3.1.1 Submit balance calculations a minimum of 3 intervals as specified herein to the owner for review and approval. A Professional Engineer licensed in the State of New Hampshire must perform the balance calculations. Format calculations such that each removal and installation is in sequential order according to the Design-Builder's planned schedule. Base these calculations on weights of approved shop details and material tests for the actual material on the movable span, including the counterweights. Ensure the calculated weight is extremely accurate and account for all material, weld fillets, bolt heads, washers, nuts, paint, normal overruns on plate thickness, etc. Update the balance calculations and summary tables throughout construction and submit to the owner periodically as required to meet the requirements in these Special Provisions. Ensure the balance calculations are approved by the owner before removal operations can begin. Prepare the balance calculations summary using an Excel spreadsheet. Submit the calculations and results with a Microsoft Windows compatible CD.

3.1.2 Develop weights for new work on the shop drawings for each component. Develop and show summary balance tables on the shop drawings. Develop summary tables for all phases of the balance and the proposed imbalances. Account for temporary balance material, if used, in the summary tables. Submit all summary tables and back-up materials for review. Include a narrative with the outline of the proposed phasing, the duration of the imbalance condition, and all other aspects of the work in accordance with the approved construction schedule. Coordinate this information with scheduling requirements and submit to the owner for review.

3.1.3 Provide temporary bracing and supports and/or temporary balance material as required to stabilize the movable span during construction. Coordinate work such that the movable span is never in an unbalanced condition that may be detrimental in any way to the structure, electrical/mechanical components or the safety of construction personnel.

3.1.4 Review of the balance calculations, counterweight details, and quantity and location of balance material does not relieve the Design-Builder from making such changes in the counterweights and balance material as deemed necessary to balance the movable span. Submit all changes for approval

3.2 Measurement of Span Balance.

3.2.1 Measure the balance of the movable span using the dynamic strain gauging technique. Furnish and install all equipment, materials, instruments and labor necessary to determine the imbalance by dynamic strain gauging.

3.2.2 Employ the services of an established testing company experienced in dynamic strain gage measurement of movable bridge imbalance, subject to approval of the owner. Demonstrate such experience by identifying a minimum of six movable bridges including two span drive vertical lift bridges for which the company has provided complete and satisfactory dynamic strain gage measurements and reporting. The measurements must made under the immediate direction of a Professional Engineer registered in the State of New Hampshire who has had hands-on-experience measuring movable span imbalance by the dynamic strain gage procedure.

3.2.3 The testing company must furnish and install the required strain gages, all cabling and transmission equipment, data acquisition equipment and strip chart recorders and produce fully documented reports detailing the results of the measurements. Acceptable testing companies include:

1. Teledyne Engineering Services, Waburn, MA
2. Stafford Bandlow Engineering, Washington Crossing, PA
3. Gresham Consulting, Chalfont, PA
4. Flanders Engineering, Orange Park, FL

3.2.4 Ensure the approved testing company submits the following items to the Department for approval:

1. Description of experimental procedure including type and method of installation of strain gage rosettes, method of transmission of low level signals, data acquisition equipment and/or strip chart recorders.
2. An analysis of system accuracy including all system components (strain gages, amplifiers, A/D convertors, etc.). A system calibration procedure shall be included in the field work procedure.
3. Layout of span drive machinery showing proposed location of strain gages, amplifiers, cable or radio links, data acquisition equipment and all associated cabling.
4. Details of method of transmission of signals from shafting to data acquisition units.
5. Elementary wiring diagrams of interconnection of strain gages, amplifiers, data acquisition equipment, and strip chart recorders.
6. Description of electrical and mechanical factors including sample computations of: shaft torque from measured strains, span imbalance, curve fitting and basis for friction correction

SECTION 804 – WATER AND SEWER PIPING ON BRIDGE

PART 1 - GENERAL

1.1 DESCRIPTION

A. The work under this Section shall consist of furnishing all labor, equipment and materials and performing all work necessary to install, test and place in correct, satisfactory operating condition the new water supply and sewer piping systems on the bridge structure. The Design-Builder is responsible for the complete design and routing of the piping from the control house to an interconnection point at the Portsmouth approach.

B. The work under this section also includes the installation of the heat trace apparatus on the on bridge water and sewer piping.

1.2 QUALITY ASSURANCE

A. American Water Works Association Standard AWWA-C601: Sterilization Standard.

B. American Society for Sanitary Engineering Standard ASSE 1001: Pipe Applied Atmospheric Type Vacuum Breakers.

C. American Society for Sanitary Engineering Standard ASSE 1013: Reduced Pressure Principle Backflow Preventers and Reduced Pressure Fire Protection Principle Backflow Preventers.

D. Standard: American Society for Sanitary Engineering Standard ASSE 1020: Pressure Vacuum Breaker Assembly.

PART 2 - PRODUCTS

2.1 GENERAL

A. The Design-Builder is permitted to substitute an equivalent material from those shown on the Plans and specified herein. All required design and/or modifications associated with the substitution shall be the exclusive responsibility of the Design-Builder. The equivalent product shall be subject to the approval of the Engineer.

2.2 PIPE AND FITTINGS

A. The aboveground water supply piping shall be seamless copper tubing conforming to ASTM B88, Type L, or approved equal.

B. Fittings for copper water supply pipe shall conform to ANSI B16.22. Solder filler metal shall conform to ASTM B32, 95-5 Tin-Antimony, or approved equal.

C. The sewer pipe on bridge will be hubless, cast iron soil pipe conforming to Cast Iron Soil Pipe Institute (CISPI) 310 and ASTM A888, or approved equal.

D. Fittings for sewer pipe on bridge shall be the hubless type conforming to ASTM A888. Fittings shall utilize neoprene gasket, double stainless steel band and clamp (2 per side of fitting) conforming to CISPI 301, or approved equal.

E. Exposed gas piping 1½ inches and smaller shall be seamless Schedule 40 black steel, ASTM A106 or ASTM A53 Type "S", Grade A or B, with Class 150 black malleable iron threaded fittings conforming to ASME B16.3.

F. Piping 2 inches and larger shall be Type "S" seamless or Type "E" electric resistance welded Schedule 40 black steel, ASTM A53, Grade A or B, with Schedule 40 wrought carbon steel fittings, ASTM A 234 and butt weld joints.

G. Pipe and fitting insulation shall be AP-T jacketed Micro-lok fiberglass pipe insulation as manufactured by Manville Corporation. Thickness as shown on the plans. Insulation at pipe supports shall be Therma-12/Blue Hydrous Calcium Silicate as manufactured by Manville Corporation. Insulation shall be covered over pipe and fittings with Zestron 2000 PVC covers, 20 mils thick, as manufactured by Manville Corporation. PVC covers shall be secured using stainless steel clamps. A wear shield as shown on the plans, shall be placed between each support and the PVC insulation jacket. The wear shield shall be secured to the PVC jacket.

H. The water pipe shall be provided with linear expansion compensators. Expansion compensators shall have stainless steel bellows and stainless steel housing with copper sweat ends. Expansion compensator shall have a minimum working pressure rating of 175 psi (250 psi test pressure), minimum temperature rating of 500F with minimum straight line travel action of 2-in compression and ½-in expansion. Pipe must be properly guided and anchored per the recommendations of the Expansion Joint Manufacturers Association.

I. Supports assemblies for sewer and water pipe installation shall be supplied as specified/detailed in the Plans and as required per International Plumbing Code.

J. Supports assemblies for gas pipe installation shall be supplied as specified/detailed in the Plans and as required per International Fuel Gas Code.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Design-Builder shall field verify all locations where the water, sewer, and gas piping are to be installed to ensure piping will maintain as straight a line as possible.

B. Before beginning construction of any portion of the work, the Design-Builder shall determine the exact locations of all pipes, utilities, and other features to ensure there are no conflicts.

C. All horizontal portions of water and sewer piping shall be supported using reinforced insulation as previously specified so that the weight of the pipe will not crush the insulation at the supports. A wear shield shall be placed between each horizontal support and the PVC insulation jacket. The wear shield shall be secured to the jacket utilizing stainless steel clamps. All supports for horizontal gas piping shall be directly fastened to the piping.

D. All supports for vertical portions of piping shall be directly fastened to the piping prior to the installation of the insulation. The Design-Builder shall include additional supports as required to accommodate thrust loads at all elbows and turns. Additional extraneous loads on the piping such as cleanouts and valves shall be properly supported.

E. Prior to the installation of the insulation, the Design-Builder shall install and secure the two heat trace lines to both the water and sewer piping. The heat trace shall be loosely wrapped around the pipe expansion joints to ensure free movement of the joints.

F. All costs associated with permitting and tie-in coordination for the gas system shall be the sole responsibility of the Design-Builder.

3.2 TESTS AND DISINFECTION

A. The Design-Builder shall not enclose, cover or put into operation the water, sewer, or gas piping systems until they have been inspected, disinfected (water only), and approved by the Engineer or other duly authorized representative. The Design-Builder shall give two (2) weeks notice to the Engineer prior to performing any tests.

B. Testing of the water and sewer piping shall be in accordance with the procedures of the authority having jurisdiction or, in the absence of a published procedure in accordance to the International Plumbing Code.

C. Testing of the gas piping shall be in accordance with the procedures of the authority having jurisdiction or, in the absence of a published procedure in accordance to the International Fuel Gas Code.

D. Disinfection of the water lines shall be in accordance with the Plumbing Code or the Authority having jurisdiction.

E. The Design-Builder shall furnish all labor, materials and equipment necessary to perform the above pressure testing and disinfection.

SECTION 805 – UNDERGROUND WATER AND SEWER PIPING

PART 1 - GENERAL

1.1 DESCRIPTION

A. The work under this Section shall consist of furnishing all labor, equipment and materials and performing all work necessary to install, test and place in correct, satisfactory operating condition the new underground sewer and water piping systems.

B. This Section also shall also consist of furnishing all labor, equipment and materials and performing all work necessary to install, test and place in correct, satisfactory operating condition the new water meter, backflow preventer, and water meter enclosure.

C. The work under this section also includes the installation of the heat trace apparatus on the underground water and sewer piping. All heat tracing components, including wiring and controls, for the underground water and sewer piping shall be paid for under Section 822 House and Bridge Electrical. All testing, electrical connection and adjustment of heat trace shall also be included in Section 822 House and Bridge Electrical.

D. All materials, workmanship, and installation of the on underground sewer piping shall meet all applicable requirements of the International Plumbing Code 2006, or as required by the Authority having jurisdiction.

1.2 QUALITY ASSURANCE

A. American Water Works Association Standard AWWA-C601: Sterilization Standard.

B. American Society for Sanitary Engineering Standard ASSE 1001: Pipe Applied Atmospheric Type Vacuum Breakers.

C. American Society for Sanitary Engineering Standard ASSE 1013: Reduced Pressure Principle Backflow Preventers and Reduced Pressure Fire Protection Principle Backflow Preventers.

D. Standard: American Society for Sanitary Engineering Standard ASSE 1020: Pressure Vacuum Breaker Assembly.

PART 2 - PRODUCTS

2.1 GENERAL

A. The Design-Builder is permitted to substitute an equivalent material from those shown on the Plans and specified herein. All required design and/or modifications associated with the substitution shall be the exclusive responsibility of the Design-Builder. The equivalent product shall be subject to the approval of the Engineer.

2.2 PIPE AND FITTINGS

A. The underground sewer pipe shall be hubless, cast iron soil pipe conforming to Cast Iron Soil Pipe Institute (CISPI) 301 and ASTM A888, or approved equal.

B. Fittings for the underground sewer pipe shall be the hubless type conforming to ASTM A888, CISPI 310, or approved equal. Fittings shall utilize neoprene gasket, double stainless steel band and clamp (2 per side of fitting).

C. The underground water supply piping shall be seamless copper tubing conforming to ASTM B88, Type K, or approved equal.

D. Fittings for copper water supply pipe shall conform to ANSI B16.22. Solder filler metal shall conform to ASTM B32, 95-5 Tin-Antimony, or approved equal.

E. Underground pipe sleeves shall hubless, cast iron soil pipe conforming to Cast Iron Soil Pipe Institute (CISPI) 301 and ASTM A888, or approved equal.

F. Underground pipe insulation shall be Therma-12/Blue Hydrous Calcium Silicate as manufactured by Manville Corporation. Insulation shall be covered over pipe and fittings with Zestron 2000 PVC cover, 20 mils thick, as manufactured by Manville Corporation. PVC covers shall be secured using stainless steel clamps.

G. The annular space between the insulated water pipe and sleeve shall be sealed with modular sealing assembly part number LS-475-610 and a rubber end cap PSI model C (at each end) as manufactured by Link Seal, or approved equal.

H. The insulated water pipe shall be supported in the sleeve with casing spacers, part number PE, sized as required, as manufactured by Link Seal, or approved equal.

I. The annular space between the sewer pipe and sleeve shall be sealed with a modular sealing assembly part number LS-500-410 and a rubber end cap PSI model C (at each end) as manufactured by Link Seal, or approved equal.

J. The sewer pipe shall be supported in the sleeve with casing spacers part number PE, sized as required, as manufactured by Link Seal, or approved equal.

2.3 WATER METER ASSEMBLY

A. The water meter shall be model number T-10 as manufactured by Neptune Technology Group Inc., or approved equal.

B. The backflow preventer shall be a Double Check Valve Assembly (DCVA) model 007QT-S as manufactured by Watts, or approved equal.

C. The water meter enclosure shall be model number LB1.5 with GP1.5 as manufactured by Hot Box, Inc., or approve equal.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Design-Builder shall field verify all locations where the sewer piping is to be installed to ensure piping will maintain as straight a line as possible.

B. Before beginning construction of any portion of the work the Design-Builder shall determine the exact locations of all pipes, utilities, and other features underground to ensure there are no conflicts.

C. All trenching, excavation, and backfilling shall comply with the requirement of the International Plumbing Code, or as required by the Authority having jurisdiction.

D. Heat trace for the underground sewer pipe shall terminate 4'-0" below grade. The heat trace for the water pipe shall continue to the water meter enclosure and beyond to provide adequate freeze protection to 4'-0" below grade. Insulation terminations shall be sealed.

E. Insulation system for the underground sewer pipe shall terminate 4'-0" below grade. The insulation system for the water pipe shall continue to the water meter enclosure. In addition, the Design-Builder shall also provide insulation on the supply water pipe to 4'-0" below grade. Insulation terminations shall be sealed.

F. All costs associated with the complete installation of the water and sewer systems including permitting, tie-in, pump station coordination, and excavation coordination shall be the sole responsibility of the Design-Builder.

G. Design-Builder shall restore all pavement and/or concrete where the installation of water and/or sewer pipe requires the removal of roadway and/or sidewalk at no cost to the Department.

3.2 TESTS AND DISINFECTION

A. The Design-Builder shall not enclose, cover or put into operation the underground sewer piping system until it has been inspected and approved by the Engineer or other duly authorized representative. The Design-Builder shall give two (2) weeks notice to the Engineer prior to performing any tests.

B. Testing of the sewer piping shall be in accordance with the procedures of the authority having jurisdiction or, in the absence of a published procedure in accordance to the International Plumbing Code.

C. The Design-Builder shall furnish all labor, materials and equipment necessary to perform the above testing.

D. Disinfection of the water lines shall be in accordance with the Plumbing Code or the Authority having jurisdiction.

E. The Design-Builder shall furnish all labor, materials and equipment necessary to perform the above pressure testing and disinfection.

SECTION 806 – CONTROL HOUSE WATER, GAS AND SEWER PIPING

PART 1 - GENERAL

1.1 DESCRIPTION

A. The work under this Section shall consist of furnishing all labor, equipment and materials and performing all work necessary to install, test and place in correct, satisfactory operating condition the new water supply and sewage piping systems located in the control house. The work under this section also includes the material and installation associated with the control house plumbing fixtures.

1.2 QUALITY ASSURANCE

A. American Water Works Association Standard AWWA-C601: Sterilization Standard.

B. American Society for Sanitary Engineering Standard ASSE 1001: Pipe Applied Atmospheric Type Vacuum Breakers.

C. American Society for Sanitary Engineering Standard ASSE 1013: Reduced Pressure Principle Backflow Preventers and Reduced Pressure Fire Protection Principle Backflow Preventers.

D. Standard: American Society for Sanitary Engineering Standard ASSE 1020: Pressure Vacuum Breaker Assembly.

PART 2 - PRODUCTS

2.1 GENERAL

A. The Design-Builder is permitted to substitute an equivalent material from those shown on the Plans and specified herein. All required design and/or modifications associated with the substitution shall be the exclusive responsibility of the Design-Builder. The equivalent product shall be subject to the approval of the Engineer.

2.2 PIPE AND FITTINGS

A. The control house water supply piping shall be seamless copper tubing conforming to ASTM B88, Type L, or approved equal.

B. Fittings for copper water supply pipe shall conform to ANSI B16.22. Solder filler metal shall conform to ASTM B32, 95-5 Tin-Antimony, or approved equal.

C. The sewer pipe on bridge will be hubless, cast iron soil pipe conforming to Cast Iron Soil Pipe Institute (CISPI) 301 and ASTM A888, or approved equal.

D. Fittings for sewer pipe on bridge shall be the hubless type conforming to ASTM A888. Fittings shall utilize neoprene gasket, double stainless steel band and clamp (2 per side of fitting) conforming to CISPI 310, or approved equal.

E. Exposed gas piping inside of Building 1½ inches and smaller shall be seamless Schedule 40 black steel, ASTM A106 or ASTM A53 Type "S", Grade A or B, with Class 150 black malleable iron threaded fittings conforming to ASME B16.3.

F. Piping 2 inches and larger shall be Type "S" seamless or Type "E" electric resistance welded Schedule 40 black steel, ASTM A53, Grade A or B, with Schedule 40 wrought carbon steel fittings, ASTM A 234 and butt weld joints.

G. Pipe and fitting insulation (in unconditioned spaces only) shall be 2" thick AP-T jacketed Micro-lok fiberglass pipe insulation as manufactured by Manville Corporation. Insulation at pipe supports shall be Therma-12/Blue Hydrous Calcium Silicate as manufactured by Manville Corporation. Insulation shall be covered over pipe and fittings with Zestron 2000 PVC covers, 20 mils thick, as manufactured by Manville Corporation. PVC covers shall be secured using stainless steel clamps. A wear shield as shown on the plans, shall be placed between each support and the PVC insulation jacket. The wear shield shall be secured to the PVC jacket.

H. All gas valves shall be designed, manufactured and approved for natural gas service.

I. Ball Valves for copper piping shall be two-piece construction with bronze body conforming to ASTM B-62, having standard porting and solder ends. Valve shall include chrome-plated ball, replaceable Teflon seats and seals, blow proof stem and vinyl covered handle. Valves shall be rated for 600 psi working pressure. Size shall be equal to the size of the pipe on which it is installed.

2.3 PLUMBING FIXTURES

A. Mop Sink shall be 14-gauge, Type 304, stainless steel service sink, or approved equal.

B. Mop Sink faucet shall be commercial faucet, solid brass construction, rough chrome finish, or approved equal.

C. Lavatory shall be 21-1/4" x 18-1/8", white vitreous china, front overflow, self-rimming; 1/4-inch x 1 1/4-inch cast brass "P" trap with cleanout, slip inlet, threaded outlet;

D. Lavatory faucet shall be widespread lavatory faucet, polished chrome faucet, or approved equal.

E. Water Closet shall be white vitreous china, 1.6 gallon flush, elongated bowl, floor mount, solid plastic seat, with open front with concealed stainless steel check hinge, or approved equal.

F. Kitchen Sink shall be 20-gauge, Type 301, nickel bearing stainless steel, self rimming sink, or approved equal.

G. Kitchen Sink faucet shall be solid brass construction, chrome finish, or approved equal.

H. Funnel Drain shall be model number Z325 as manufactured by Zurn or approved equal.

I. Wall Hydrant shall Watts HY-420 non-freeze key operated wall hydrant with chrome plated face, integral vacuum breaker, 3/4"(19) hose connection, 3/4"(19) female x 1"(25) male pipe connection, all bronze head, seat casting and internal working parts, bronze wall casing, and loose key, or approved equal. Design-Builder shall coordinate wall thickness and assembly length.

J. Water Heater shall be as manufactured by A.O. Smith, or approved equal.

K. Water Filter unit shall be Household Water filtration System as manufactured by General electric Company, or approved equal.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Design-Builder shall field verify all locations where the water and sewer piping are to be installed to ensure piping will maintain as straight a line as possible.

B. Before beginning construction of any portion of the work the Design-Builder shall determine the exact locations of all pipes and other features with the control house to ensure there are no conflicts.

C. All horizontal portions of piping (in unconditioned spaces only) shall be supported using reinforced insulation as previously specified so that the weight of the pipe will not crush the insulation at the supports. A wear shield shall be placed between each horizontal support and the PVC insulation jacket. The wear shield shall be secured to the jacket utilizing stainless steel clamps.

D. All supports for vertical portions of piping shall be directly fastened to the piping prior to the installation of the insulation. The Design-Builder shall include additional supports as required to accommodate thrust loads at all elbows and turns. Additional extraneous loads on the piping such as cleanouts and valves shall be properly supported.

E. Prior to the installation of the insulation, the Design-Builder shall install and secure the two heat trace lines to the water and sewer piping (in unconditioned spaces only).

3.2 TESTS AND DISINFECTION

A. The Design-Builder shall not enclose, cover or put into operation the water or sewer piping systems until they have been inspected, disinfected (water only), and approved by the Engineer or other duly authorized representative. The Design-Builder shall give two (2) weeks notice to the Engineer prior to performing any tests.

B. Testing of the water and sewer piping shall be in accordance with the procedures of the authority having jurisdiction or, in the absence of a published procedure in accordance to the International Plumbing Code.

C. Disinfection of the water lines shall be in accordance with the Plumbing Code or the Authority having jurisdiction.

D. The Design-Builder shall furnish all labor, materials and equipment necessary to perform the above pressure testing and disinfection.

END OF SECTION 22 10 30

SECTION 807 – HVAC

PART 1 - GENERAL

1.1 DESCRIPTION

A. The work under this Section shall consist of designing all HVAC systems and furnishing all labor, equipment and materials and performing all work necessary to install, test and place in correct, satisfactory operating condition the new HVAC systems located in the control house and machinery house.

B. The Design/Build Design-Builder shall be responsible for the load calculations, design, equipment layout, duct design and controls of all components associated with the HVAC systems for the Control House, Machinery House, and Gate / Storage Sheds.

1.2 QUALITY ASSURANCE

A. All materials, workmanship, and installation of the on bridge piping shall meet all applicable requirements of the International Mechanical Code 2010, or as required by the Authority having jurisdiction.

B. The Design-Builder shall comply with the requirements of the following codes and standards:

Furnace unit shall be rated in accordance with ARI Standards 210-75 and 240-76.

Furnace and condensing units shall be constructed in accordance with UL regulations and shall carry the UL label of approval.

Refrigeration system of condensing units shall be constructed in accordance with ASHRAE Standard ASHRAE 15 "Safety Code for Mechanical Refrigeration".

Condensing units shall meet or exceed the minimum COP/Efficiency levels as prescribed in ASHRAE 90A "Energy Conservation in New Building Design".

NFPA 90A, "Standard for the Installation of Air Conditioning and Ventilating Systems," except as indicated otherwise.

SMACNA Compliance: Comply with applicable portions of SMACNA "HVAC Duct Construction Standards, Metal and Flexible".

Industry Standards: Comply with ASHRAE recommendations pertaining to construction of ductwork accessories, except as otherwise indicated.

UL Compliance: Construct, test, and label fire dampers in accordance with UL Standard 555 "Fire Dampers and Ceiling Dampers".

NFPA Compliance: Comply with applicable provisions of NFPA 90A "Air Conditioning and Ventilating Systems", pertaining to installation of ductwork accessories.

ARI Compliance: Test and rate air outlets and inlets in accordance with ARI 650 "Standard for Air Outlets and Inlets".

ASHRAE Compliance: Test and rate air outlets and inlets in accordance with ASHRAE 70 "Method of Testing for Rating the Air Flow Performance of Outlets and Inlets".

NFPA Compliance: Install air outlets and inlets in accordance with NFPA 90A "Standard for the Installation of Air Conditioning and Ventilating Systems".

AABC: "National Standards for Total System Balance."

ASHRAE: ASHRAE Handbook, HVAC APPLICATIONS, Chapter 34, Testing, Adjusting, and Balancing.

PART 2 - PRODUCTS

2.1 GENERAL

A. Design-Builder is permitted to substitute an equivalent material from those shown on the Plans and specified herein. All required design and/or modifications associated with the substitution shall be the exclusive responsibility of the Design-Builder. The equivalent product shall be subject to the approval of the Engineer.

2.2 HVAC EQUIPMENT

A. Gas Furnace (GF-1) shall be as manufactured by Carrier Infinity Series with variable speed drive and a three (3) stage burner. Accessories shall include programmable thermostat, outdoor air temperature sensor, communication link with Heat Pump (HP-1), occupancy scheduling capability, and interlock capabilities with third party energy recovery ventilator (ERV). GF-1 shall run continuously at all times when the ERV is energized.

B. Heat Pump (HP-1) shall be as manufactured by Carrier Infinity Series, or approved equal, capable of operating in 0 degree Fahrenheit weather.

C. Condensate pump shall be as manufactured by Little Giant Pump Company, or approved equal.

D. Energy Recovery Ventilator (ERV-1) shall be as manufactured by RenewAire, or equal.

E. Diffusers shall be model number TDCA with integral damper, as manufactured by Titus, or approved equal. Color shall be approved by the architect.

F. Registers shall be model number 350RL, as manufactured by Titus, or approved equal.

G. Fire Dampers shall be model number DIBD2SS, as manufactured by Ruskin, or approved equal. Design-Builder shall size fire dampers to duct size as shown on the Plans.

H. Ductwork and associated material:

1. Ductwork: Except as otherwise indicated, fabricate rectangular ducts with galvanized sheet steel, in accordance with SMACNA "HVAC Duct Construction Standards," Tables 1-3 through 1-19, including the associated details. Conform to the requirements in the referenced standard for metal thickness, reinforcing types and intervals, tie rod applications, and joint types and intervals. Fabricate rectangular ducts

in lengths appropriate to reinforcement and rigidity class required for pressure classification. Provide materials that are free from visual imperfections such as pitting, seam marks, roller marks, stains, and discoloration. Except where otherwise indicated, construct duct systems to the following pressure classifications:

Supply Ducts:	3 inches water gage.
Return Ducts:	2 inches water gage, negative pressure.
Exhaust Ducts:	2 inches water gage.

2. Exposed ductwork in view in occupied spaces, Design-Builder shall provide materials which are free from visual imperfections including pitting, seam marks, roller marks, oil canning, stains and discoloration and other imperfections including those which impair painting.

3. Galvanized Sheet Steel: Lock-forming quality, ASTM A653, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, Coating Designation G 90. Provide mill-phosphatized finish for exposed surfaces of ducts exposed to view.

4. Sheet Metal, General: Provide sheet metal in thickness indicated, packaged and marked as specified in ASTM A700, Standard Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment.

5. Reinforcement Shapes and Plates: Unless otherwise indicated, provide galvanized steel reinforcing, installed on galvanized sheet metal ducts. For aluminum and stainless steel ducts provide reinforcing of compatible materials.

6. Tie Rods: Galvanized steel, 1/4 inch minimum diameter for 36 inch length or less; 3/8 inch minimum diameter for lengths longer than 36 inches.

7. Manufactured Turning Vanes: Provide turning vanes constructed of 1 1/2" wide curved blades set at 3/4" o.c., supported with bars perpendicular to blades set at 2" o.c., and set into side strips suitable for mounting in ductwork.

I. Electric Unit Heaters for machinery house shall be a vertical air delivery type heater as manufactured by Modine, or approved equal. Optional accessories shall include permanent washable filter, ceiling mount kit, and built in thermostat.

J. Gas Unit Heaters for machinery house shall be a direct vent sealed combustion gas heater with horizontal delivery, as manufactured by Modine, or approved equal. Optional accessories shall include permanent washable filter, ceiling mount kit, and built in thermostat.

K. Electric baseboard heater for the storage sheds shall be as manufactured by Chromalox, or approved equal. Optional accessories shall remote wall mounted thermostat.

L. In Wall Exhaust Fans shall be as manufactured by Cook Industries with integral bird screen, weather hood, and damper.

M. Louvers shall be as manufactured by Ruskin, with a maximum operating pressure drop of 0.1 in wg and 500 fpm face velocity.

N. Dampers shall be as manufactured by Greenheck and shall be aluminum in construction. Motor operator shall be as manufactured by Belimo and interlocked to the respective exhaust fan start/stop circuit.

O. Pipe insulation shall be AP/Armaflex SS expanded closed-cell pipe insulation as manufactured by Armacell, or approved equal. Thickness as shown on the plans. Insulation shall be covered with Zestron 2000 PVC covers, 20 mils thick, as manufactured by Manville Corporation and shall be secured using stainless steel clamps. A wear shield shall be placed between each support and the PVC insulation jacket. The wear shield shall be secured to the PVC jacket.

P. Supports assemblies for the HVAC pipe installation shall be supplied as detailed in the Plans and as required per the International Mechanical Code.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Before beginning construction of any portion of the work the Design-Builder shall determine the exact locations of all equipment and other features with the structures to ensure there are no conflicts.

B. Design-Builder shall provide all necessary options and/or additional components to place the HVAC systems, at all locations, in satisfactory working order at no additional cost to the Department.

C. Design-Builder shall balance air flow in the control house according to requirements shown on the plans. The Design-Builder shall submit a balance test report to the engineer for review and approval at the conclusion of balancing effort. The balance report shall include a drawing sheet identifying diffuser/return register location and throw qty/direction. Report shall also include, in tabular format for each location, total CFM and supply temperature for both heating and cooling modes.

S P E C I A L   P R O V I S I O N

SECTION 810 – ELECTRICAL WORK

Description

The provisions of this section apply to the general construction of the Electrical Work, excluding mechanical, heating, ventilating and air conditioning, plumbing and Architectural/Building Structures work. Refer to the following related sections:

Sections 801 to 803 – Mechanical
Sections 804 to 807 – HVAC and Plumbing
Section 895.1 – Architectural/Building Structures

Materials and Construction Requirements

All work shall conform to the requirements outlined in the following subsections:

GENERAL REQUIREMENTS	
01 73 20	Opening and Penetrations in Construction
ELECTRICAL	
26 05 00	Electrical – Basic Requirements
26 05 09	Motors
26 05 19	Wire and Cable – 600 Volt and Below
26 05 26	Grounding
26 05 33	Raceways
26 05 45	Droop Cable System
26 05 48	Seismic Bracing Systems
26 08 13	Acceptable Testing
26 09 13	Electrical Metering Services
26 09 16	Control Equipment Accessories
26 12 19	Distribution Transformers
26 22 13	Dry-Type Transformers
26 24 16	Panelboards
26 24 19	Motor Control Equipment
26 27 26	Wiring Devices
26 28 00	Overcurrent and Short Circuit Protective Devices
26 28 16	Safety Switches
26 29 23	Variable Frequency Drives: Low Voltage
26 32 14	Engine Generator: Diesel
26 36 00	Transfer Switches
26 40 10	Bridge Control System
26 40 20	Bridge Electrical Equipment

26 41 13	Lightning Protection System
26 43 13	Low Voltage Surge Protection Devices (SPD)
26 50 00	Interior and Exterior Lighting

DATA COMMUNICATIONS

27 05 00	Passive Telecommunication System

ELECTRONIC SAFETY AND SECURITY

28 23 00	Video Surveillance System
28 31 00	Fire Alarm System

TRANSPORTATION

34 41 16	Traffic Control Equipment

PROCESS INTEGRATION

40 41 13	Heat Tracing Cable
40 94 43	Programmable Logic Controls (PLC) Control System

Method of Measurement

Payment will be made on the contract on a lump sum basis, which shall be full compensation for all materials, labor, tools, equipment, and incidentals necessary to completely manufacture, fabricate, install, and test to the satisfaction of the Engineer.

Basis of Payment

PAY ITEMS AND UNITS

810	Electrical Work	Lump Sum

SECTION 01 73 20

OPENINGS AND PENETRATIONS IN CONSTRUCTION

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Methods of installing and sealing openings and penetrations in construction.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Specification Section 562 - Silicone Joint Sealant.
   2. New Hampshire Department of Transportation Specification Section 708 - Paints.
   3. Section 07 84 00 - Firestopping.
   4. Section 07 62 00 - Flashing and Sheet Metal.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. American Concrete Institute (ACI):
      a. 318, Building Code Requirements for Structural Concrete.
   2. ASTM International (ASTM):
      a. A36, Standard Specification for Carbon Structural Steel.
      b. A53, Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless.
   3. National Fire Protection Association (NFPA):
      a. 70, National Electrical Code (NEC):
         1) Article 501, Class 1 Locations.
      b. 90A, Standard for Installation of Air Conditioning and Ventilating Systems.
   4. Sheet Metal and Air Conditioning Contractors' National Association (SMACNA).

B. Assure all firestopping materials are in full compliance with Specification Section 07 84 00.

C. Obtain prior approval from Engineer when any opening larger than 100 SQ IN must be made in existing or newly completed construction.

1.3 DEFINITIONS

A. Hazardous Areas: Areas shown in the Contract Documents as having Class I or Class II area classifications.

B. Washdown Areas: Areas having floor drains or hose bibs.

1.4 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of the submittal process.
   2. For each structure provide dimensioned or scaled (minimum 1/8 IN = 1 FT) plan view drawings containing the following information:
      a. Vertical and horizontal location of all required openings and penetrations.
      b. Size of all openings and penetrations.
      c. Opening type.
      d. Seal type.
   3. Manufacturer's installation instructions for standard manufactured products.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Pipe Sleeves: Steel, ASTM A53, Schedule 40, black.

B. Pipe Sleeves Penetrating into Corrosive Areas: Stainless steel, 1/4 IN minimum thickness.

C. Backing Rod and Sealant: See New Hampshire Department of Transportation Specification Section 562.

D. Modular Mechanical Seals:
   1. Acceptable manufacturers:
      a. Link-Seal.
   2. {304} {316} stainless steel bolts, nuts and washers.

E. Firestopping Material: See Specification Section 07 84 00.

F. Sheet Metal Sleeves: Steel, ASTM A36, 12 GA.

G. Commercial Wall Castings:
   1. For unclassified areas both sides of penetration:
      a. Ductile iron, class equal to connecting piping system.
   2. For wet/corrosive areas either side of penetration:
      a. Stainless steel, 304L.

PART 3 - EXECUTION

3.1 INSTALLATION AND APPLICATION

A. Perform HVAC penetrations in accordance with NFPA 90A.

B. Perform electrical penetrations in accordance with NFPA 70, Article 501.

C. Install sleeves and castings in accordance with ACI 318, Chapter #6.

D. Hot dip galvanize or paint in accordance with New Hampshire Department of Transportation Specification Section 708 all steel sleeves installed.

E. When mechanical or electrical work cannot be installed as structure is being erected, provide and arrange for building-in of boxes, sleeves, insets, fixtures or devices necessary to permit installation later.
   1. Lay out chases, holes or other openings which must be provided in masonry, concrete or other work.

F. Where pipes, conduits or ducts pass through floors in washdown areas, install sleeves with top 3 IN above finish floors.
   1. In non-washdown areas, install sleeves with ends flush with finished surfaces.

G. Size sleeves, blockouts and cutouts which will receive sealant seal such that free area to receive sealant is minimized and seal integrity may be obtained.

H. For insulated piping and ducts, size sleeves, blockouts and cutouts large enough to accommodate full thickness of insulation.

I. Do not cut into or core drill any beams, joists, or columns.

J. Do not install sleeves in beams, joists, or columns.

K. Do not install recesses in beams, joists, columns, or slabs.

L. Field Cutting and Coring:
   1. Saw or core drill with non-impact type equipment.
   2. Mark opening and drill small 3/4 IN or less holes through structure following opening outline.
   3. Sawcut opening outline on both surfaces.
      a. Knock out within sawcuts using impact type equipment.
      b. Do not chip or spall face of surface to remain intact.
      c. Do not allow any overcut with saw kerf.

M. Precast-Prestressed Concrete Construction:
   1. Do not cut openings nor core drill vertically or horizontally through stems of members.
   2. Do not locate or install sleeves or recess sleeves vertically or horizontally through or in stems of members.
   3. Cast openings and sleeves into flanges of units.
   4. Cast openings larger than 6 IN in diameter or 6 IN maximum dimension in units at time of manufacture.
   5. Cast openings smaller than 6 IN in diameter or 6 IN maximum dimensions in flanges of units at time of manufacture or field cut.

N. Where alterations are necessary or where new and old work join, restore adjacent surfaces to their condition existing prior to start of work.

O. Provide waterstop plate/anchor flange for piping, ducts, castings and sleeves cast-in-place in concrete.
   1. For fabricated units, weld plate to sleeve, pipe, or ductwork.
   2. For commercial castings, cast water stop/anchor with wall pipe.
   3. Plate is to be same thickness as sleeve, pipe, casting or ductwork.
   4. For fabricated units, diameter of plate or flange to be 4 IN larger than outside diameter of sleeve, pipe or ductwork.
   5. For commercial castings, waterstop/anchor size to be manufacturer standard.
   6. Provide continuous around entire circumference of sleeve, pipe, or ductwork.

P. Where area is blocked out to receive sheet metal sleeve at later date:
   1. If blockout size is sufficient to allow placement, utilize dowels for interface of initially placed concrete and sleeve encasement concrete which is placed later.
      a. Size blockout based on sleeve size required plus 4 to 6 IN each side of sleeve for concrete encasement.
      b. Provide #4 dowels at 12 IN spacing along each side of blockout with minimum of two (2) dowels required per side.
   2. If blockout size is not sufficient to allow placement of dowels, provide keyway along all sides of blockout.
      a. Size blockout based on sleeve size required plus 2 to 4 IN each side of sleeve for concrete encasement.

Q. For interior wall applications where backer rod and sealant are specified, provide backer rod and sealant at each side of wall.

R. Refer to Drawings for location of fire-rated walls, floors, and ceilings.
   1. Utilize firestopping materials and procedures specified in Specification Section 07 84 00 in conjunction with scheduled opening type to produce the required fire rating.

S. Use full depth expanding foam sealant for seal applications where single or multiple pipes, conduits, etc., pass through a single sleeve.

T. Do not make duct or conduit penetrations below high water levels when entering or leaving tankage, wet wells, or other water holding structures.

U. Modular Mechanical Seals:
   1. Utilize one (1) seal for concrete thickness less than 8 IN and two (2) seals for concrete, 8 IN thick or greater.
   2. Utilize two (2) seals for piping 16 IN diameter and larger if concrete thickness permits.
   3. Install seals such that bolt heads are located on the most accessible side of the penetration.

V. Backer Rod and Sealant:
   1. Install in accordance with New Hampshire Department of Transportation Specification Section 562.
   2. Provide backer rod and sealant for modular mechanical seal applications.
      a. Apply on top side of slab penetrations and on interior, dry side wall penetrations.

3.2 SCHEDULES

A. General Schedule of Penetrations through Floors, Roofs, Foundation Base Slabs, Foundation Walls, Foundation Footings, Partitions and Walls for Ductwork, Piping, and Conduit:
   1. Provide the following opening and penetration types:
      a. Type A - Block out 2 IN larger than outside dimensions of duct, pipe, or conduits.
      b. Type B - Saw cut or line-drill opening. Place new concrete with integrally cast sheet metal or pipe sleeve.
      c. Type C - Fabricated sheet metal sleeve or pipe sleeve cast-in-place. Provide pipe sleeve with water ring for wet and/or washdown areas.
      d. Type D - Commercial type casting or fabrication.
      e. Type E - Saw cut or line-drill opening. Place new concrete with integrally cast pipe, duct or conduit spools.
      f. Type F - Integrally cast pipe, duct or conduit.
      g. Type G - Saw cut or line-drill and remove area 1 IN larger than outside dimensions of duct, pipe or conduit.
      h. Type H - Core drill.
      i. Type I - Block out area. At later date, place new concrete with integrally cast sheet metal or pipe sleeve.
   2. Provide seals of material and method described as follows.
      a. Category 1 - Modular Mechanical Seal.
      b. Category 2 - Roof curb and flashing according to SMACNA specifications unless otherwise noted on Drawings. Refer to Specification Section 07 62 00 and roofing Specification Sections for additional requirements.
      c. Category 3 - 12 GA sheet metal drip sleeve set in bed of silicon sealant with backing rod and sealant used in sleeve annullus.
      d. Category 4 - Backer rod and sealant.
      e. Category 5 - Full depth compressible sealant with escutcheons on both sides of opening.
      f. Category 6 - Full depth compressible sealant and flanges on both sides of opening. Flanges constructed of same material as duct, fastened to duct and minimum 1/2 IN larger than opening.
      g. Category 7 - Full depth compressible sealant and finish sealant or full depth expanding foam sealant depending on application.
   3. Furnish openings and sealing materials through new floors, roofs, partitions and walls in accordance with Schedule A, Openings and Penetrations for New Construction.
   4. Furnish openings and sealing materials through existing floors, roofs, partitions and walls in accordance with Schedule B, Openings and Penetrations for Existing Construction.

**SCHEDULE A. OPENINGS AND PENETRATIONS SCHEDULE
FOR NEW CONSTRUCTION**

	DUCTS		PIPING		CONDUIT	
APPLICATIONS	OPENING TYPE	SEAL CATEGORY	OPENING TYPE	SEAL CATEGORY	OPENING TYPE	SEAL CATEGORY
Through floors with bottom side a hazardous location	C F I	7 Not Req 7	D F I (1)	Not Req Not Req 7	C F	7 Not Req
Through floors on grade above water table	C F I	4 Not Req 4	C F I (1)	7 Not Req 7	C F I (1)	4 Not Req 7
Through slab on grade below water table	F	Not Req	F	Not Req	F	Not Req
Through floors in washdown areas	C I	4 4	C H (2) I (1)	4 3 4	F H (2) I (1)	Not Req 3 7
Through walls where one side is a hazardous area	C F I	7 Not Req 7	D F I (1)	Not Req Not Req 7	C F	7 Not Req
Through exterior wall below grade above water table	C F I	7 Not Req 7	C D F I (1)	1 Not Req Not Req 1	F I (1)	Not Req 7
Through wall from tankage or wet well (above high water level) to dry well or dry area	C F I	7 Not Req 7	C D F H (2)	1 Not Req Not Req 1	C F H (2) I (1)	7 Not Req 7 7
Through wall from tankage or wet well (below high water level) to dry well or dry area	F	Not Req	F	Not Req	F	Not Req
Through exterior wall above grade	A B C	6 6 6	A B D H (2)	5 5 Not Req 5	C H (2)	5 4
Roof penetrations	A	2	A	2	A	2
Through interior walls and slabs not covered by the above applications	A C	4 4	A C	4 4	A C F	4 4 Not Req

SCHEDULE B. OPENINGS AND PENETRATIONS SCHEDULE FOR EXISTING CONSTRUCTION

APPLICATIONS	DUCTS		PIPING		CONDUIT	
	OPENING TYPE	SEAL CATEGORY	OPENING TYPE	SEAL CATEGORY	OPENING TYPE	SEAL CATEGORY
Through floors with bottom side a hazardous location	B E	7 Not Req	B [(1)] E [(3)] H [(2)]	7 Not Req 7	B [(1)] E [(3)] H [(2)]	7 Not Req 7
Through floors on grade above water table	B	7	B	7	B	7
Through slab on grade below water table	E	Not Req	E	Not Req	E	Not Req
Through floors in washdown areas	G	3	G H [(2)]	3 3	G H [(2)]	3 3
Through walls where one side is a hazardous area	B E	7 Not Req	B [(1)] B [(3)] E H [(2)]	7 1 Not Req 7	B [(1)] [(3)] E H [(2)]	7 Not Req 7
Through exterior wall below grade above water table	B	7	B [(1)] B [(3)] H [(2)]	7 1 7	B [(1)] [(3)] H [(2)]	7 7
Through wall from tankage or wet well (above high water level) to dry well or dry area	B E	7 Not Req	B E H [(2)]	1 Not Req 1	B [(1)] [(3)] E H [(2)]	7 Not Req 7
Through wall from tankage or wet well (below high water level) to dry well or dry area	E	Not Req	E	Not Req	E	Not Req
Through exterior wall above grade	G	6	G [(1)] [(3)] H [(2)]	5 5	G [(1)] [(3)] H [(2)]	5 7
Roof penetrations	G	2	G [(1)] [(3)] H [(2)]	2	G	2
Through interior walls and slabs not covered by the above applications	G	4	G [(1)] [(3)] H [(2)]	4 4	G [(1)] [(3)] H [(2)]	4 4

(1) Multiple piping 3 IN and smaller or multiple conduits.
(2) Single pipe 3 IN and smaller or single conduit.
(3) Single pipe or conduit larger than 3 IN.

SECTION 26 05 00

ELECTRICAL: BASIC REQUIREMENTS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
  1. Basic requirements for electrical systems.

B. Related Specification Sections include but are not necessarily limited to:
  1. New Hampshire Department of Transportation Section 104 - Scope of Work.
  2. New Hampshire Department of Transportation Section 105 - Control of the Work.
  3. New Hampshire Department of Transportation Section 106 - Control of Material.
  4. Section 05 50 00 - Metal Fabrications.
  5. Section 01 25 13 - Product Substitution.
  6. Section 01 73 20 - Openings and Penetrations in Construction.
  7. Section 10 14 00 - Identification Devices.
  8. Section 40 05 05 - Equipment: Basic Requirements.
  9. Section 26 05 19 - Wire and Cable - 600 Volt and Below.
  10. Section 26 05 33 - Raceways and Boxes.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
  1. Aluminum Association (AA).
  2. American Iron and Steel Institute (AISI).
  3. ASTM International (ASTM):
     a. A123, Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
     b. A153, Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.
  4. ETL Testing Laboratories (ETL).
  5. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
     a. C2, National Electrical Safety Code (NESC).
  6. National Electrical Manufacturers Association (NEMA):
     a. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
  7. National Fire Protection Association (NFPA):
     a. 70, National Electrical Code (NEC).
  8. Underwriters Laboratories, Inc. (UL).

B. Where UL test procedures have been established for the product type, use UL or ETL approved electrical equipment and provide with the UL or ETL label.

1.3 DEFINITIONS

A. For the purposes of providing materials and installing electrical work the following definitions shall be used.
  1. Outdoor area: Exterior locations where the equipment is normally exposed to the weather and including below grade structures, such as vaults, manholes, handholes and in-ground pump stations.
  2. Architecturally finished interior area: Offices, laboratories, conference rooms, restrooms, corridors and other similar occupied spaces.
  3. Non-architecturally finished interior area: Pump, chemical, mechanical, electrical rooms and other similar process type rooms.

4. Highly corrosive and corrosive area: Areas identified on the Drawings where there is a varying degree of spillage or splashing of corrosive materials such as water, wastewater or chemical solutions; or chronic exposure to corrosive, caustic or acidic agents, chemicals, chemical fumes or chemical mixtures.
5. Hazardous areas: Class I, II or III areas as defined in NFPA 70.
6. Shop fabricated: Manufactured or assembled equipment for which a UL test procedure has not been established.
7. Operation and Maintenance (O&M) Manuals:
    a. Contain the information required for proper installation and maintenance of building materials and finishes.
    b. Contain the technical information required for proper installation, operation and maintenance of process, electrical and mechanical equipment and systems.

1.4 SUBMITTALS

A. Shop Drawings:
    1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
    2. See Specification Section 40 05 05 and individual specification sections for submittal requirements for products defined as equipment.
    3. General requirements:
        a. Provide manufacturer's technical information on products to be used, including product descriptive bulletin.
        b. Include data sheets that include manufacturer's name and product model number.
            1) Clearly identify all optional accessories.
        c. Acknowledgement that products are UL or ETL listed or are constructed utilizing UL or ETL recognized components.
        d. Manufacturer's delivery, storage, handling and installation instructions.
        e. Product installation details.
        f. See individual specification sections for any additional requirements.

B. Operation and Maintenance Manuals:
    1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
    2. Initial submittal within 60 days after date Shop Drawings are approved.
    3. The Design-Builder shall furnish complete instructions containing the technical information required for proper installation, operation and maintenance of each assembly of equipment supplied. See Specification Section 8.4.

C. When a Specification Section includes products specified in another Specification Section, each Specification Section shall have the required Shop Drawing transmittal form per New Hampshire Department of Transportation Specification Section 105 and all Specification Sections shall be submitted simultaneously.

1.5 DELIVERY

A. Scheduling: Schedule delivery of products or equipment as required to allow timely installation and to avoid prolonged storage.

B. Packaging: Deliver products or equipment in manufacturer's original unbroken cartons or other containers designed and constructed to protect the contents from physical or environmental damage.

C. Identification: Clearly and fully mark and identify as to manufacturer, item, and installation location.

D. Protection and Handling: Provide manufacturer's instructions for storage and handling.

1.6 STORAGE AND HANDLING

A. See New Hampshire Department of Transportation Specification Section 106.

B. Protect nameplates on electrical equipment to prevent defacing.

1.7 AREA DESIGNATIONS

A. Designation of an area will determine the NEMA rating of the electrical equipment enclosures, types of conduits and installation methods to be used in that area.
   1. Outdoor areas:
      a. Wet.
      b. Also, corrosive and/or hazardous when specifically designated on the Drawings or in the Specifications.
   2. Indoor areas:
      a. Dry.
      b. Also, wet, corrosive and/or hazardous when specifically designated on the Drawings or in the Specifications.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, refer to specific Division 26 Specification Sections and specific material paragraphs below for acceptable manufacturers.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

C. Provide all components of a similar type by one (1) manufacturer.

2.2 MATERIALS

A. Electrical Equipment Support Pedestals and/or Racks:
   1. Approved manufacturers:
      a. Modular strut:
         1) Unistrut Building Systems.
         2) B-Line.
         3) Globe Strut.
   2. Material requirements:
      a. Modular strut:
         1) Galvanized steel: ASTM A123 or ASTM A153.
         2) Stainless steel: AISI Type 316.
         3) PVC coated galvanized steel: ASTM A123 or ASTM A153 and 20 mil PVC coating.
         4) Aluminum: AA Type 6063-T6.
      b. Mounting hardware:
         1) Galvanized steel.
         2) Stainless steel.
      c. Anchorage per Specification Section 05 50 00.

B. Field touch-up of galvanized surfaces.
   1. Zinc-rich primer.
      a. One (1) coat, 3.0 mils, ZRC by ZRC Products.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install and wire all equipment, including prepurchased equipment, and perform all tests necessary to assure conformance to the Drawings and Specification Sections and ensure that equipment is ready and safe for energization.

B. Install equipment in accordance with the requirements of:
   1. NFPA 70.
   2. IEEE C2.
   3. The manufacturer's instructions.

C. In general, conduit routing is not shown on the Drawings.
   1. The Design-Builder is responsible for routing all conduits including those shown on one-line and control block diagrams and home runs shown on floor plans.
   2. Conduit routings and stub-up locations that are shown are approximate; exact routing to be as required for equipment furnished and field conditions.

D. When complete branch circuiting is not shown on the Drawings:
   1. A homerun indicating panelboard name and circuit number will be shown and the circuit number will be shown adjacent to the additional devices (e.g., light fixture and receptacles) on the same circuit.
   2. The Design-Builder is to furnish and install all conduit and conductors required for proper operation of the circuit.
   3. The indicated home run conduit and conductor size shall be used for the entire branch circuit.
   4. See Specification Section 26 05 19 for combining multiple branch circuits in a common conduit.

E. Do not use equipment that exceed dimensions or reduce clearances indicated on the Drawings or as required by the NFPA 70.

F. Install equipment plumb, square and true with construction features and securely fastened.

G. Install electrical equipment, including pull and junction boxes, minimum of 6 IN from process, gas, air and water piping and equipment.

H. Install equipment so it is readily accessible for operation and maintenance, is not blocked or concealed and does not interfere with normal operating and maintenance requirements of other equipment.

I. Device Mounting Schedule:
   1. Unless indicated otherwise on the Drawings, mounting heights are as indicated below:
      a. Light switch (to center): 48 IN.
      b. Receptacle in architecturally finished areas (to center): 18 IN.
      c. Receptacle on exterior wall of building (to center): 18 IN.
      d. Receptacle in non-architecturally finished areas (to center): 48 IN.
      e. Telephone outlet in architecturally finished areas (to center): 18 IN.
      f. Telephone outlet for wall-mounted phone (to center): 54 IN.
      g. Safety switch (to center of operating handle): 54 IN.
      h. Separately mounted motor starter (to center of operating handle): 54 IN.
      i. Pushbutton or selector switch control station (to center): 48 IN.
      j. Panelboard (to top): 72 IN.

J. Avoid interference of electrical equipment operation and maintenance with structural members, building features and equipment of other trades.

1. When it is necessary to adjust the intended location of electrical equipment, unless specifically dimensioned or detailed, the Design-Builder may make adjustments of up to 6 IN in equipment location with the Engineer's approval.
   a. Changes in equipment location exceeding those defined above require the Engineer's approval.

K. Provide electrical equipment support system per the following area designations:
1. Dry areas:
   a. Galvanized system consisting of galvanized steel channels and fittings, nuts and hardware.
   b. Field touch-up cut ends and scratches of galvanized components with the specified primer during the installation, before rust appears.
2. Wet areas:
   a. Galvanized system consisting of galvanized steel channels and fittings, nuts and hardware.
   b. Field touch-up cut ends and scratches of galvanized components with the specified primer during the installation, before rust appears.
3. Corrosive areas:
   a. Aluminum system consisting of aluminum channels and fittings with stainless steel nuts and hardware.
4. Highly corrosive areas:
   a. PVC coated steel system consisting of PVC coated steel channels and fittings with stainless steel nuts and hardware.

L. Provide all necessary anchoring devices and supports rated for the equipment load based on dimensions and weights verified from approved submittals, or as recommended by the manufacturer.
1. See Specification Section 05 50 00.
2. Do not cut, or weld to, building structural members.
3. Do not mount safety switches or other equipment to equipment enclosures, unless enclosure mounting surface is properly braced to accept mounting of external equipment.

M. Provide corrosion resistant spacers to maintain 1/4 IN separation between metallic equipment and/or metallic equipment supports and mounting surface in wet areas, on below grade walls and on walls of liquid containment or processing areas such as Basins, Clarifiers, Digesters, Reservoirs, etc.

N. Do not place equipment fabricated from aluminum in direct contact with earth or concrete.

O. Screen or seal all openings into equipment mounted outdoors to prevent the entrance of rodents and insects.

P. Do not use materials that may cause the walls or roof of a building to discolor or rust.

Q. Identify electrical equipment and components in accordance with Specification Section 10 14 00.

3.2 FIELD QUALITY CONTROL

A. Verify exact rough-in location and dimensions for connection to electrified equipment, provided by others.
1. See Specification Section 01 73 20 for openings and penetrations in structures.

B. Replace equipment and systems found inoperative or defective and re-test.

C. Cleaning: See New Hampshire Department of Transportation Specification Section 106.

D. The protective coating integrity of support structures and equipment enclosures shall be maintained.
  1. Repair galvanized components utilizing a zinc rich paint.
  2. Repair painted components utilizing touch up paint provided by or approved by the manufacturer.
  3. Repair PVC coated components utilizing a patching compound, of the same material as the coating, provided by the manufacturer of the component.
  4. Repair surfaces which will be inaccessible after installation prior to installation.
  5. See Specification Section 26 05 33 for requirements for conduits and associated accessories.

E. Replace nameplates damaged during installation.

3.3 DEMONSTRATION

A. Demonstrate the functional integrity of the mechanical, electrical, and control interfaces of the respective equipment and components comprising the bridge as evidence of Substantial Completion.

B. Duration of Demonstration Period: 120, trouble free, lefts.

C. If, during the Demonstration Period, the aggregate amount of time used for repair, alteration, or unscheduled adjustments to any equipment or systems that renders the affected equipment or system inoperative exceed 10 percent of the Demonstration Period, the demonstration of functional integrity will be deemed to have failed. In the event of failure, a new Demonstration Period will recommence after correction of the cause of failure. The new Demonstration Period shall have the same requirements and duration as the Demonstration Period previously conducted.

D. Conduct the demonstration of functional integrity under full operational conditions.

E. Owner will provide operational personnel to provide process decisions affecting plant performance. Owner's assistance will be available only for process decisions. Design-Builder will perform all other functions including but not limited to equipment operation and maintenance until successful completion of the Demonstration Period.

F. Owner reserves the right to simulate operational variables, equipment failures, routine maintenance scenarios, etc., to verify the functional integrity of automatic and manual backup systems and alternate operating modes.

G. Time of beginning and ending any Demonstration Period shall be agreed upon by Design-Builder, Owner, and Engineer in advance of initiating Demonstration Period.

H. Throughout the Demonstration Period, provide knowledgeable personnel to answer Owner's questions, provide final field instruction on select systems and to respond to any system problems or failures which may occur.

I. Provide all labor, supervision, utilities, chemicals, maintenance, equipment, vehicles or any other item necessary to operate and demonstrate all systems being demonstrated.

END OF SECTION

SECTION 26 05 09
MOTORS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Induction motors.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.
   2. Section 01 25 13 - Product Substitution.
   3. Section 40 05 05 - Equipment: Basic Requirements.
   4. Section 26 05 00 - Electrical: Basic Requirements.
   5. Section 26 05 26 - Grounding.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. American Bearing Manufacturers Association (ABMA).
   2. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
      a. 841, Standard for Petroleum and Chemical Industry - Premium-Efficiency, Severe-Duty, Totally-Enclosed Fan-Cooled (TEFC) Squirrel Cage Induction Motors - Up To and Including 370 KW (500 HP).
   3. National Electrical Manufacturers Association (NEMA):
      a. MG 1, Motors and Generators.
   4. National Fire Protection Association (NFPA):
      a. 70, National Electrical Code (NEC).

B. Miscellaneous:
   1. When motors are furnished with driven equipment, the driven equipment supplier shall be responsible for assembling the motor and driven equipment as a complete unit, correctly aligned and coupled with the coupling or sheave specified on the driven equipment data sheet, and designing for vibration, special, or unbalanced forces resulting from equipment operation.
      a. See Specification Section 40 05 05 for requirements.
   2. Variable speed equipment applications: The driven equipment manufacturer shall have single source responsibility for coordination of the equipment and VFD system and sure their compatibility.

1.3 DEFINITIONS

A. Inverter Duty Motor: An AC induction motor complying with all requirements of NEMA MG 1 Part 31 for definite-purpose inverter-fed motors.

B. Abbreviations:
   1. DPFG - Dripproof Fully Guarded.
   2. ODP - Open Dripproof.
   3. RTD - Resistance Temperature Detector.
   4. TEFC - Totally Enclosed Fan Cooled.
   5. TENV - Totally Enclosed Non-ventilated.
   6. WP-I - Weather Protected Type I.

7. WP-II - Weather Protected Type II.
8. Motor controllers:
   a. FVNR - Full Voltage Non-Reversing.
   b. RVAT - Reduced Voltage Autotransformer.
   c. RVPR - Reduced Voltage Primary Reactor.
   d. RVSS - Reduced Voltage Solid State.
   e. VFD - Variable Frequency Drive.

1.4 SUBMITTALS

A. Shop Drawings:
1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
2. Product technical data:
   a. Identify each motor by driven machine identification.
   b. Motor manufacturer and model number.
   c. Complete motor nameplate data.
   d. Weight.
   e. NEMA design type.
   f. Enclosure type.
   g. Frame size.
   h. Winding insulation class and temperature rise.
   i. Starts per hour.
   j. Performance data:
      1) Motor speed-torque curve superimposed over driven machine speed-torque curve during start-up acceleration and at rated terminal voltage and minimum permissible or specified terminal voltage for all motors over 2 HP.
      2) Time-current plots with acceleration verses current and thermal damage curves at the operating and ambient temperatures and at rated terminal voltage and minimum permissible or specified terminal voltage for all motors over 2 HP.
      3) Guaranteed minimum efficiencies at 100 percent, 75 percent and 50 percent of full load.
      4) Guaranteed minimum power factor at 100 percent, 75 percent and 50 percent of full load.
      5) Locked rotor and full load current at rated terminal voltage and minimum permissible or specified terminal voltage.
      6) Starting, full load and breakdown torque at rated terminal voltage and minimum permissible or specified terminal voltage.
   k. Bearing data and lubrication system.
   l. Thermal protection system including recommended alarm and trip settings for winding and bearing RTDs.
   m. Recommended size of power factor correction capacitors, if required, to improve power factor to 0.95 lagging when operated at full load.
3. Fabrication and/or layout drawings:
   a. Dimensioned outline Drawing.
   b. Connection diagrams including accessories (strip heaters, thermal protection, etc.).
4. Certifications:
   a. When utilized with a reduced voltage starter, certify that motor and driven equipment are compatible.
5. Test reports:
   a. Motor test reports for all testing required in this Specification Section.

B. Operation and Maintenance Manuals:
   1. See Specification Section 26 05 00 for requirements for:
      a. The mechanics and administration of the submittal process.
      b. The content of Operation and Maintenance Manuals.
   2. Installation instructions.
   3. Operation and maintenance instructions.
   4. Recommended spare parts list.

1.5 DELIVERY, STORAGE, AND HANDLING

A. See Specification Section 26 05 00.

B. Protect equipment during shipment, handling, and storage by suitable boxes, crates, or other complete enclosures.
   1. Protect equipment from exposure to elements and keep thoroughly dry.

C. Protect painted surfaces against impact, abrasion, discoloration, and other damage.
   1. Repaint damaged painted surfaces to satisfaction of Engineer.

D. Store all motors in a clean and dry indoor location until final installation.

E. Where space heaters are provided in motors, provide temporary electrical power and operate heaters during storage and after motors are installed in permanent location until equipment is placed in service.

F. As per manufacturer's storage instructions.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following manufacturers are acceptable:
   1. Baldor.
   2. General Electric.
   3. Marathon.
   4. Rockwell - Reliance.
   5. Siemens.
   6. TECO-Westinghouse.
   7. Toshiba U.S.
   8. U.S. Electrical Motors.
   9. WEG.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 EQUIPMENT

A. General Requirements:
   1. Standards: NEMA MG 1.
   2. Identify each motor by the driven machine identification.
   3. An embossed or engraved stainless steel nameplate, with the required NFPA 70 and NEMA data, to be permanently attached to the motor.
   4. Maximum motor loading shall not exceed motor nameplate horsepower rating, exclusive of service factor.
   5. All motors shall be sized to carry continuously all loads, which may be imposed through their full range of operation.

6. Altitude: For applications above 3300 FT, motors to be specifically designed and certified for operation at the specified altitude.
7. NEMA MG 1, Design B (unless otherwise required), constant speed squirrel-cage induction type having normal starting torque with low starting current.
8. Suitable for the starting method indicated (e.g., full voltage, autotransformer, solid state reduced voltage, VFD, etc.).
9. Where frequent starting occurs, design for frequent starting duty equivalent to duty service required by driven equipment.
10. Lifting devices: Motors weighing 265 LBS or more shall have suitable lifting eyes for installation and removal.
11. Grounding:
    a. Lug suitable to terminate ground wire in terminal box, sized as indicated on the Drawings.
    b. Frame ground pad on medium voltage induction motors.
12. Stator windings: Copper.
13. Rotor cage: Aluminum or copper.
14. Motor leads shall be non-wicking with permanent identifiers.
15. Totally enclosed motor to have one-way breather drains.
16. Efficiency:
    a. Meet NEMA MG 1 (NEMA Premium) efficiencies.
    b. If motor type, horsepower or speed is not included in the NEMA requirements for NEMA Premium, provide manufacturers "premium energy efficient" design.
17. Power factor:
    a. Minimum of 80 percent lagging at full load, except on motors with speed slower than 900 RPM.
    b. Power factor correction capacitors to be utilized when indicated on the Drawings.
18. Service factor:
    a. 100 hp or less: 1.15.
    b. Greater than 100 hp: 1.0 unless noted otherwise.
    c. Inverter duty: 1.0.
19. Standards: NEMA MG 1, {UL 674, } {UL 1836}.

2.3 FRACTIONAL INDUCTION MOTORS

A. Electrical Ratings:
   1. Appropriate for the voltage system indicated, single phase, 60 Hz.
   2. Dual voltage rated motors (e.g., 115/230 V) are acceptable, provided all leads are brought out to the terminal box and permanently marked.

B. Enclosure: TENV or TEFC, rolled steel enclosure permitted.

C. Bearings: Lubricated-for-Life ball bearings

D. Insulation: Class F insulation with temperature rise not to exceed the insulation class.

E. Thermal Protection: Integral manual or automatic reset thermal protector.

2.4 INDUCTION MOTORS, 600 VOLT AND LESS

A. Horizontal Shaft:
   1. Electrical rating:
      a. Appropriate for the voltage system indicated, 3 PH, 60 Hz.
      b. Dual voltage rated motors (e.g., 230/460 V) are acceptable, provided all leads are brought out to the terminal box and permanently marked.
   2. Enclosure:

a. Cast iron (exception: fan covers can be steel).
b. Type: DPFG, TEFC, WP-I or WP-II as indicated in the schedule.

3. Terminal box:
   a. Gasketed.
   b. Diagonally split.
   c. Field adjustable in 90-degree increments.
   d. Oversized to accept the required conductors and conduits.
   e. Located on “F1” side unless specifically indicated to be on the “F2” side.
   f. Separate terminal box with terminal blocks for winding thermal protection devices (RTD and thermocouples).
4. Bearings:
   a. 5 HP and less: Lubricated-for-Life ball bearings.
   b. Greater than 5 HP:
      1) Relubricatable.
      2) Antifriction.
      3) Minimum rated ABMA L-10 life of 10 years or 100,000 HRS.
5. Insulation:
   a. As per NEMA MG-1.
6. Accessories: See the ACCESSORIES Article in PART 2 and the SCHEDULES Article in PART 3.
7. Modifications:
   a. Inverter duty:
      1) At a minimum, applied to motors connected to a VFD.
      2) Windings insulated for 1600 peak volts and voltage rise times of 0.1 microseconds.
      3) Nameplate identification of meeting NEMA MG 1 Part 31 requirements.
      4) Have the following minimum turndown ratio without the use of a blower to provide continuous supply of cooling air over the motor.
         a) Variable torque: 10:1.
         b) Constant torque: 6:1.
      5) For motors 250 HP and larger, both bearings shall be of the insulated type.
   b. Severe duty:
      1) Standard: IEEE 841.
      2) All cast iron enclosure.
      3) Terminal box threaded and gasketed.
      4) Internal and external epoxy base paint system.
      5) Drain and breather.

B. Vertical Solid or Hollow Shaft:
   1. Electrical rating:
      a. Appropriate for the voltage system indicated, 3 PH, 60 Hz.
      b. Dual voltage rated motors (e.g., 230/460 V) are acceptable, provided all leads are brought out to the terminal box and permanently marked.
   2. Enclosure:
      a. Cast iron.
      b. Type: DPFG, TEFC, WP-I or WP-II as indicated in the schedule.
   3. Terminal box:
      a. Gasketed.
      b. Diagonally split.
      c. Oversized to accept the required conductors and conduits.
      d. Separate terminal box with terminal blocks for winding thermal protection devices.
   4. Bearings (Solid Shaft):

a. Relubricatable.
b. Antifriction.
c. Minimum rated AMBA L-10 life of 10 years or 100,000 HRS.

5. Bearings (Hollow Shaft):
   a. Relubricatable.
   b. Antifriction.
   c. Oil or grease lubricated thrust bearings.
   d. Grease lubricated guide bearings.
   e. Minimum rated ABMA L-10 life of 10 years or 100,000 HRS.
6. Insulation:
   a. As Per NEMA MG-1.
7. Accessories: See the ACCESSORIES Article in PART 2 and the SCHEDULES Article in PART 3.
8. Modifications:
   a. Inverter duty:
      1) At a minimum, applied to motors connected to a VFD.
      2) Windings insulated for 1600 peak volts and voltage rise times of 0.1 microseconds.
      3) Nameplate identification of meeting NEMA MG 1 Part 31 requirements.
      4) Have the following minimum turndown ratio without the use of a blower to provide continuous supply of cooling air over the motor.
         a) Variable torque: 10:1.
         b) Constant torque: 6:1.
      5) For motors 250 HP and larger, both bearings shall be of the insulated type.
   b. Severe duty:
      1) Standard: IEEE 841.
      2) All cast iron enclosure.
      3) Terminal box threaded and gasketed.
      4) Internal and external epoxy base paint system.
      5) Drain and breather.

2.5 ACCESSORIES

A. Thermal Protection:
   1. Thermostats:
      a. One (1) winding Thermostat per phase for shutdown.
      b. One (1) bearing oil Thermostat for shutdown.
      c. Snap action, bi-metallic, temperature-actuated switch type.
      d. Normally closed, wired in series.
      e. Automatic reset.
      f. Switch point shall be pre-calibrated by the manufacturer.
   2. Thermistors:
      a. One (1) winding thermostat per phase for shutdown mounted in end turns.
      b. Positive temperature coefficient type.
      c. Normally closed, wired in series.
      d. 115 V rated.
   3. Thermocouples:
      a. Two (2) winding thermocouples per phase for alarm/shutdown mounted in end turns.
   4. RTD's:
      a. One (1) winding RTDs per phase imbedded in windings.
      b. One (1) bearing RTD per bearing.
      c. 100 ohm platinum.

B. Space Heaters:
   1. Silicone rubber strip type, 120 V rated.
   2. Provided on:
      a. All motors.

2.6 SOURCE QUALITY CONTROL

A. Test motors in accordance with NEMA, IEEE and manufacturer procedures.
   1. The test shall include but not necessarily be limited to the following:
      a. Routine test:
         1) No-load current and speed at rated voltage and frequency.
         2) Locked rotor current.
         3) Winding resistance.
         4) Vibration check.
         5) High potential.
      b. Complete test (in addition to the routine tests):
         1) Rated load temperature rise.
         2) Winding resistance.
         3) Slip test, measured in percent slip.
         4) Locked rotor amperes (3 PH, full voltage).
         5) Locked rotor torque.
         6) Breakdown torque.
         7) Efficiencies tabulated at 100, 75, and 50 percent of full load.
         8) Power factor tabulated at 100, 75, and 50 percent of full load.

B. Motors to be tested:
   1. All motors above 3 HP to receive a full test.
   2. All motors less than 3 HP to receive, at the minimum, a routine test.

C. The Owner reserves the right to select and have tested any motor included within the project.
   1. If motor passes testing requirements, the Buyer shall be responsible for any shipping and testing costs incurred.
   2. Costs shall be determined by current freight rates and manufacturer's published rates at the time of the test.
   3. If motor fails test, Supplier shall be responsible for all costs incurred.
   4. If two successive motors fail the test, the Owner has the right to reject any or all motors from that manufacturer.
   5. The Owner also reserves the right to witness any routine or complete tests at the Buyer’s expense.
   6. Notify the Owner a minimum of 14 days in advance of the testing.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install products in accordance with manufacturer's instructions.

B. Ground all motors in accordance with Specification Section 26 05 26.

3.2 SCHEDULES

A. Motors: A schedule to be filled out by the Design-Builder and submitted to the Engineer for review and approval.

3.3 FIELD QUALITY CONTROL

A. Acceptance Testing: See Specification Section 40 05 05.

END OF SECTION

SECTION 26 05 19

WIRE AND CABLE: 600 VOLT AND BELOW

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Material and installation requirements for:
      a. Building wire.
      b. Power cable.
      c. Control cable.
      d. Instrumentation cable.
      e. Wire connectors.
      f. Insulating tape.
      g. Pulling lubricant.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.
   2. Section 01 25 13 - Product Substitution.
   3. Section 26 05 00 - Electrical: Basic Requirements.
   4. Section 26 08 13 - Acceptance Testing.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. Canadian Standards Association (CSA):
      a. Test Methods for Electrical Wires and Cables (FT-4 Vertical Cable Tray Test).
   2. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
      a. 1202, Standard for Flame-Propagation Testing of Wire and Cable.
   3. National Electrical Manufacturers Association (NEMA):
      a. ICS 4, Industrial Control and Systems: Terminal Blocks.
   4. National Electrical Manufacturers Association/Insulated Cable Engineers Association (NEMA/ICEA):
      a. WC 57/S-73-532, Standard for Control Cables.
      b. WC 70/S-95-658, Non-Shielded Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy.
   5. National Fire Protection Association (NFPA):
      a. 70, National Electrical Code (NEC).
   6. Underwriters Laboratories, Inc. (UL):
      a. 44, Standard for Safety Thermoset-Insulated Wires and Cables.
      b. 83, Standard for Safety Thermoplastic-Insulated Wires and Cables.
      c. 467, Standard for Safety Grounding and Bonding Equipment.
      d. 486A, Standard for Safety Wire Connectors and Soldering Lugs for use with Copper Conductors.
      e. 486C, Standard for Safety Splicing Wire Connections.
      f. 510, Standard for Safety Polyvinyl Chloride, Polyethylene and Rubber Insulating Tape.
      g. 1277, Standard for Safety Electrical Power and Control Tray Cables with Optional Optical-Fiber Members.
      h. 1581, Standard for Safety Reference Standard for Electrical Wires, Cables, and Flexible Cords.
      i. 2250, Standard for Safety Instrumentation Tray Cable.

1.3 DEFINITIONS

A. Cable: Multi-conductor, insulated, with outer sheath containing either building wire or instrumentation wire.

B. Instrumentation Cable:
1. Multiple conductor, insulated, twisted or untwisted, with outer sheath.
2. The following are specific types of instrumentation cables:
   a. Analog signal cable:
      1) Used for the transmission of low current (e.g., 4-20mA DC) or low voltage (e.g., 0-10 Vdc) signals, using No. 16 AWG and smaller conductors.
      2) Commonly used types are defined in the following:
         a) TSP: Twisted shielded pair.
         b) TST: Twisted shielded triad.
   b. Digital signal cable: Used for the transmission of digital signals between computers, PLC's, RTU's, etc.

C. Power Cable: Multi-conductor, insulated, with outer sheath containing building wire, No. 8 AWG and larger.

D. Control Cable: Multi-conductor, insulated, with outer sheath containing building wires, No. 14, No. 12 or No. 10 AWG.

E. Building Wire: Single conductor, insulated, with or without outer jacket depending upon type.

F. Droop Cable: See Droop Cable Spec. # XXX.

1.4 SUBMITTALS

A. Shop Drawings:
1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
2. Product technical data:
   a. Provide submittal data for all products specified in Part 2 of this specification except:
      1) Wire connectors.
      2) Insulating tape.
      3) Cable lubricant.
   b. See Specification Section 26 05 00 for additional requirements.

1.5 DELIVERY, STORAGE, AND HANDLING

A. See Specification Section 26 05 00.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following manufacturers are acceptable:
1. Building wire, power and control cable and multiplex cable:
   a. American Insulated Wire Corporation.
   b. General Cable.
   c. Manhattan/CDT.
   d. Southwire Company.
2. Instrumentation cable:
   a. Analog cable:
      1) Alpha Wire Corporation.

        2) American Insulated Wire Corporation.
        3) Belden CDT Inc.
        4) General Cable.
        5) Manhattan/CDT.
    3. Droop Cable: See Droop Cable Specifications for details.
    4. Wire connectors:
        a. Burndy Corporation.
        b. Buchanan.
        c. Ideal.
        d. Ilsco.
        e. 3M Co.
        f. Teledyne Penn Union.
        g. Thomas and Betts.
        h. Phoenix Contact.
    5. Insulating and color coding tape:
        a. 3M Co.
        b. Plymouth Bishop Tapes.
        c. Red Seal Electric Co.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 MANUFACTURED UNITS

A. Building Wire:
    1. Conductor shall be copper with 600 V rated insulation.
    2. Conductors shall be stranded, except for conductors used in lighting and receptacle circuits which may be stranded or solid.
    3. Surface mark with manufacturer's name or trademark, conductor size, insulation type and UL label.
    4. Conform to NEMA/ICEA WC 70/S-95-658 and UL 83 for type THHN/THWN and THHN/THWN-2 insulation.
    5. Conform to NEMA/ICEA WC 70/S-95-658 and UL 44 for type XHHW-2 insulation.

B. Power Cable:
    1. Conductor shall be copper with 600 V rated insulation.
    2. Surface mark with manufacturer's name or trademark, conductor size, insulation type and UL label.
    3. Conform to NEMA/ICEA WC 70/S-95-658 and UL 83 and UL 1277 for type THHN/THWN insulation with an overall PVC jacket.
    4. Number of conductors as required, including a bare ground conductor.
    5. Individual conductor color coding:
        a. ICEA Method 4.
        b. See PART 3 of this Specification Section for additional requirements.
    6. Conform to NFPA 70 Type TC and IEEE 1202 or CSA FT-4.

C. Control Cable:
    1. Conductor shall be copper with 600 V rated insulation.
    2. Surface mark with manufacturer's name or trademark, conductor size, insulation type and UL label.
    3. Conform to NEMA/ICEA WC 57/S-73-532 and UL 83 and UL 1277 for type THHN/THWN insulation with an overall PVC jacket.
    4. Number of conductors as required, provided with or without bare ground conductor of the same AWG size.

a. When a bare ground conductor is not provided, an additional insulated conductor shall be provided and used as the ground conductor (e.g., 6/c No. 14 w/g and 7/c No. 14 are equal).
5. Individual conductor color coding:
a. NEMA/ICEA Method 1, Table E-2.
b. See Part 3 of this Specification for additional requirements.
6. Conform to NFPA 70 Type TC and IEEE 1202, CSA FT-4 or NFPA 262.

D. Electrical Equipment Control Wire:
1. Conductor shall be copper with 600 V rated insulation.
2. Conductors shall be stranded.
3. Surface mark with manufacturer's name or trademark, conductor size, insulation type and UL label.
4. Conform to UL 44 for Type SIS insulation.
5. Conform to UL 83 for Type MTW insulation.

E. Instrumentation Cable:
1. Surface mark with manufacturer's name or trademark, conductor size, insulation type and UL label.
2. Analog cable:
a. Tinned copper conductors.
b. 300 V or 600 V PVC insulation with PVC jacket.
c. Twisted with 100 percent foil shield coverage with drain wire.
d. Six (6) twists per foot minimum.
e. Individual conductor color coding: ICEA Method 1, Table K-2.
f. Conform to IEEE 1202 or CSA FT-4 or NFPA 262, UL 2250, UL 1581 and NFPA 70 Type ITC.
3. Digital cable:
a. As recommended by equipment (e.g., PLC, RTU) manufacturer.
b. Horizontal voice and data cable:
1) Category 6 per TIA/EIA/ANSI 568.
2) Cable shall be label-verified.
3) Cable jacket shall be factory marked at regular intervals indicating verifying organization and performance level.
4) Conductors: solid untinned copper sized as needed.
5) Rated CMP per NFPA 70.
c. Conform to IEEE 1202 or CSA FT-4 or NFPA 262 and NFPA 70 Type ITC.

F. Droop Cable: See droop cables specifications.

G. Wire Connectors:
1. Twist/screw on type:
a. Insulated pressure or spring type solderless connector.
b. 600 V rated.
c. Ground conductors: Conform to UL 486C and/or UL 467 when required by local codes.
d. Phase and neutral conductors: Conform to UL 486C.
2. Compression and mechanical screw type:
a. 600 V rated.
b. Ground conductors: Conform to UL 467.
c. Phase and neutral conductors: Conform to UL 486A.
3. Terminal block type:
a. High density, screw-post barrier-type with white center marker strip.
b. 600 V and ampere rating as required, for power circuits.

c. 600 V, 20 ampere rated for control circuits.
d. 300 V, 15 ampere rated for instrumentation circuits.
e. Conform to NEMA ICS 4 and UL 486A.

H. Insulating and Color Coding Tape:
1. Pressure sensitive vinyl.
2. Premium grade.
3. Heat, cold, moisture, and sunlight resistant.
4. Thickness, depending on use conditions: 7, 8.5, or 10 mil.
5. For cold weather or outdoor location, tape must also be all-weather.
6. Color:
a. Insulating tape: Black.
b. Color coding tape: Fade-resistant color as specified herein.
7. Comply with UL 510.

I. Pulling Lubricant: Cable manufacturer's standard containing no petroleum or other products which will deteriorate insulation.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Permitted Usage of Insulation Types:
1. Type XHHW-2:
a. Building wire and power and control cable in architectural and non-architectural finished areas.
b. Building wire and power and control cable in conduit below grade.
2. Type THHN/THWN and THHN/THWN-2:
a. Building wire and power and control cable sized as needed in architectural and non-architectural finished areas.
3. Type SIS and MTW:
a. For the wiring of control equipment within control panels and field wiring of control equipment within switchgear, switchboards, motor control centers.

B. Conductor Size Limitations:
1. Feeder and branch power conductors shall not be smaller than No. 12 AWG unless otherwise indicated on the Drawings.
2. Control conductors shall not be smaller than No. 14 AWG unless otherwise indicated on the Drawings.
3. Instrumentation conductors shall not be smaller than No. 18 AWG unless otherwise indicated on the Drawings.

C. Color Code All Wiring as Follows:
1. Building wire:

	240 V, 208 V, 240/120 V, 208/120 V	480 V, 480/277 V
Phase 1	Black	Brown
Phase 2	Red *	Orange
Phase 3	Blue	Yellow
Neutral	White	White or Gray
Ground	Green	Green

* Orange when it is a high leg of a 120/240 V Delta system.

a. Conductors No. 6 AWG and smaller: Insulated phase, neutral and ground conductors shall be identified by a continuous colored outer finish along its entire length.
b. Conductors larger than No. 6 AWG:
   1) Insulated phase and neutral conductors shall be identified by one (1) of the following methods:
      a) Continuous colored outer finish along its entire length.
      b) 3 IN of colored tape applied at the termination.
   2) Insulated grounding conductor shall be identified by one (1) of the following methods:
      a) Continuous green outer finish along its entire length.
      b) Stripping the insulation from the entire exposed length.
      c) Using green tape to cover the entire exposed length.
   3) The color coding shall be applied at all accessible locations, including but not limited to: Junction and pull boxes, wireways, manholes and handholes.

2. Power cables ICEA Method 4 with:
   a. Phase and neutral conductors identified with 3 IN of colored tape, per the Table herein, applied at the terminations.
   b. Ground conductor: Bare.
3. Control cables NEMA/ICEA Method 1, Table E-2:
   a. When a bare ground is not provided, one (1) of the colored insulated conductors shall be re-identified by stripping the insulation from the entire exposed length or using green tape to cover the entire exposed length.
   b. When used in power applications the colored insulated conductors used as phase and neutral conductors may have to be re-identified with 3 IN of colored tape, per the Table herein, applied at the terminations.

D. Install all wiring in raceway unless otherwise indicated on the Drawings.

E. Feeder, branch, control and instrumentation circuits shall not be combined in a raceway, cable tray, junction or pull box, except as permitted in the following:
   1. Where specifically indicated on the Drawings.
   2. Where field conditions dictate and written permission is obtained from the Engineer.
   3. Control circuits shall be isolated from feeder and branch power and instrumentation circuits but combining of control circuits is permitted.
      a. The combinations shall comply with the following:
         1) 12 Vdc, 24 Vdc and 48 Vdc may be combined.
         2) 125 Vdc shall be isolated from all other AC and DC circuits.
         3) AC control circuits shall be isolated from all DC circuits.
   4. Instrumentation circuits shall be isolated from feeder and branch power and control circuits but combining of instrumentation circuits is permitted.
      a. The combinations shall comply with the following:
         1) Analog signal circuits may be combined.
         2) Digital signal circuits may be combined but isolated from analog signal circuits.
   5. Multiple branch circuits for lighting, receptacle and other 120 Vac circuits are allowed to be combined into a common raceway.
      a. Design-Builder is responsible for making the required adjustments in conductor and raceway size, in accordance with all requirements of the NFPA 70, including but not limited to:
         1) Up sizing conductor size for required ampacity de-ratings for the number of current carrying conductors in the raceway.
         2) {The neutral conductor may be shared on sequential circuits (e.g., circuit numbers 1,3,5) if multiple circuit breakers are provided.}{The neutral conductors may not be shared.}

3) Up sizing raceway size for the size and quantity of conductors.

F. Ground the drain wire of shielded instrumentation cables at one (1) end only.
1. The preferred grounding location is at the load (e.g., control panel), not at the source (e.g., field mounted instrument).

G. Splices and terminations for the following circuit types shall be made in the indicated enclosure type using the indicated method.
1. Feeder and branch power circuits:
a. Device outlet boxes:
1) Twist/screw on type connectors.
b. Junction and pull boxes and wireways:
1) Twist/screw on type connectors for use on No. 8 and smaller wire.
2) Compression, mechanical screw or terminal block or terminal strip type connectors for use on No. 6 AWG and larger wire.
c. Motor terminal boxes:
1) Twist/screw on type connectors for use on No. 10 AWG and smaller wire.
2) Insulated mechanical screw type connectors for use on No. 8 AWG and larger wire.
d. Manholes or handholes:
1) Twist/screw on type connectors pre-filled with epoxy for use on No. 8 AWG and smaller wire.
2) Watertight compression or mechanical screw type connectors for use on No. 6 AWG and larger wire.
2. Control circuits:
a. Junction and pull boxes: Terminal block type connector.
b. Manholes or handholes: Twist/screw on type connectors pre-filled with epoxy.
c. Control panels and motor control centers: Terminal block or strips provided within the equipment or field installed within the equipment by the Design-Builder.
3. Instrumentation circuits can be spliced where field conditions dictate and written permission is obtained from the Engineer.
a. Maintain electrical continuity of the shield when splicing twisted shielded conductors.
b. Junction and pull boxes: Terminal block type connector.
c. Control panels and motor control centers: Terminal block or strip provided within the equipment or field installed within the equipment by the Design-Builder.
4. Non-insulated compression and mechanical screw type connectors shall be insulated with tape or hot or cold shrink type insulation to the insulation level of the conductors.

H. Insulating Tape Usage:
1. For insulating connections of No. 8 AWG wire and smaller: 7 mil vinyl tape.
2. For insulating splices and taps of No. 6 AWG wire or larger: 10 mil vinyl tape.
3. For insulating connections made in cold weather or in outdoor locations: 8.5 mil, all weather vinyl tape.

I. Color Coding Tape Usage: For color coding of conductors.

3.2 FIELD QUALITY CONTROL

A. Acceptance Testing: See Specification Section 26 08 13.

END OF SECTION

SECTION 26 05 26
GROUNDING

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Material and installation requirements for grounding system(s).

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.
   2. Section 01 25 13 - Product Substitution.
   3. Section 01 73 20 - Openings and Penetrations in Construction.
   4. Section 10 14 00 - Identification Devices.
   5. Section 26 05 00 - Electrical: Basic Requirements.
   6. Section 26 08 13 - Acceptance Testing.
   7. Section 26 05 19 - Wire and Cable - 600 Volt and Below.
   8. Section 26 05 33 - Raceways and Boxes.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. ASTM International (ASTM):
      a. B8, Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft.
   2. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
      a. 837, Standard for Qualifying Permanent Connections Used in Substation Grounding.
   3. National Fire Protection Association (NFPA):
      a. 70, National Electrical Code (NEC).
         1) Article 250, Grounding and Bonding.
         2) Article 610, Cranes and Hoists.
         3) Article 620, Elevators, Dumbwaiters, Escalators, Moving Walks, Platform Lifts, and Stairway Chairlifts.
   4. Underwriters Laboratories, Inc. (UL):
      a. 467, Grounding and Bonding Equipment.

B. Assure ground continuity is continuous throughout the entire Project.

1.3 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
   2. Product technical data.
      a. Provide submittal data for all products specified in PART 2 of this Specification Section except:
         1) Grounding clamps, terminals and connectors.
         2) Exothermic welding system.
      b. See Specification Section 26 05 00 for additional requirements.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following manufacturers are acceptable:
   1. Ground rods and bars and grounding clamps, connectors and terminals:
      a. Burndy.
      b. Harger Lightning Protection.
      c. Heary Brothers.
      d. Joslyn.
      e. Robbins Lightning Protection.
      f. Thomas & Betts (Blackburn).
      g. Thompson.
   2. Exothermic weld connections:
      a. Erico Products Inc., Cadweld.
      b. Harger Lightning Protection.
      c. Thermoweld.
   3. Prefabricated composite test stations:
      a. Quazite Composolite.
      b. Armorcast Products Company.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 COMPONENTS

A. Wire and Cable:
   1. Bare conductors: Soft drawn stranded copper meeting ASTM B8.
   2. Insulated conductors: Color coded green, per Specification Section 26 05 19.

B. Conduit: As specified in Specification Section 26 05 33.

C. Ground Bars:
   1. Solid copper:
      a. 1/4 IN thick.
      b. 2 or 4 IN wide.
      c. 24 IN long minimum in main service entrance electrical rooms, 12 IN long elsewhere.
   2. Predrilled grounding lug mounting holes.
   3. Stainless steel or galvanized steel mounting brackets.
   4. Insulated standoffs.

D. Ground Rods:
   1. 3/4 IN x 10 FT.
   2. Copperclad:
      a. Heavy uniform coating of electrolytic copper molecularly bonded to a rigid steel core.
      b. Corrosion resistant bond between the copper and steel.
      c. Hard drawn for a scar-resistant surface.

E. Grounding Clamps, Connectors and Terminals:
   1. Mechanical type:
      a. Standards: UL 467.
      b. High copper alloy content.
   2. Compression type for interior locations:
      a. Standards: UL 467.
      b. High copper alloy content.
      c. Non-reversible.

    d. Terminals for connection to bus bars shall have two bolt holes.
  3. Compression type suitable for direct burial in earth or concrete:
    a. Standards: UL 467, IEEE 837.
    b. High copper alloy content.
    c. Non-reversible.

F. Exothermic Weld Connections:
  1. Copper oxide reduction by aluminum process.
  2. Molds properly sized for each application.

PART 3 - EXECUTION

3.1 INSTALLATION

A. General:
  1. Install products in accordance with manufacturer's instructions.
  2. Size grounding conductors and bonding jumpers in accordance with NFPA 70, Article 250, except where larger sizes are indicated on the Drawings.
  3. Remove paint, rust, or other nonconducting material from contact surfaces before making ground connections.
  4. Where ground conductors pass through floor slabs or building walls provide non-metallic sleeves and install per Specification Section 01 73 20.
  5. Do not splice grounding conductors except at ground rods.
  6. Install ground rods and grounding conductors in undisturbed, firm soil.
    a. Provide excavation required for installation of ground rods and ground conductors.
    b. Use driving studs or other suitable means to prevent damage to threaded ends of sectional rods.
    c. Unless otherwise specified, connect conductors to ground rods with compressor type connectors or exothermic weld.
    d. Provide sufficient slack in grounding conductor to prevent conductor breakage during backfill or due to ground movement.
    e. Backfill excavation completely, thoroughly tamping to provide good contact between backfill materials and ground rods and conductors.
  7. Do not use exothermic welding if it will damage the structure the grounding conductor is being welded to.

B. Grounding Electrode System:
  1. Provide a grounding electrode system in accordance with NFPA 70, Article 250 and as indicated on the Drawings.
  2. Grounding conductor terminations:
    a. Ground bars mounted on wall, use compression type terminal and bolt it to the ground bar with two bolts.
    b. Ground bars in electrical equipment, use compression type terminal and bolt it to the ground bar.
    c. Piping systems use mechanical type connections.
    d. Building steel, below grade and encased in concrete, use compression type connector or exothermic weld.
    e. At all above grade terminations, the conductors shall be labeled per Specification Section 10 14 00.
  3. Ground ring grounding system:
    a. Ground ring consists of ground rods and a grounding conductor looped around the structure.

b. Placed at a minimum of 10 FT from the structure foundation and 2 FT-6 IN below grade.
c. Provide a minimum of four (4) ground rods placed at the corners of the structure and additional rods so that the maximum distance between ground rods does not exceed 50 FT.
d. Building/Structure grounding:
   1) Bond building/structure metal support columns to the ground ring at all corners of the structure.
e. Grounding conductor: Bare conductor, size as indicated on the Drawings.

C. Supplemental Grounding Electrode:
   1. Provide the following grounding in addition to the equipment ground conductor supplied with the feeder conductors whether or not shown on the Drawings.
   2. Metal light poles:
      a. Connect metal pole to a ground rod.
      b. Grounding conductor: Bare #6 AWG minimum.
   3. Equipment support rack and pedestals mounted outdoors:
      a. Connect metallic structure to a ground rod.
      b. Grounding conductor: #6 AWG minimum.

D. Low Voltage Transformer Separately Derived Grounding System:
   1. Ground separately mounted step-down transformers XO terminal to one of the following:
      a. Closest building steel using mechanical type terminal bolted to the steel, compression type connection or exothermic weld.
      b. Closest water pipe using a mechanical type connection.
   2. Ground step-down transformer integrally mounted in motor control center to motor control center ground bus.

E. Raceway Bonding/Grounding:
   1. All metallic conduit shall be installed so that it is electrically continuous.
   2. All conduits to contain a grounding conductor with insulation identical to the phase conductors, unless otherwise indicated on the Drawings.
   3. NFPA 70 required grounding bushings shall be of the insulating type.
   4. Provide double locknuts at all panels.
   5. Bond all conduit, at entrance and exit of equipment, to the equipment ground bus or lug.
   6. Provide bonding jumpers if conduits are installed in concentric knockouts.
   7. Make all metallic raceway fittings and grounding clamps tight to ensure equipment grounding system will operate continuously at ground potential to provide low impedance current path for proper operation of overcurrent devices during possible ground fault conditions.

F. Equipment Grounding:
   1. All utilization equipment shall be grounded with an equipment ground conductor.

G. Manhole and Handhole Grounding:
   1. Provide a ground rod and ground bar, when indicated or as needed, in each manhole and handhole with exposed metal parts.
      a. Expose a minimum of 4 IN of the rod above the floor for field connections to the rod.
   2. Connect all exposed metal parts (e.g., conduits and cable racks) to the ground rod.

3.2 FIELD QUALITY CONTROL

A. Leave grounding system uncovered until observed by Owner.

B. Acceptance testing: See Specification Section 26 08 13.

END OF SECTION

SECTION 26 05 33
RACEWAYS AND BOXES

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
1. Material and installation requirements for:
   a. Conduits.
   b. Conduit fittings.
   c. Conduit supports.
   d. Wireways.
   e. Outlet boxes.
   f. Pull and junction boxes.

B. Related Specification Sections include but are not necessarily limited to:
1. New Hampshire Department of Transportation Section 105 - Control of the Work.
2. New Hampshire Department of Transportation Section 209 - Granular Backfill.
3. Section 01 25 13 - Product Substitution.
4. Section 01 73 20 - Openings and Penetrations in Construction.
5. Section 26 05 00 - Electrical: Basic Requirements.
6. Section 26 27 26 - Wiring Devices.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
1. American Iron and Steel Institute (AISI).
2. ASTM International (ASTM):
   a. A123, Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
   b. A153, Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.
   c. D2564, Standard Specification for Solvent Cements for Poly (Vinyl Chloride) (PVC) Plastic Piping Systems.
3. National Electrical Manufacturers Association (NEMA):
   a. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
   b. RN 1, Polyvinyl Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit (IMC).
   c. TC 2, Electrical Polyvinyl Chloride (PVC) Tubing and Conduit.
   d. TC 3, Polyvinyl Chloride (PVC) Fittings for Use with Rigid PVC Conduit and Tubing.
4. National Electrical Manufacturers Association/American National Standards Institute (NEMA/ANSI):
   a. C80.1, Electric Rigid Steel Conduit (ERSC).
   b. C80.3, Steel Electrical Metallic Tubing (EMT).
   c. OS 1, Sheet-Steel Outlet Boxes, Device Boxes, Covers, and Box Supports.
5. National Fire Protection Association (NFPA):
   a. 70, National Electrical Code (NEC).
6. Underwriters Laboratories, Inc. (UL):
   a. 1, Standard for Flexible Metal Conduit.
   b. 6, Standard for Electrical Rigid Metal Conduit - Steel.
   c. 50, Enclosures for Electrical Equipment, Non-Environmental Considerations.
   d. 360, Standard for Liquid-Tight Flexible Steel Conduit.

e. 467, Grounding and Bonding Equipment.
f. 514A, Metallic Outlet Boxes.
g. 514B, Conduit, Tubing, and Cable Fittings.
h. 651, Standard for Schedule 40 and 80 Rigid PVC Conduit and Fittings.
i. 797, Electrical Metallic Tubing - Steel.
j. 870, Standard for Wireways, Auxiliary Gutters, and Associated Fittings.
k. 886, Standard for Outlet Boxes and Fittings for Use in Hazardous (Classified) Locations.

1.3 SUBMITTALS

A. Shop Drawings:
1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
2. Product technical data:
   a. Provide submittal data for all products specified in PART 2 of this Specification Section except:
      1) Conduit fittings.
      2) Support systems.
   b. See Specification Section 26 05 00 for additional requirements.
3. Fabrication and/or layout drawings:
   a. Identify dimensional size of pull and junction boxes to be used.

1.4 DELIVERY, STORAGE, AND HANDLING

A. See Specification Section 26 05 00.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following manufacturers are acceptable:
1. Rigid metallic conduits:
   a. Allied Tube and Conduit Corporation.
   b. Triangle PWC Inc.
   c. Western Tube and Conduit Corporation.
   d. Wheatland Tube Company.
   e. LTV Steel Company.
2. PVC coated rigid metallic conduits and repair kits:
   a. Occidental Coating Company.
   b. Perma-Cote.
   c. Rob-Roy Ind.
   d. Raychem "GelTek" tape.
3. Rigid non-metallic conduit:
   a. Carlon.
   b. Cantex.
   c. Osburn Associates.
4. Flexible conduit:
   a. AFC Cable Systems.
   b. Anamet, Inc.
   c. Electri-Flex.
   d. Flexible Metal Hose Company.
   e. International Metal Hose Company.

f. Triangle PWC Inc.
g. LTV Steel Company.

5. Wireway:
    a. Hoffman Engineering Company.
    b. Wiegmann.
    c. Square D.
6. Conduit fittings and accessories:
    a. Appleton.
    b. Carlon.
    c. Cantex.
    d. Crouse-Hinds.
    e. Killark.
    f. Osburn Associates.
    g. OZ Gedney Company.
    h. RACO.
    i. Steel City.
    j. Thomas and Betts.
7. Support systems:
    a. Unistrut Building Systems.
    b. B-Line Systems Inc.
    c. Kindorf.
    d. Minerallac Fastening Systems.
    e. Caddy.
8. Outlet, pull and junction boxes:
    a. Appleton Electric Co.
    b. Crouse-Hinds.
    c. Killark.
    d. O-Z/Gedney.
    e. Steel City.
    f. Raco.
    g. Bell.
    h. Hoffman Engineering Co.
    i. Wiegmann.
    j. B-Line Circle AW.
    k. Adalet.
    l. Rittal.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 RIGID METALLIC CONDUITS

A. Rigid Galvanized Steel Conduit (RGS):
1. Mild steel with continuous welded seam.
2. Metallic zinc applied by hot-dip galvanizing or electro-galvanizing.
3. Threads galvanized after cutting.
4. Internal coating: Baked lacquer, varnish or enamel for a smooth surface.
5. Standards: NEMA/ANSI C80.1, UL 6.

B. PVC-Coated Rigid Steel Conduit (PVC-RGS):
1. Nominal 40 mil Polyvinyl Chloride Exterior Coating:
    a. Coating: Bonded to hot-dipped galvanized rigid steel conduit conforming to NEMA/ANSI C80.1.
    b. The bond between the PVC coating and the conduit surface: Greater than the tensile strength of the coating.

2. Nominal 2 mil, minimum, urethane interior coating.
3. Urethane coating on threads.
4. Conduit: Epoxy prime coated prior to application of PVC and urethane coatings.
5. Female Ends:
   a. Have a plastic sleeve extending a minimum of 1 pipe diameter or 2 IN, whichever is less beyond the opening.
   b. The inside diameter of the sleeve shall be the same as the outside diameter of the conduit to be used with it.
6. Standards: NEMA/ANSI C80.1, UL 6, NEMA RN 1.

C. Electrical Metallic Tubing (EMT):
1. Mild steel with continuous welded seam.
2. Metallic zinc applied by hot-dip galvanizing or electro-galvanizing.
3. Internal coating: Baked lacquer, varnish, or enamel for a smooth surface.
4. Standards: NEMA/ANSI C80.3, UL 797.

2.3 RIGID NON-METALLIC CONDUIT

A. Schedules 40 (PVC-40) and 80 (PVC-80):
1. Polyvinyl-chloride (PVC) plastic compound which includes inert modifiers to improve weatherability and heat distribution.
2. Rated for direct sunlight exposure.
3. Fire retardant and low smoke emission.
4. Shall be suitable for use with 90 DegC wire and shall be marked "maximum 90 DegC".
5. Standards: NEMA TC 2, UL 651.

2.4 FLEXIBLE CONDUIT

A. Flexible Galvanized Steel Conduit (FLEX):
1. Formed of continuous, spiral wound, hot-dip galvanized steel strip with successive convolutions securely interlocked.
2. Standard: UL 1.

B. PVC-Coated Flexible Galvanized Steel (liquid-tight) Conduit (FLEX-LT):
1. Core formed of continuous, spiral wound, hot-dip galvanized steel strip with successive convolutions securely interlocked.
2. Extruded PVC outer jacket positively locked to the steel core.
3. Liquid and vaportight.
4. Standard: UL 360.

2.5 WIREWAY

A. General:
1. Suitable for lay-in conductors.
2. Designed for continuous grounding.
3. Covers:
   a. Hinged or removable in accessible areas.
   b. Non-removable when passing through partitions.
4. Finish: Rust inhibiting primer and manufacturers standard paint inside and out except for stainless steel type.
5. Standards: UL 870, NEMA 250.

B. General Purpose (NEMA 1 rated) Wireway:
1. 14 or 16 gage steel without knockouts.
2. Cover: Solid, non-gasketed and held in place by captive screws.

C. Raintight (NEMA 3R) Wiring Trough:

1. 14 or 16 GA galvanized steel without knockouts.
2. Cover: Non-gasketed and held in place by captive screws.

D. Watertight (NEMA 4X rated) Wireway:
1. 14 GA Type 304 or 316 stainless steel bodies and covers without knockouts and 10 GA stainless steel flanges.
2. Cover: Fully gasketed and held in place with captive clamp type latches.
3. Flanges: Fully gasketed and bolted.

E. Dusttight (NEMA 12 rated) Wireway:
1. 14 GA steel bodies and covers without knockouts and 10 GA steel flanges.
2. Cover: Fully gasketed and held in place with captive clamp type latches.
3. Flanges: Fully gasketed and bolted.

2.6 CONDUIT FITTINGS AND ACCESSORIES

A. Fittings for Use with RGS:
1. General:
   a. In hazardous locations listed for use in Class I, Groups C and D locations.
2. Locknuts:
   a. Threaded steel or malleable iron.
   b. Gasketed or non-gasketed.
   c. Grounding or non-grounding type.
3. Bushings:
   a. Threaded, insulated metallic.
   b. Grounding or non-grounding type.
4. Hubs: Threaded, insulated and gasketed metallic for raintight connection.
5. Couplings:
   a. Threaded straight type: Same material and finish as the conduit with which they are used on.
   b. Threadless type: Gland compression or self-threading type, concrete tight.
6. Unions: Threaded galvanized steel or zinc plated malleable iron.
7. Conduit bodies (ells and tees):
   a. Body: Zinc plated cast iron or cast copper free aluminum with threaded hubs.
   b. Standard and mogul size.
   c. Cover:
      1) Clip-on type with stainless steel screws.
      2) Gasketed or non-gasketed galvanized steel, zinc plated cast iron or cast copper free aluminum.
8. Conduit bodies (round):
   a. Body: Zinc plated cast iron or cast copper free aluminum with threaded hubs.
   b. Cover: Threaded screw on type, gasketed, galvanized steel, zinc plated cast iron or cast copper free aluminum.
9. Sealing fittings:
   a. Body: Zinc plated cast iron or cast copper free aluminum with threaded hubs.
   b. Standard and mogul size.
   c. With or without drain and breather.
   d. Fiber and sealing compound: UL listed for use with the sealing fitting.
10. Hazardous location flexible coupling (HAZ-FLEX):
   a. Liquid tight and arc resistant.
   b. Electrically conductive so no bonding jumper is required.
   c. Dry and wet areas:
      1) Bronze braided covering over flexible brass core.
      2) Bronze end fittings.

3) Zinc-plated steel or malleable iron unions and nipples.

d. Corrosive areas:
1) Stainless steel braided covering over flexible stainless steel core.
2) Stainless steel end fittings.
3) Aluminum unions and nipples.

11. Service entrance head:
a. Malleable iron, galvanized steel or copper free aluminum.
b. Insulated knockout cover for use with a variety of sizes and number of conductors.

12. Expansion couplings:
a. 2 IN nominal straight-line conduit movement in either direction.
b. Galvanized steel with insulated bushing.
c. Gasketed for wet locations.
d. Internally or externally grounded.

13. Expansion/deflection couplings:
a. 3/4 IN nominal straight-line conduit movement in either direction.
b. 30-degree nominal deflection from the normal in all directions.
c. Metallic hubs, neoprene outer jacket and stainless steel jacket clamps.
d. Internally or externally grounded.
e. Watertight, raintight and concrete tight.

14. Standards: UL 467, UL 514B, UL 886.

B. Fittings for Use with PVC-RGS:
1. The same material and construction as those fittings listed under paragraph "Fittings for Use with RGS " and coated as defined under paragraph "PVC Coated Rigid Steel Conduit (PVC-RGS)."

C. Fittings for Use with EMT:
1. Connectors:
a. Straight, angle and offset types furnished with locknuts.
b. Zinc plated steel.
c. Insulated gland compression type.
d. Concrete and raintight.

2. Couplings:
a. Zinc plated steel.
b. Gland compression type.
c. Concrete and raintight.

3. Conduit bodies (ells and tees):
a. Body: Copper free aluminum with threaded hubs.
b. Standard and mogul size.
c. Cover:
1) Screw down type with steel screws.
2) Gasketed or non-gasketed galvanized steel or copper free aluminum.

4. Standard: UL 514B.

D. Fittings for Use with FLEX:
1. Connector:
a. Zinc plated malleable iron.
b. Squeeze or clamp-type.

2. Standard: UL 514B.

E. Fittings for Use with FLEX-LT:
1. Connector:
a. Straight or angle type.
b. Metal construction, insulated and gasketed.

c. Composed of locknut, grounding ferrule and gland compression nut.
d. Liquid tight.
2. Standards: UL 467, UL 514B.

F. Fittings for Use with Rigid Non-Metallic PVC Conduit:
1. Coupling, adapters and conduit bodies:
a. Same material, thickness, and construction as the conduits with which they are used.
b. Homogeneous plastic free from visible cracks, holes or foreign inclusions.
c. Bore smooth and free of blisters, nicks or other imperfections which could damage the conductor.
2. Solvent cement for welding fittings shall be supplied by the same manufacturer as the conduit and fittings.
3. Standards: ASTM D2564, NEMA TC 3, UL 651, UL 514B.

G. Weather and Corrosion Protection Tape:
1. PVC based tape, 10 mils thick.
2. Protection against moisture, acids, alkalis, salts and sewage and suitable for direct bury.
3. Used with appropriate pipe primer.

2.7 ALL RACEWAY AND FITTINGS

A. Mark Products:
1. Identify the nominal trade size on the product.
2. Stamp with the name or trademark of the manufacturer.

2.8 OUTLET BOXES

A. Metallic Outlet Boxes:
1. Hot-dip galvanized steel.
2. Conduit knockouts and grounding pigtail.
3. Styles:
a. 2 IN x 3 IN rectangle.
b. 4 IN square.
c. 4 IN octagon.
d. Masonry/tile.
4. Accessories:
a. Flat blank cover plates.
b. Barriers.
c. Extension, plaster or tile rings.
d. Box supporting brackets in stud walls.
e. Adjustable bar hangers.
5. Standards: NEMA/ANSI OS 1, UL 514A.

B. Cast Outlet Boxes:
1. Zinc plated cast iron or die-cast copper free aluminum with manufacturers standard finish.
2. Threaded hubs and grounding screw.
3. Styles:
a. "FS" or "FD".
b. "Bell".
c. Single or multiple gang and tandem.
d. "EDS" or "EFS" for hazardous locations.
4. Accessories: 40 mil PVC exterior coating and 2 mil urethane interior coating.
5. Standards: UL 514A, UL 886.

C. See Specification Section 26 27 26 for wiring devices, wallplates and coverplates.

2.9 PULL AND JUNCTION BOXES

A. NEMA 1 Rated:
   1. Body and cover: 14 GA minimum, galvanized steel or 14 GA minimum, steel finished with rust inhibiting primer and manufacturers standard paint inside and out.
   2. With or without concentric knockouts on four (4) sides.
   3. Flat cover fastened with screws.

B. NEMA 4 Rated:
   1. Body and cover: 14 GA steel finished with rust inhibiting primer and manufacturers standard paint inside and out.
   2. Seams continuously welded and ground smooth.
   3. No knockouts.
   4. External mounting flanges.
   5. Hinged or non-hinged cover held closed with stainless steel screws and clamps.
   6. Cover with oil resistant gasket.

C. NEMA 4X Rated (metallic):
   1. Body and cover: 14 GA Type 304 or 316 stainless steel.
   2. Seams continuously welded and ground smooth.
   3. No knockouts.
   4. External mounting flanges.
   5. Hinged door and stainless steel screws and clamps.
   6. Door with oil-resistant gasket.

D. NEMA 4X Rated (non-metallic):
   1. Body and cover: Ultraviolet light protected fiberglass-reinforced polyester boxes.
   2. No knockouts.
   3. External mounting flanges.
   4. Hinged door with quick release latches and padlocking hasp.
   5. Door with oil resistant gasket.

E. NEMA 7 and NEMA 9 Rated:
   1. Cast gray iron alloy or copper-free aluminum with manufacturers standard finish.
   2. Drilled and tapped openings or tapered threaded hub.
   3. Cover bolted-down with stainless steel bolts or threaded cover with neoprene gasket.
   4. External mounting flanges.
   5. Grounding lug.
   6. Accessories: 40 mil PVC exterior coating and 2 mil urethane interior coating.

F. NEMA 12 Rated:
   1. Body and cover:
      a. 14 GA steel finished with rust inhibiting primer and manufacturers standard paint inside and out.
      b. Type 5052 H-32 aluminum, unpainted.
   2. Seams continuously welded and ground smooth.
   3. No knockouts.
   4. External mounting flanges.
   5. Non-hinged cover held closed with captivated cover screws threaded into sealed wells or hinged cover held closed with stainless steel screws and clamps.
   6. Flat door with oil resistant gasket.

G. Miscellaneous Accessories:
   1. Rigid handles for covers larger than 9 SF or heavier than 25 LBS.
   2. Split covers when heavier than 25 LBS.

3. Weldnuts for mounting optional panels and terminal kits.
4. Terminal blocks: Screw-post barrier-type, rated 600 volt and 20 ampere minimum.

H. Standards: NEMA 250, UL 50.

2.10 SUPPORT SYSTEMS

A. Multi-conduit Surface or Trapeze Type Support and Pull or Junction Box Supports:
  1. Material requirements.
    a. Galvanized steel: ASTM A123 or ASTM A153.
    b. Stainless steel: AISI Type 316.
    c. PVC coat galvanized steel: ASTM A123 or ASTM A153 and 20 mil PVC coating.

B. Single Conduit and Outlet Box Support Fasteners:
  1. Material requirements:
    a. Zinc plated steel.
    b. Stainless steel.
    c. Malleable iron.
    d. PVC coat malleable iron or steel: 20 mil PVC coating.
    e. Steel protected with zinc phosphate and oil finish.

2.11 OPENINGS AND PENETRATONS IN WALLS AND FLOORS

A. Sleeves, smoke and fire stop fitting through walls and floors:
  1. See Specification Section 01 73 20.

PART 3 - EXECUTION

3.1 RACEWAY INSTALLATION - GENERAL

A. Shall be in accordance with the requirements of:
  1. NFPA 70.
  2. Manufacturer instructions.

B. Size of Raceways:
  1. Raceway sizes are shown on the Drawings, if not shown on the Drawings, then size in accordance with NFPA 70.
  2. Unless specifically indicated otherwise, the minimum raceway size shall be:
    a. Conduit: 3/4 IN.
    b. Wireway: 2-1/2 IN x 2-1/2 IN.

C. Field Bending and Cutting of Conduits:
  1. Utilize tools and equipment recommended by the manufacturer of the conduit, designed for the purpose and the conduit material to make all field bends and cuts.
  2. Do not reduce the internal diameter of the conduit when making conduit bends.
  3. Prepare tools and equipment to prevent damage to the PVC coating.
  4. Degrease threads after threading and apply a zinc rich paint.
  5. Debur interior and exterior after cutting.

D. Male threads of conduit systems shall be coated with an electrically conductive anti-seize compound.

E. The protective coating integrity of conduits, fittings, outlet, pull and junction boxes and accessories shall be maintained.
  1. Repair galvanized components utilizing a zinc rich paint.
  2. Repair painted components utilizing touch up paint provided by or approved by the manufacturer.

3. Repair PVC coated components utilizing a patching compound, of the same material as the coating, provided by the manufacturer of the conduit; or a self-adhesive, highly conformable, cross-linked silicone composition strip, followed by a protective coating of vinyl tape.
   a. Total nominal thickness: 40 mil.
4. Repair surfaces which will be inaccessible after installation prior to installation.

F. Remove moisture and debris from conduit before wire is pulled into place.
   1. Pull mandrel with diameter nominally 1/4 IN smaller than the interior of the conduit, to remove obstructions.
   2. Swab conduit by pulling a clean, tight-fitting rag through the conduit.
   3. Tightly plug ends of conduit with tapered wood plugs or plastic inserts until wire is pulled.

G. Only nylon or polyethylene rope shall be used to pull wire and cable in conduit systems.

H. Where portions of a raceway are subject to different temperatures and where condensation is known to be a problem, as in cold storage areas of buildings or where passing from the interior to the exterior of a building, the raceway shall be sealed to prevent circulation of warm air to colder section of the raceway.

I. Fill openings in walls, floors, and ceilings and finish flush with surface.
   1. See Specification Section 01 73 20.

3.2 RACEWAY ROUTING

A. Raceways shall be routed in the field unless otherwise indicated.
   1. Conduit and fittings shall be installed, as required, for a complete system that has a neat appearance and is in compliance with all applicable codes.
   2. Run in straight lines parallel to or at right angles to building lines.
   3. Do not route conduits:
      a. Through areas of high ambient temperature or radiant heat.
      b. In suspended concrete slabs.
   4. Conduit shall not interfere with, or prevent access to, piping, valves, ductwork, or other equipment for operation, maintenance and repair.
   5. Provide pull boxes or conduit bodies as needed so that there is a maximum of 360 degrees of bends in the conduit run or in long straight runs to limit pulling tensions.

B. All rigid conduits within a structure shall be installed exposed except as follows:
   1. As indicated on the Drawings.
   2. Concealed above gypsum wall board or acoustical tile suspended ceilings.
   3. Concealed within stud frame, poured concrete, concrete block and brick walls of an architecturally finished area.

C. Maintain minimum spacing between parallel conduit and piping runs in accordance with the following when the runs are greater than 30 FT:
   1. Between instrumentation and telecommunication: 1 IN.
   2. Between instrumentation and 125 V, 48 V and 24 Vdc, 2 IN.
   3. Between instrumentation and 600 V and less AC power or control: 6 IN.
   4. Between instrumentation and greater than 600 Vac power: 12 IN.
   5. Between telecommunication and 125 V, 48 V and 24 Vdc, 2 IN.
   6. Between telecommunication and 600 V and less AC power or control: 6 IN.
   7. Between telecommunication and greater than 600 Vac power: 12 IN.
   8. Between 125 V, 48 V and 24 Vdc and 600 V and less AC power or control: 2 IN.
   9. Between 125 V, 48 V and 24 Vdc and greater than 600 Vac power: 2 IN.
   10. Between 600 V and less AC and greater than 600 Vac: 2 IN.
   11. Between process, gas, air and water pipes: 6 IN.

D. Conduits shall be installed to eliminate moisture pockets.
   1. Where water cannot drain to openings, provide drain fittings in the low spots of the conduit run.

E. Conduit shall not be routed on the exterior of structures except as specifically indicated on the Drawings.

F. Where sufficient room exists within the housing of roof-mounted equipment, the conduit shall be stubbed up inside the housing.

G. Provide all required openings in walls, floors, and ceilings for conduit penetration.
   1. See Specification Section 01 73 20.

3.3 RACEWAY APPLICATIONS

A. Permitted Raceway Types Per Wire or Cable Types:
   1. Power wire or cables: All raceway types.
   2. Control wire or cables: All raceway types.
   3. Instrumentation cables: Metallic raceway except non-metallic may be used underground.
   4. Motor leads from a VFD: RGS, RAC or shielded VFD cables in all other raceways.
   5. Telecommunication cables: All raceway types.

B. Permitted Raceway Types Per Area Designations:
   1. Dry areas:
      a. RGS.
      b. RAC.
   2. Wet areas:
      a. RGS.
      b. RAC.
   3. Corrosive areas:
      a. PVC-RGS.
      b. RAC.
      c. Fiberglass.
   4. Highly corrosive areas:
      a. PVC-RGS.
      b. PVC-80.
      c. Fiberglass.
   5. NFPA 70 hazardous areas:
      a. RGS.
      b. RAC when required by other area designations.

C. Permitted Raceway Types Per Routing Locations:
   1. In stud framed walls:
      a. EMT.
   2. In concrete block or brick walls:
      a. PVC-40.
   3. Above acoustical tile ceilings:
      a. EMT.
      b. NEMA 1 rated wireway.
   4. Embedded in poured concrete walls and floors:
      a. PVC-40.
      b. Fiberglass.
      c. Fiberglass when emerging from concrete into areas designated as wet, corrosive or highly corrosive.

    d. PVC-RGS when emerging from concrete into areas designated as wet, corrosive or highly corrosive.
5. Beneath floor slab-on-grade:
    a. PVC-40.
    b. Fiberglass.
6. Through floor penetrations, see Specification Section 01 73 20:
    a. Fiberglass in areas designated as wet, corrosive or highly corrosive.
    b. PVC-RGS in areas designated as wet, corrosive or highly corrosive.
7. Direct buried conduits and ductbanks:
    a. PVC-80.
    b. Fiberglass.
    c. 90 degree elbows for transitions to above grade:
        1) PVC-RGS.
        2) Fiberglass.
    d. Long sweeping bends greater than 15 degrees:
        1) PVC-RGS.
        2) Fiberglass.
8. Concrete encased ductbanks:
    a. PVC-40.
    b. PVC-EB.
    c. Fiberglass.
    d. 90 degree elbows for transitions to above grade:
        1) PVC-RGS.
        2) Fiberglass.
    e. Long sweeping bends greater than 15 degrees:
        1) RGS for sizes 2 IN and larger.
        2) Fiberglass.

D. FLEX conduits shall be installed for connections to light fixtures, HVAC equipment and other similar devices above the ceilings.
    1. The maximum length shall not exceed:
        a. 6 FT to light fixtures.
        b. 3 FT to all other equipment.

E. FLEX-LT {and FLEX-NM} conduits shall be install as the final conduit connection to light fixtures, dry type transformers, motors, electrically operated valves, instrumentation primary elements, and other electrical equipment that is liable to vibrate.
    1. The maximum length shall not exceed:
        a. 6 FT to light fixtures.
        b. 3 FT to motors.
        c. 2 FT to all other equipment.

F. HAZ-FLEX coupling shall be installed as the final conduit to motors, electrically operated valves, instrumentation primary elements and electrical equipment that is liable to vibrate.
    1. The maximum length shall not exceed:
        a. 3 FT to motors.
        b. 2 FT to all other equipment.

G. NEMA 1 Rated Wireway:
    1. Surface mounted in electrical rooms.
    2. Surface mounted above removable ceilings tiles of an architecturally finished area.

H. NEMA 3R Wiring Trough:
    1. Surface mounted in exterior locations.

I. NEMA 4X Rated Wireway:
   1. Surface mounted in areas designated as wet and or corrosive.

J. NEMA 12 Rated Wireway:
   1. Surface mounted in areas designated as dry in architecturally and non-architecturally finished areas.

K. Underground Conduit
   1. Duct Spacers/Supports:
      a. High density polyethylene or high impact polystyrene.
      b. Interlocking.
      c. Provide 2 IN minimum spacing between conduits.
      d. Accessories, as required:
         1) Hold down bars.
         2) Ductbank strapping.
   2. General Installation Requirements:
      a. Ductbank types per location:
         1) Concrete encased ductbank:
            a) Under roads.
            b) Conduits containing medium voltage cables.
            c) Pad mounted transformer secondaries.
            d) As indicated on the plans.
         2) Direct-buried conduit(s):
            a) Area/Roadway lighting.
            b) As indicated on the plans.
      b. Do not place concrete or soil until conduits have been observed by the Engineer.
      c. Ductbanks shall be sloped a minimum of 4 IN per 100 FT or as detailed on the Drawings.
         1) Low points shall be at manholes or handholes.
      d. During construction and after conduit installation is complete, plug the ends of all conduits.
      e. Provide conduit supports and spacers.
         1) Place supports and spacers for rigid nonmetallic conduit on maximum centers as indicated for the following trade sizes:
            a) 1 IN and less: 3 FT.
            b) 1-1/4 to 3 IN: 5 FT.
            c) 3-1/2 to 6 IN: 7 FT.
         2) Place supports and spacers for rigid steel conduit on maximum centers as indicated for the following trade sizes:
            a) 1 IN and less: 10 FT.
            b) 1-1/4 to 2-1/2 IN: 14 FT.
            c) 3 IN and larger: 20 FT.
         3) Securely anchor conduits to supports and spacers to prevent movement during placement of concrete or soil.
      f. Stagger conduit joints at intervals of 6 IN vertically.
      g. Make conduit joints watertight and in accordance with manufacturer's recommendations.
      h. Accomplish changes in direction of runs exceeding a total of 15 degrees by long sweep bends having a minimum radius of 25 FT.
         1) Sweep bends may be made up of one or more curved or straight sections or combinations thereof.
      i. Furnish manufactured bends at end of runs.

1) Minimum radius of 18 IN for conduits less than 3 IN trade size and 36 IN for conduits 3 IN trade size and larger.

j. Field cuts requiring tapers shall be made with the proper tools and shall match factory tapers.

k. After the conduit run has been completed:
   1) Prove joint integrity and test for out-of-round duct by pulling a test mandrel through each conduit.
      a) Test mandrel:
         (1) Length: Not less than 12 IN
         (2) Diameter: Approximately 1/4 IN less than the inside diameter of the conduit.
   2) Clean the conduit by pulling a heavy duty wire brush mandrel followed by a rubber duct swab through each conduit.

l. Pneumatic rodding may be used to draw in lead wire.
   1) Install a heavy nylon cord free of kinks and splices in all unused new ducts.
   2) Extend cord 3 FT beyond ends of conduit.

m. Transition from rigid non-metallic conduit to rigid metallic conduit, per Specification Section 26 05 33, prior to entering a structure or going above ground.
   1) Except rigid non-metallic conduit may be extended directly to manholes, handholes, pad mounted transformer boxes and other exterior pad mounted electrical equipment where the conduit is concealed within the enclosure.
   2) Terminate rigid PVC conduits with end bells.
   3) Terminate steel conduits with insulated bushings.

n. Place warning tape in trench directly over ductbanks, direct-buried conduit, and direct-buried wire and cable in accordance with Specification Section 10 14 00.

o. Placement of conduits stubbing into handholes and manholes shall be located to allow for proper bending radiuses of the cables.

3. Concrete Encased Ductbank:
   a. Ductbank system consists of conduits completely encased in minimum 2 IN of concrete and with separations between different cabling types as required in Specification Section 26 05 33 or as detailed on the Drawings.
   b. Install so that top of concrete encased duct, at any point:
      1) Is not less than 24 IN below grade.
      2) Is below pavement sub-grading.
   c. Where identified and for a distance 10 FT either side of the area, the concrete shall be reinforced.
      1) The reinforcement shall consist of #4 bars and #4 ties placed 12 IN on center, in accordance with New Hampshire Department of Transportation Division 500 Specification Sections or as detailed on the Drawings.
   d. Conduit supports shall provide a uniform minimum clearance of 2 IN between the bottom of the trench and the bottom row of conduit.
   e. Conduit separators shall provide a uniform minimum clearance of 2 IN between conduits or as required in Specification Section 26 05 33 for different cabling types.

4. Direct-Buried Conduit(s):
   a. Install so that the top of the uppermost conduit, at any point:
      1) Is not less than 30 IN below grade.
      2) Is below pavement sub-grading.
   b. Provide a uniform minimum clearance of 2 IN between conduits or as required in Specification Section 26 05 33 for different cabling types.
      1) Maintain the separation of multiple planes of conduits by one of the following methods:

a) Install multilevel conduits with the use of conduit supports and separators to maintain the required separations, and backfill with flowable fill (100 PSI) or concrete per New Hampshire Department of Transportation Specification Section 209.
b) Install the multilevel conduits one level at a time.
    (1) Each level is backfilled with the appropriate amount of soil and compaction, per New Hampshire Department of Transportation Specification Section 209, to maintain the required separations.

3.4 CONDUIT FITTINGS AND ACCESSORIES

A. Conduit Seals:
   1. Installed in conduit systems located in hazardous areas as required by the NFPA 70.

B. Rigid non-metallic conduit and fittings shall be joined utilizing solvent cement.
   1. Immediately after installation of conduit and fitting, the fitting or conduit shall be rotated 1/4 turn to provide uniform contact.

C. Install Expansion Fittings:
   1. Where conduits are exposed to the sun and conduit run is greater than 200 FT.
   2. Elsewhere as identified on the Drawings.

D. Install Expansion/Deflection Fittings:
   1. Where conduits enter a structure.
      a. Except electrical manholes and handholes.
      b. Except where the ductbank is tied to the structure with rebar.
   2. Where conduits span structural expansions joints.
   3. Elsewhere as identified on the Drawings.

E. Threaded connections shall be made wrench-tight.

F. Conduit joints shall be watertight:
   1. Where subjected to possible submersion.
   2. In areas classified as wet.
   3. Underground.

G. Terminate Conduits:
   1. In metallic outlet boxes:
      a. RGS {and IMC and RAC}:
         1) Conduit hub and locknut.
         2) Insulated bushing and two (2) locknuts.
         3) Use grounding type locknut or bushing when required by NFPA 70.
      b. EMT: Compression type connector and locknut.
   2. In NEMA 1 rated enclosures:
      a. RGS {and IMC and RAC}:
         1) Conduit hub and locknut.
         2) Insulated bushing and two (2) locknuts.
         3) Use grounding type locknut or bushing when required by NFPA 70.
      b. EMT: Compression type connector and locknut.
   3. In NEMA 12 rated enclosures:
      a. Watertight, insulated and gasketed hub and locknut.
      b. Use grounding type locknut or bushing when required by NFPA 70.
   4. In NEMA 4 and NEMA 4X rated enclosures:
      a. Watertight, insulated and gasketed hub and locknut.
   5. In NEMA 7 and NEMA 9 rated enclosures:
      a. Into an integral threaded hub.

6. When stubbed up through the floor into floor mount equipment:
   a. With an insulated grounding bushing on metallic conduits.
   b. With end bells on non-metallic conduits.

H. Threadless couplings shall only be used to join new conduit to existing conduit when the existing conduit end is not threaded and it is not practical or possible to cut threads on the existing conduit with a pipe threader.

3.5 CONDUIT SUPPORT

A. Permitted multi-conduit surface or trapeze type support system per area designations and conduit types:
   1. Dry or wet and/or hazardous areas:
      a. Galvanized system consisting of: Galvanized steel channels and fittings, nuts and hardware and conduit clamps.
      b. Aluminum system consisting of: Aluminum channels, fittings and condit clamps with stainless steel nuts and hardware.
   2. Corrosive areas:
      a. Aluminum system consisting of: Aluminum channels, fittings and conduit clamps with stainless steel nuts and hardware.
      b. PVC coated steel system consisting of: PVC coated galvanized steel channels and fittings and conduit clamps with stainless steel nuts and hardware.
   3. Highly corrosive areas:
      a. PVC coated steel system consisting of: PVC coated galvanized steel channels and fittings and conduit clamps with stainless steel nuts and hardware.
      b. Fiberglass system consisting of: Fiberglass channels and fittings, nuts and hardware and conduit clamps.
   4. Conduit type shall be compatible with the support system material.
      a. Galvanized steel system may be used with RGS.
      b. Stainless steel system may be used with RGS.
      c. PVC coated galvanized steel system may be used with PVC-RGS and Fiberglass.

B. Permitted single conduit support fasteners per area designations and conduit types:
   1. Architecturally finished areas:
      a. Material: Zinc plated steel, or steel protected with zinc phosphate and oil finish.
      b. Types of fasteners: Spring type hangers and clips, straps, hangers with bolts, clamps with bolts and bolt on beam clamps.
      c. Provide anti-rattle conduit supports when conduits are routed through metal studs.
   2. Dry or wet and/or hazardous areas:
      a. Material: Zinc plated steel, stainless steel and malleable iron.
      b. Types of fasteners: Straps, hangers with bolts, clamps with bolts and bolt on beam clamps.
   3. Corrosive areas:
      a. Material: Stainless steel and PVC coat malleable iron or steel.
      b. Types of fasteners: Straps, hangers with bolts, clamps with bolts and bolt on beam clamps.
   4. Highly corrosive areas:
      a. Material: PVC coat malleable iron or steel.
      b. Types of fasteners: Straps, hangers with bolts, clamps with bolts and bolt on beam clamps.
   5. Conduit type shall be compatible with the support fastener material.
      a. Zinc plated steel, steel protected with zinc phosphate and oil finish and malleable iron fasteners may be used with RGS.
      b. Stainless steel system may be used with RGS.

c. PVC coated fasteners may be used with PVC-RGS.
d. Non-metallic fasteners may be used with fiberglass.

C. Conduit Support General Requirements:
1. Maximum spacing between conduit supports per NFPA 70.
2. Support conduit from the building structure.
3. Do not support conduit from process, gas, air or water piping; or from other conduits.
4. Provide hangers and brackets to limit the maximum uniform load on a single support to 25 LBS or to the maximum uniform load recommended by the manufacturer if the support is rated less than 25 LBS.
   a. Do not exceed maximum concentrated load recommended by the manufacturer on any support.
   b. Conduit hangers:
      1) Continuous threaded rods combined with struts or conduit clamps: Do not use perforated strap hangers and iron bailing wire.
   c. Do not use suspended ceiling support systems to support raceways.
   d. Hangers in metal roof decks:
      1) Utilize fender washers.
      2) Not extend above top of ribs.
      3) Not interfere with vapor barrier, insulation, or roofing.
5. Conduit support system fasteners:
   a. Use sleeve-type expansion anchors as fasteners in masonry wall construction.
   b. Do not use concrete nails and powder-driven fasteners.

3.6 OUTLET, PULL AND JUNCTION BOX INSTALLATION

A. General:
1. Install products in accordance with manufacturer's instructions.
2. See Specification Section 26 05 00 and the Drawings for area classifications.
3. Fill unused punched-out, tapped, or threaded hub openings with insert plugs.
4. Size boxes to accommodate quantity of conductors enclosed and quantity of conduits connected to the box.

B. Outlet Boxes:
1. Permitted uses of metallic outlet boxes:
   a. Housing of wiring devices:
      1) Recessed in all stud framed walls and ceilings.
      2) Recessed in poured concrete, concrete block and brick walls of architecturally finished areas and exterior building walls.
   b. Pull or junction box:
      1) Above gypsum wall board or acoustical tile ceilings.
      2) Above 10 FT in an architecturally finished area where there is no ceiling.
2. Permitted uses of cast outlet boxes:
   a. Housing of wiring devices surface mounted in non-architecturally finished dry, wet, corrosive, highly corrosive and hazardous areas.
   b. Pull and junction box surface mounted in non-architecturally finished dry, wet, corrosive and highly corrosive areas.
3. Mount device outlet boxes where indicated on the Drawings and at heights as scheduled in Specification Section 26 05 00.
4. Set device outlet boxes plumb and vertical to the floor.
5. Outlet boxes recessed in walls:
   a. Install with appropriate stud wall support brackets or adjustable bar hangers so that they are flush with the face of the wall.

b. Locate in ungrouted cell of concrete block with bottom edge of box flush with bottom edge of block and flush with the face of the block.

6. Place barriers between switches in boxes with 277 V switches on opposite phases.
7. Back-to-back are not permitted.
8. When an outlet box is connected to a PVC coated conduit, the box shall also be PVC coated.

C. Pull and Junction Boxes:
1. Install pull or junction boxes in conduit runs where indicated or required to facilitate pulling of wires or making connections.
    a. Make covers of boxes accessible.
2. Permitted uses of NEMA 1 enclosure:
    a. Pull or junction box surface mounted above removable ceiling tiles of an architecturally finished area.
3. Permitted uses of NEMA 4 enclosure:
    a. Pull or junction box surface mounted in areas designated as wet.
4. Permitted uses of NEMA 4X metallic enclosure:
    a. Pull or junction box surface mounted in areas designated as wet and/or corrosive.
5. Permitted uses of NEMA 7 enclosure:
    a. Pull or junction box surface mounted in areas designated as Class I hazardous.
        1) Provide PVC coating in corrosive and highly corrosive areas when PVC coated conduit is used.
6. Permitted uses of NEMA 12 enclosure:
    a. Pull or junction box surface mounted in areas designated as dry.

END OF SECTION

SECTION 26 05 45

DROOP CABLE SYSTEM

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Basic requirements for droop cable system.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. Aluminum Association (AA).
   2. American Iron and Steel Institute (AISI).
   3. ASTM International (ASTM):
      a. A123, Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
      b. A153, Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.
   4. ETL Testing Laboratories (ETL).
   5. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
      a. C2, National Electrical Safety Code (NESC).
   6. National Electrical Manufacturers Association (NEMA):
      a. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
   7. National Fire Protection Association (NFPA):
      a. 70, National Electrical Code (NEC).
   8. Underwriters Laboratories, Inc. (UL).

1.3 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
   2. General requirements:
      a. Provide manufacturer's technical information on products to be used, including product descriptive bulletin.
      b. Include data sheets that include manufacturer's name and product model number.
         1) Clearly identify all optional accessories.
      c. Acknowledgement that products are UL or ETL listed or are constructed utilizing UL or ETL recognized components.
      d. Manufacturer's delivery, storage, handling and installation instructions.
      e. Product installation details.

B. Operation and Maintenance Manuals:
   1. See Specification Section 26 05 00 for requirements for the mechanics and administration of submittal process.
   2. The Design-Builder shall furnish complete instructions containing the technical information required for proper installation, operation and maintenance of each assembly of equipment supplied. See Specification Section 8.4.

C. Factory Test Data - Information to be submitted:
   1. Material undergoing test
   2. Description of test performed
   3. Results (measured or observed)
   4. Value and limits required by ICEA/NEMA Standard for acceptance

D. Insulation Data:
   1. Typical published test data of proposed cable insulating compound
      a. Physical characteristics
      b. Electrical characteristics
   2. Must be submitted for approval before accepting shipment from manufacturer

E. Certificate of Compliance:
   1. Statement certifying that cable delivered passed the required factory inspections and tests and complies with all requirements of the contract

PART 2 - PRODUCTS

2.1 MANUFACTURER

A. Manufacturer of the droop cable must be experienced in producing flexible droop cable.

B. Approved Manufacturer for Bronze Insulated Grounding Bushings, Watertight Cable Strain Relief Fittings, Conduit Expansion Fittings
   1. O.Z./Gedney

C. Approved Manufacturer for Breather Fitting
   1. Appleton Electric

D. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 MATERIALS

A. Droop Cables
   1. True length of each cable between the droop cable terminal cabinets and junction boxes on the movable span must be determined before cable orders are placed with any manufacturer.
      a. No splices or joining of conductors will be permitted.
      b. Length of cables must provide sufficient excess length to accommodate pulling eyes, adequate slack for full range of travel, cable clamping, connections and test samples.
   2. Minimum of 20% of the specified conductors shall be provided as spare conductors.
   3. Cables shall be designed and manufactured in accordance with:
      a. ICEA S-73-532, NEMA WC-57 (22-26 AWG)
      b. ICEA S-95-658, NEMA WC-70 (14 AWG and larger)
   4. Configuration
      a. Multiple conductor extra flexible copper conductors
         1) Conductors shall be annealed copper and stranded in accordance with ASTM B-174 for 10 AWG and smaller, and ASTM B-172 for 9 AWG and larger. Stranding shall be per Section 2 of ICEA S-95-658, NEMA WC-70, as applicable.
      b. Ethylene propylene rubber (EPR) insulation
         1) Shall be in accordance with ICEA S-73-532, NEMA WC-57, Table 3-2 (22-16 AWG) for 600V and ICEA S-95-658, NEMA WC-70, Table 3-1 (14 AWG and larger) for 600V.
      c. Cabled with fillers as necessary
      d. Binder tape

   e. Jacketed with weather resistant arctic Neoprene jacket reinforced with aramid (Kevlar) fiber reinforcement.
5. Physical and aging of the cable shall meet the following requirements:

Unaged	
Tensile Strength – psi, min	1200
Elongation – percent, min	150
Tensile Stress @ 100% elongation, psi, min	500
Aged - After air oven 168 hours @ 121C	
Tensile Strength and Elongation: At rupture – percent of unaged, min	75
Hot Creep @150C: Hot Creep Elongation, percent, max	50

6. Water Absorption Requirements:
   a. EPR insulation shall meet the accelerated water absorption requirements in accordance with ICEA T-27-581, NEMA WC-53, Electrical Method EM-60:

Dielectric Constant after one day max	6.0
Stability factor after 14 days, max	1.0
Increase in capacitance – percent, max	
1 to 14 days	5.0
7 to 14 days	3.0

7. Insulation thickness shall comply with:
   a. ICEA S-73-532, NEMA WC-57, paragraph 3.2 and Table 3-1
   b. ICEA S-95-658, NEMA WC-70, paragraph 3.3 and Table 3-4
8. The insulation shall be readily removable from the conductor. A separator shall be employed between the conductor and the insulation to enhance strippability. The separator shall be colored as to be distinguished from the conductor after the insulation is removed.
9. Color coding of the insulated conductors shall be accomplished by surface printed legends consisting of numbers and words (1-One, 2-Two… 19-Nineteen, etc) and shall be in accordance with ICEA S-73-532, NEMA WC-57, Appendix E, Method No. 4.
   a. The numbering sequence shall begin from the inner conductor layer and progress to the outer conductor layer.
   b. Contrasting color print shall be employed and be legible after normal handling during installation.
10. Cable Assembly:
   a. Cable components shall be cabled into a tight concentric configuration with the direction of lay for adjacent layers of cable conductors being reversed.
   b. Maximum lay length: 12xOD of the cabled layer.
   c. Non-hygroscopic fillers shall be employed as necessary within cable core to produce substantially circular cross section.
   d. Cabled conductors shall be covered with a rubber/fabric binder tape that shall be applied helically with a minimum overlap of 25 percent.
11. Cable Jacket Material:
   a. Cable core shall be covered with two layers of black arctic heavy-duty Neoprene (polychloroprene) jacket in accordance with ICEA S-95-658, NEMA WC-70, paragraph 4.1.3.
   b. Jacket shall be sunlight (ultraviolet) and weather resistant.

c. Jacket shall meet the following physical and thermal aging requirements:

Unaged	
Tensile Strength – psi, min	1800
Elongation – percent, min	300
Tensile Stress @ 200% elongation, psi, min	500
Aged	
After air oven 168 hours @ 100C Tensile Strength and Elongation: At rupture – percent of unaged, min	85/65
After oil immersion 18 hours @ 121C Tensile Strength and Elongation: At rupture – percent of unaged, min	60

d. The two-layer cable jacket thickness shall be as follows:

Calculated Diameter of Cable Under Jacket (inches)	Jacket Average Thickness (mils)
Less than 0.325	60
0.326-0.430	80
0.431-0.540	95
0.541-0.640	110
0.641-0.740	125
0.741-0.850	140
0.851-1.000	155
1.001-1.320	170
1.321-1.550	190
1.551-1.820	205
1.821-2.050	220
2.051-2.300	235
2.301-2.550	250
2.551-2.800	265
2.801-3.100	280
3.101-3.500	295
3.501-3.950	310
3.951-4.450	330
4.451-5.000	345

12. Communication Conductors:
    a. Fiber optic
        1) If required.
        2) Individual fiber cables shall be composed of 62.5/125/250 micrometer multimode fiber, encased in gel-filled loose tubes, cabled, a central strength member, water swellable tape, aramid fiber strength member, and a polypropylene jacket.
    b. Allow provision for communication conductors as per manufacturer instructions.
13. Packaging of the finished cable shall be on reels capable of supporting the weight during transportation and normal handling. Cable ends shall be suitably sealed to prevent moisture from entering the conductor core area during shipping. The reel designated to be spare shall be encased with wooden slats affixed to the entire perimeter of the reel to protect the cable while in storage.

B. Droop Cable Terminal Cabinets and Junction Boxes
1. Droop Cable Terminal Cabinet:
    a. Shall be furnished and installed to provide termination for the droop cables.

b. Shall be sized to accommodate mounting of all terminal blocks and to provide ample space between blocks for routing the wires.
c. Terminal blocks shall be provided for connections of all conductors in the droop cables.
    a) Sufficient terminals shall be provided for termination of all spare conductors and other conductors to be terminated inside the cabinet.
    b) Shall be one-piece blocks suitable for use in highly corrosive atmospheres
d. Two doors
    1) Shall be constructed of No. 10 gauge steel sheet, suitably reinforced
    2) Shall be provided with a three-point, vault-type latch
    3) Shall have rubber gaskets
e. Floor mounted
f. NEMA 4X type enclosure
g. 12 inch floor stands
h. Fabricated from No. 10 gauge steel sheet

2. Ends of Conduits:
    a. Ends of all conduits projecting into terminal cabinets and junction boxes shall be provided with bronze insulated grounding bushings. The insulated portion shall be of molded phenolic compound, and each fitting shall have a screw type combination lug for bonding.
    b. All bushings in any box or enclosure shall be bonded together with No. 8 AWG bare copper wire.
3. Watertight Cable Strain Relief Fitting:
    a. Shall be used to complete each droop cable termination at all terminal cabinets and junction boxes.
4. Junction Boxes:
    a. Aluminum NEMA 4X
    b. Shall have a continuous hinge on one side and screw type clasps on the remaining three sides.
    c. Shall be provided with a stainless steel NEMA 4X breather fitting to minimize condensation

C. Cable Supports:
1. On either end of the traveling section of cable, all droop cables shall be supported with heavy-duty, double-eye, split mesh, stainless steel cable grips.
2. Each cable shall be supported by two mesh grips
    a. one attached to support structure on fixed tower
    b. one attached to support structure on movable span
3. All vertical and horizontal installations of droop cable shall be attached to support plates by stainless steel U-bolts and double nuts.
    a. U-bolts shall be fabricated with stainless steel saddles welded in place
    b. Shall be sized to match droop cable diameter
4. Framing channel will not be an acceptable support system.

D. Conduit:
1. All conduit shall be rigid aluminum conduit.
2. Shall be manufactured in conformance to UL and ANSI standards
3. Bends and offsets shall be made by cold bending using approved methods and equipment if required.
4. Shall be securely clamped and supported using stainless steel U-bolts
    a. U-bolts shall be provided with medium-series lock washers and hexagonal nuts.
    b. Bolts, nuts, and washers shall be of stainless steel in conformance with the Standard Specifications for Stainless and Heat-Resisting Steel Bars and Shapes, ASTM Designation A276.

5. Conduit expansion fittings shall be bronze/neoprene deflection/expansion fittings and shall be provided with flexible bonding jumpers to maintain electrical continuity across the joints.
6. Ends of all conduits projecting into boxes and equipment enclosures shall be provided with bronze insulated grounding bushings. The insulated portion shall be of molded phenolic compound, and each fitting shall have a screw type combination lug for bonding.
    a. All bushings in any box or enclosure shall be bonded together with No. 8 AWG bare copper wire.
7. All conduits shall be cleaned before and after installation. Upon completion of conduit and box installation, the Design-Builder shall clear each conduit by snaking with a steel band to which shall be attached an approved tube cleaner equipped with a mandrel of a diameter not less than 85 percent of the nominal inside diameter of the conduit and with a wire brush of the same diameter as the conduit. The cable shall then be drawn into the conduit.

PART 3 - EXECUTION

3.1 TESTING

A. Shop Testing
1. Individual insulated conductors to be incorporated in cable shall be tested for quality of production prior to assembly and fabrication of droop cables
2. Tests to be performed after cable is completely assembled:
    a. High voltage testing
    b. Insulation resistance testing
    c. Conductor resistance testing
3. Tests to be performed on section of cable sample taken from each reel in accordance with ICEA/NEMA standards:
    a. Individual conductors shall be tested in accordance with ICEA S-95-658, NEMA WC-70, Table 3-4
    b. Finished cable shall withstand between each conductor and all other conductors an AC (rms) voltage in accordance with:
        1) ICEA S-73-532, NEMA WC-57, table 3-3, paragraphs 3.4 and 6.17.1 (22-16 AWG)
        2) ICEA S-95-658, NEMA WC-70, table 3-4, paragraphs 3.6.2 and 6.10.1.1 (14 AWG and larger)
        3) ICEA T-27-581, NEMA WC-53, paragraph 2.2.2
    c. Insulation resistance shall be measured after completed AC voltage test in accordance with:
        1) ICEA S-73-532, NEMA WC-57, paragraphs 3.5 and 6.18
        2) ICEA S-95-658, NEMA WC-70, paragraphs 3.6.3 and 6.10.2 (14 AWG and larger)
        3) ICEA T-27-581, NEMA WC-53, paragraph 2.3
        4) Insulation resistance constant (IRK) for EPR insulation shall be 10,000 in accordance with ICEA S-95-658, NEMA WC-70, paragraph 3.6.3, and table 3-7 for insulation Class E-2
    d. The DC resistance of each conductor in the completed cable shall be measured and comply with:
        1) ICEA S-73-532, NEMA WC-57, paragraph 2.3.4
        2) ICEA S-95-658, NEMA WC-70, paragraph 2.3 (14 AWG and larger)
        3) ICEA T-27-581, NEMA WC-53, paragraph 2.1

B. Field Testing
1. Test methods for measuring insulation resistance of cables installed in the field shall be in accordance with the specified NEMA Publications.

2. Test equipment shall include a megohm meter capable of generating a constant 1000V DC source, calibrated in a range legible from 0 to 1000 megohms and up to infinity, with heavy-duty, rubber-insulated, alligator-clip leads, and a guard-circuit terminal available if used.
3. Polarity for connecting the megohm meter to cable under test and the duration of time for electrifying the cable before taking the resistance reading shall be in accordance with the NEMA Publication.
4. Measured values of insulation resistance of each conductor shall be recorded for comparison with the factory test values. the failure of any conductor in an installed droop cable to demonstrate satisfactory insulation resistance will be cause for the rejection of the droop cable. Should this occur, the rejected cable shall be promptly removed and replaced with a new cable subject to all aforementioned tests and acceptances.
5. Records of the measured insulation resistance for each cable, the cable length installed, cable and reel identifications, date of test, and ambient temperature shall be taken. the test results and data shall be submitted to the Engineer for approval in addition to submission of a certificate identifying the test equipment used stating its accuracy within the limits rated by the manufacturer.

3.2 INSTALLATION

A. Equipment and installation shall conform to AASHTO Standard Specifications for Movable Highway Bridges.

B. Materials and construction shall conform to NFPA 70/NEC latest revision and any applicable local rules and ordinances.
   1. All required permits and approvals must be obtained.

C. All work shall be in conformance with the requirements of the United States Coast Guard.

END OF SECTION

SECTION 26 05 48
SEISMIC BRACING SYSTEMS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. The design and installation of seismic bracing and anchorage required for electrical equipment, conduit, cable tray, and bus ducts.

B. Related Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.
   2. Section 01 25 13 - Product Substitution.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. ASTM International (ASTM):
      a. A36, Standard Specification for Carbon Structural Steel.
      b. A307, Standard Specification Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength.
      c. F1554, Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength.
   2. Building code:
      a. International Building Code (IBC).
      b. International Conference of Building Officials (ICBO).

1.3 SYSTEM DESCRIPTION

A. Design-Builder is responsible for design and installation of seismic bracing and anchorage systems.

B. Description of Systems:
   1. Transverse and longitudinal bracing for seismic forces on suspended electrical systems including conduit, cable tray, bus duct, and equipment.
   2. Anchorage of floor and roof mounted electrical equipment.

C. Seismic Design Requirements:
   1. Seismic design criteria: Provide bracing and anchoring for equipment, conduit, cable tray, bust duct, designed, constructed, and installed to resist stresses produced by lateral forces.

D. Design and install seismic anchorage and bracing for all floor or roof mounted equipment weighing 400 LBS or more and all suspended or wall mounted equipment weighing 20 LBS or more.

E. The following components are exempt from the requirements of this Specification Section:
   1. Electrical components in structures assigned to Seismic Design Category C provided that the importance factor (I_p) is equal to 1.0.
   2. Electrical components in Seismic Design Categories D, E, and F where I_p = 1.0 and flexible connections between the components and associated ductwork, piping, and conduit are provided and that are mounted at 4 FT (1.22 m) or less above a floor level and weigh 400 LBS (1780 N)or less.

3. Electrical components in Seismic Design Categories D, E, and F weighing 20 LBS (95 N) or less where $I_p = 1.0$ and flexible connections between the components and conduit are provided, or for distribution systems, weighing 5 LBS/FT (7 N/m) or less.

F. Seismic forces shall be presumed to act through the center of mass of the equipment in a direction that will produce the largest single anchor force.

1.4 SUBMITTALS

A. Shop Drawings:
1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
2. Product technical data:
   a. Seismic control devices.
3. Fabrication and/or layout drawings:
   a. Layout and mounting detail drawings showing system and proposed brace locations for all systems including pre-engineered systems.
   b. The specific detail for each type of brace or anchor must be referenced on a plan that identifies the required location.
      1) Supplying a book of details without referencing the proper detail to a specific location on a plan is not acceptable.
   c. Structural calculations for required lateral force level for each component.
   d. All submittals, including pre-approved systems, shall be signed and sealed by a licensed engineer, licensed in the state in which the project is located.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following manufacturers are acceptable:
1. Pre-engineered suspended bracing systems:
   a. International Seismic Application Technology (ISAT) “Engineered Seismic Bracing of Suspended Utilities”.
   b. Unistrut.
   c. Tolco.
   d. B-Line.
2. Custom engineered systems designed using specified criteria and common building materials.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 EQUIPMENT ANCHORS AND SUPPORTS

A. Drilled-in-place concrete anchors shall have an approved ICBO Evaluation Services Report.

B. Cast-in-place anchors shall comply with ASTM A36, ASTM A307, or ASTM F1554, 36 ksi.

C. Anchors permanently exposed to weather or corrosive environments shall be stainless steel or hot-dipped galvanized.

D. Structural steel for supports: ASTM A36.

E. Cold formed metal and connection material: Unistrut.

F. Any details provided are based on assumed equipment and arrangement.

1. Design-Builder shall be responsible for design and acquiring approval for support and anchorage of equipment and arrangement which varies from equipment and arrangement assumed in detail provided.

PART 3 - EXECUTION

3.1 GENERAL REQUIREMENTS

A. Every run which requires bracing shall have a minimum of two (2) transverse braces and one (1) longitudinal brace.
   1. A “run” is defined as suspended pipe, conduit, cable tray, bus ductor trapeze rack having a minimum 5 FT straight run length.

B. Brace spacing shall not exceed the maximum allowable brace spacing as engineered by the manufacturer or custom bracing designer.

C. Bracing may be omitted from conduit, cable tray and bus duct runs less than 5 FT in length.

D. Bracing may be omitted from conduit, cable tray and bus duct runs where rod hung supports of less than 12 IN. (305mm) in length are required.
   1. All unbraced suspended utility systems having 2 IN conduit and larger or systems weighing more then 5 LBS/FT shall be installed with a minimum 6 IN clearance to suspended ceiling vertical hanger wires.
   2. The conduit, cable tray, or bus duct shall be installed such that the lateral motion of the members will not cause damaging impact with other systems or structural members or loss of vertical support.

E. A longitudinal brace at a 90 degree change in direction may act as a transverse brace if it is located within 2 FT of the change in direction.

F. A transverse brace may act as a longitudinal brace if it is located within 2 FT of a change in direction and if the brace arm and anchorage have been sized to meet or exceed the requirements of the longitudinal brace.

G. When bracing equipment or a utility system that is suspended from an overhead deck, brace back to the overhead deck or to the supporting structure supporting the deck.
   1. Do not brace to another element of the structure which may respond differently during a seismic event.

H. Obtain approval from the Structural Engineer prior to attaching any brace elements to structural steel or wood framing.

I. When utilizing cable bracing, tension the cable to remove slack without inducing uplift of the suspended element.
   1. Tension seismic bracing system prior to system start-up and adjust if necessary after equipment start-up.

J. As a general rule, do not mix rigid bracing with cable bracing in the same run.
   1. However, once bracing has transitioned a 90 degree change in run direction, the bracing may switch from rigid to cable or vice versa if required due to a significant change in overhead deck elevation or to provide an implementable bracing scheme in a congested area.

K. Install brace members at an angle of 45 degrees from horizontal within a tolerance of plus 2 1/2 degrees or minus 45 degrees provided the brace length is accounted for in design.
   1. Brace angle may be increased to 60 degrees provided the brace spacing is reduced to 1/2 that required for a 45 degree brace.

L. Seismic bracing may not pass through a building separation joint.
   1. Utility systems that pass through a separation joint must be seismically restrained no greater than 5 FT from the point of connection.
   2. Any hardware designed to accommodate seismic movement across the span of the separation joint shall be installed per manufacturer's installation and listing instructions.

M. With approval of the Structural Engineer, utility systems that are suspended from the overhead deck may be braced to load bearing concrete or CMU (concrete masonry) walls provided that the walls and the overhead decks will respond similarly during a seismic event.

N. Each layer of a multiple layer trapeze rack shall be braced individually based on the weight of the individual layer.

O. Conduit, cable tray, or bus duct constructed of non ductile material (plastic or fiberglass), shall have brace spacing reduced to 1/2 of the spacing allowed for ductile materials.

P. Where brace elements are through-bolted, the mounting hole in the element is to be no more than 1/16 IN in diameter larger then the bolt or threaded rod.

Q. Seismic braces shall directly brace the system and not the hanger.

3.2 SUSPENDED ELECTRICAL SYSTEMS

A. Install seismic bracing for all conduit 2-1/2 IN trade size or greater.

B. All trapeze assemblies supporting conduits, cable trays or bus ducts shall be braced considering the total weight of the elements on the trapeze.
   1. For the purposes of calculating weight, all conduits are to be treated as full.

C. Brace all trapeze racks which support conduit 2-1/2 IN trade size or larger.
   1. Brace all other conduit rack, cable tray or bus duct trapezes having a minimum weight in excess of 10 LBS/LF.
   2. Include a minimum 10 percent additional capacity for future additions.

D. Seismic bracing may be omitted from cable trays, conduit and bus ducts suspended by rod hung supports 12 IN or less in length form the top of the element to the bottom of the structural attachment of the hanger provided lateral motion will not cause damaging impacts to other systems or loss of system vertical support.

E. All vertical risers involving conduit 2-1/2 IN in diameter or larger shall include lateral restraint at maximum 30 FT intervals and at the top and bottom of the riser.

3.3 FLOOR OR ROOF MOUNTED EQUIMENT

A. Provide one (1) anchor on each leg or corner.
   1. Support with a minimum of three (3) 3/8 IN DIA anchors.

B. Friction shall be neglected when designing anchors for shear.

C. Vertical seismic forces, when required, shall be presumed to act concurrently with horizontal seismic forces.

END OF SECTION

SECTION 26 08 13
ACCEPTANCE TESTING

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Basic requirements for acceptance testing.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.
   2. Section 40 05 05 - Equipment: Basic Requirements.
   3. Division 26 - Electrical.
   4. Section 26 32 14 - Engine Generator - Diesel.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
      a. 400, Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems.
      b. 400.3, Guide for Partial Discharge Testing of Power Cable Systems in a Field Environment.
   2. InterNational Electrical Testing Association (NETA):
      a. ATS, Standard for Acceptance Testing Specifications for Electric Power Equipment and Systems.
   3. Nationally Recognized Testing Laboratory (NRTL).
   4. Telecommunications Industry Association/Electronic Industries Alliance/American National Standards Institute (TIA/EIA/ANSI):
      a. 455-78-B, Optical Fibres - PART 1-40: Measurement Methods and Test Procedures - Attenuation.

B. Qualifications:
   1. Testing firm qualifications: See Specification Section 40 05 05.
   2. Field personnel:
      a. See Specification Section 40 05 05.
      b. As an alternative, supervising technician may be certified by the equipment manufacturer.
   3. Analysis personnel:
      a. See Specification Section 40 05 05.
      As an alternative, supervising technician may be certified by the equipment manufacturer.

C. Phasing Diagram:
   1. Coordinate with Utility Company for phase rotations and Phase A, B and C markings.
      a. Create a phasing diagram showing the coordinated phase rotations with generators and motors through the transformers.

1.3 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.

2. See Specification Section 40 05 05 for electrical equipment and connection testing plan submittal requirements.

B. Miscellaneous Submittals:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
   2. Prior to energizing equipment:
      a. Coordinated phasing diagram.
      b. Photocopies of continuity tests.
   3. Within two (2) weeks after successful completion of Demonstration Period (Commissioning Period):
      a. Single report containing information including:
         1) Summary of Project.
         2) Information from pre-energization testing.
         3) See testing and monitoring reporting requirements in Specification Section 40 05 05.

PART 2 - PRODUCTS

2.1 FACTORY QUALITY CONTROL

A. Provide Division 26 equipment with all routing factory tests required by the applicable industry standards or NRTL.

B. Factory testing will not be accepted in lieu of field acceptance testing requirements specified in this Specification Section and Specification Section 40 05 05.

PART 3 - EXECUTION

3.1 FIELD QUALITY CONTROL

A. General:
   1. See Specification Section 40 05 05.
   2. Complete electrical testing in three (3) phases:
      a. Pre-energization testing phase.
      b. Equipment energized with no load.
      c. Equipment energized under load.
   3. Perform testing in accordance with this Specification Section and NETA ATS.
   4. Provide field setting and programming of all adjustable protective devices and meters to settings as determined by the approved coordination study.

B. Equipment Monitoring and Testing Plan: See Specification Section 40 05 05.

C. Instruments Used in Equipment and Connections Quality Control Testing: See Specification Section 40 05 05.

D. Testing and Monitoring Program Documentation: See Specification Section 40 05 05.

E. Electrical Equipment and Connections Testing Program:
   1. See Specification Section 40 05 05.
   2. See individual Division 26 Specification Sections for equipment specific testing requirements.
   3. Test all electrical equipment.
      a. Perform all required NETA testing.

b. Perform all required NETA testing plus the optional testing identified with each specific type of equipment in Article 3.2 of this Specification Section.

3.2 SPECIFIC EQUIPMENT TESTING REQUIREMENTS

A. Switchgear and Switchboards:
1. Perform inspections and tests per NETA ATS 7.1.
2. Components: Test all components per applicable paragraphs of this Specification Section and NETA ATS.

B. Transformers - Small Dry Type:
1. Perform inspections and tests per NETA ATS 7.2.1.1.
2. Perform the following additional tests:
   a. Record phase-to-phase, phase-to-neutral, and neutral-to-ground voltages at no load after energizing, and at operating load after startup.
3. Adjust tap connections as required to provide secondary voltage within 2-1/2 percent of nominal under normal load after approval of Engineer.
4. Record as-left tap connections.

C. Transformers - Large Dry Type:
1. Perform inspections and tests per NETA ATS 7.2.1.2.
2. Components: Test all components per applicable paragraphs of this Specification Section and NETA ATS.
3. Perform the following additional tests:
   a. Record phase-to-phase, phase-to-neutral, and neutral-to-ground voltages at no load after energizing, and at operating load after start-up.
4. Adjust tap connections as required to provide secondary voltage within 2-1/2 percent of nominal under normal load.
5. Record as-left tap connections.

D. Transformers - Liquid Filled:
1. Perform inspections and tests per NETA ATS 7.2.2.
2. Components: Test all components per applicable paragraphs of this Specification Section and NETA ATS.
3. Perform the following additional tests:
   a. Record phase-to-phase, phase-to-neutral, and neutral-to-ground voltages at no load after energizing, and at operating load after start-up.
4. Adjust tap changer setting as required to provide secondary voltage within 2-1/2 percent of nominal under normal load after approval of Engineer.
5. Record as-left tap changer setting.

E. Transformer Cooling Fans/Temperature Controllers:
1. Verify each temperature sensor is of the correct type and rating and provides the correct output signal at ambient temperature.
2. Using a thermocouple or RTD simulator, verify correct temperature indication and alarm and fan control relay operation by signal injection.
3. Verify operation of controls in manual and automatic mode.
4. Verify operation of all cooling fans, record running current and compare to nameplate value.
5. Verify trip circuit operation where provided.

F. Cable - Low Voltage:
1. Perform inspections and tests per NETA ATS 7.3.2.

G. Cable - Medium Voltage:
1. Perform inspections and tests per NETA ATS 7.3.3.
2. Non-destructive partial discharge test:

a. After energization, perform a partial discharge test for baseline data for future partial discharge maintenance testing.
b. Perform the work while the medium voltage circuits and equipment are energized.
    1) The cables shall not be disconnected or de-energized and the testing shall not expose the cables to voltages that exceed normal operating voltage.
c. Use a frequency domain detection process incorporating a spectrum analyzer with radio frequency current transformer (RF CT) sensors.
    1) The detection system, including spectrum analyzer, RF CT's and interconnecting cable, shall have a partial discharge detection range that at least covers the frequency range of 10 kHz to 300 MHz.
    2) Testing shall be performed in a manner that complies with the requirements of IEEE 400 and IEEE 400.3.

H. Cable - Optical Fiber:
1. Perform inspections on tests per TIA/EIA/ANSI 455-78-B, including:
    a. Optional time domain reflectometer test.
    b. Power attenuation test.
    c. Gain margin test.

I. Busway and Busduct:
1. Perform inspections and tests per NETA ATS 7.4.
2. Components: Test all components per applicable paragraphs of this Specification Section and NETA ATS.

J. Air Interrupter Switches:
1. Perform inspections and tests per NETA ATS 7.5 and NETA ATS 7.6.
2. Components: Test all components per applicable paragraphs of this Specification Section and NETA ATS.
3. Perform the following optional tests per NETA ATS on all medium voltage switches:
    a. Insulation resistance phase-to-phase, phase-to-ground in open and closed positions and across each open pole.

K. Medium Voltage Source Transfer System;
1. Perform applicable inspections and test per:
    a. NETA ATS for Air Interrupter Switches.
    b. Manufacturer's instructions.

L. SF6 Insulated Switches:
1. Perform applicable inspections and tests per NETA ATS 7.6.
2. Components: Test all components per applicable paragraphs of this Specification Section and NETA ATS.
3. Perform the following optional tests per NETA ATS:
    a. Insulation resistance phase-to-phase, phase-to-ground in open and closed positions and across each open pole.
4. Test {low pressure}{low density} alarm circuit.

M. Medium Voltage Circuit Breakers:
1. Perform inspections and tests per NETA ATS 7.6.2.
2. Components: Test all components per applicable paragraphs of this Specification Section and NETA ATS.
3. Perform the following optional tests per NETA ATS:
    a. Control wiring insulation resistance.
    b. Minimum trip and close voltage.
    c. Overpotential.
4. Perform the following additional tests:

a. High-potential vacuum integrity test per manufacturer's recommendations.

N. Low Voltage Power Circuit Breakers:
1. Perform inspections and tests per NETA ATS 7.6.1.2.
   a. Tests shall include primary current injection testing of all breakers at final settings.
   b. Where short-time or instantaneous settings on large frame breakers are beyond the current capability of field testing, primary injection tests at reduced currents shall be permitted if combined with secondary injection calibration test of trip unit at final settings.
2. Components: Test all components per applicable paragraphs of this Specification Section and NETA ATS.
3. Perform the following additional tests:
   a. Shunt trip devices minimum tripping voltage.
4. Record as-left settings.

O. Low Voltage Molded Case Circuit Breakers:
1. Perform inspections and tests per NETA ATS 7.6.1.1.
2. Components:
   a. Test all components per applicable paragraphs of this Specification Section and NETA ATS.
   b. Thermal magnetic breakers: Visual and mechanical inspection per NETA ATS only.
   c. Solid state trip type: Visual and mechanical inspection and electrical tests per NETA ATS.
3. Record as-left settings.

P. Network Protectors:
1. Perform inspections and tests per NETA ATS 7.8.
2. Components: Test all components per applicable paragraphs of this Specification Section and NETA ATS.
3. Perform all tests identified as optional per NETA ATS:
4. Perform the following additional tests:
   a. Verify reverse current sensitivity by opening transformer primary switch with feeder energized and no load on transformer and observing that network protector opens on magnetizing current alone.

Q. Protective Relays:
1. Perform inspections and tests per NETA ATS 7.9.
   a. Tests to be performed using secondary injection of 3 PH current and potential at final settings.
   b. Test at manufacturer's recommended test points and critical timing points identified on relay setting sheet.
2. Perform all tests identified as optional per NETA ATS.
3. Perform the following additional tests:
   a. Verification of direct trip of associated lockout relay or circuit breaker(s) by using relay test function or shorting trip contact at relay case.
   b. Microprocessor-based relays:
      1) Complete commissioning procedure per manufacturer's instructions, followed by tests of each relay element at final settings.
      2) Verification of all internally-programmed logic.
   c. Verification of all auxiliary input and output signals.
   d. Verification of power supply/self-diagnostic alarm contact and remote annunciation.
4. Record as-left settings.

R. Instrument Transformers:

1. Perform inspections and tests per NETA ATS 7.10.
2. Components: Test all components per applicable paragraphs of this Specification Section and NETA ATS.
3. Perform the following optional tests per NETA ATS:
   a. Dielectric withstand test on potential transformers.

S. Metering:
1. Perform inspections and tests per NETA ATS 7.11.
2. Components: Test all components per applicable paragraphs of this Specification Section and NETA ATS.

T. Grounding:
1. Perform inspections and tests per NETA ATS 7.13.
2. Components: Test all components per applicable paragraphs of this Specification Section and NETA ATS.

U. Ground Fault Protection:
1. Perform inspections and tests per NETA ATS 7.14.
2. Components: Test all components per applicable paragraphs of this Specification Section and NETA ATS.
3. Perform the following optional tests per NETA ATS:
   a. Control wiring insulation resistance.
4. Perform the following additional tests for four-wire systems:
   a. Primary current injection into switchgear bus with test set configured to simulate transformer source and high current jumper used to simulate unbalanced load and ground fault conditions.
   b. Verify no tripping for unbalanced load on each feeder and each main breaker.
   c. Verify no tripping for unbalanced load across tie breaker for dual-source schemes.
   d. Verify tripping for ground fault on load side of feeder each feeder and on each main bus.
   e. Verify tripping for ground fault on a single feeder and on each main bus through tie breaker(s) for multiple-source schemes.

V. Motors:
1. Perform inspections and tests per NETA ATS 7.15.
2. See Specification Section 40 05 05.

W. Motor Controllers:
1. Perform inspections and tests per NETA ATS 7.16.
2. Components: Test all components per applicable paragraphs of this Specification Section and NETA ATS.

X. Generators:
1. Perform inspections and tests per NETA ATS 7.15.2.
2. Components: Test all components per applicable paragraphs of this Specification Section and NETA ATS.
3. Perform the following additional tests:
   a. Load and cycle crank test per Specification Section 26 32 14.

Y. DC Power Systems:
1. Perform inspections and tests per NETA ATS 7.18.
2. Components: Test all components per applicable paragraphs of this Specification Section and NETA ATS.
3. Perform the following optional tests per NETA ATS:
   a. Cell impedance test.

Z. Control System Functional Test:
   1. Perform test upon completion of equipment acceptance tests.
   2. The test is to prove the correct interaction of all sensing, processing and action devices.
   3. Develop a test plan and parameters for the purpose of evaluating the performance of the system.
   4. Perform the following tests:
      a. Verify the correct operation of all interlock safety devices for fail-safe functions in addition to design function.
      b. Verify the correct operation of all sensing devices, alarms and indicating devices.
   5. Systems to be tested:

END OF SECTION

SECTION 26 09 13

ELECTRICAL METERING DEVICES

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Digital metering equipment.
   2. Analog metering equipment.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.
   2. Section 01 25 13 - Product Substitution.
   3. Section 26 05 00 - Electrical: Basic Requirements.
   4. Section 26 08 13 - Acceptance Testing.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. National Electrical Manufacturers Association (NEMA):
      a. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
   2. National Electrical Manufacturers Association/American National Standards Institute (NEMA/ANSI):
      a. C12.20, For Electricity Meter - 0.2 and 0.5 Accuracy Classes.
   3. National Fire Protection Association (NFPA):
      a. 262, Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces.
   4. Underwriters Laboratories, Inc. (UL):
      a. 508, Standard for Safety Industrial Control Equipment.

1.3 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
   2. Product technical data including:
      a. Provide submittal data for all products specified in PART 2 of this Specification:
      b. See Specification Section 26 05 00 for additional requirements.

B. Operation and Maintenance Manuals:
   1. See Specification Section 26 05 00 for requirements for:
      a. The mechanics and administration of the submittal process.
      b. The content of Operation and Maintenance Manuals.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following manufacturers are acceptable:
   1. Cutler Hammer.
   2. Electro Industries.
   3. General Electric Company.

4. Power Measurement.
5. Square D Company.
6. Siemens.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 DIGITAL METERING DEVICES

A. General:
1. Direct reading metered or calculated values.
2. Microprocessor based.
3. Integral LED or LCD display.
4. Current and potential transformers as required.
5. Integral fusing.
6. Operating temperature: 0 DegF to 150 DegF.
7. Standards:
    a. NEMA/ANSI C12.20.
    b. UL 508.

B. Type 'A' Low Range Meter:
1. Display the following minimum electrical parameters (accuracy):
    a. RMS current per phase (+0.3 percent full scale).
    b. RMS voltage line-to-line and line-to-neutral (+0.3 percent full scale).
2. Communication ports and protocols: As specified herein and/or as required for a functioning system.
3. Supply voltage: 120 Vac.

C. Type 'B' Midrange Meter:
1. Display the following minimum electrical parameters (accuracy):
    a. RMS current per phase (+0.3 percent full scale).
    b. RMS voltage line-to-line and line-to-neutral (+0.3 percent full scale).
    c. Real power (W): 3 PH total (+0.6 percent full scale).
    d. Apparent power (VA): 3 PH total (+0.6 percent full scale).
    e. Reactive power (VAR): 3 PH total (+0.6 percent full scale).
    f. Power factor (+1.0 percent).
    g. Frequency (+0.17 percent).
    h. Percent current total harmonic distortion (31st).
    i. Percent voltage total harmonic distortion (31st).
2. Communication ports and protocols: As specified herein and/or as required for a functioning system.
3. Supply voltage: 120 Vac.

D. Type 'C' High Range Meter:
1. Display the following minimum electrical parameters (accuracy):
    a. RMS current per phase (+0.2 percent full scale).
    b. RMS voltage line-to-line and line-to-neutral (+0.2 percent full scale).
    c. Real power (W): 3 PH total (+0.4 percent full scale).
    d. Apparent power (VA): 3 PH total (+0.4 percent full scale).
    e. Reactive power (VAR): 3 PH total (+0.4 percent full scale).
    f. Power factor (+1.0 percent).
    g. Frequency (+0.04 percent).
    h. Percent current individual harmonic and total harmonic distortion (50th).
    i. Percent voltage individual harmonic and total harmonic distortion (50th).
    j. Watt-hours (0.5 percent).
    k. VAR-hours (1.0 percent).

l. VA-hours (0.5 percent).
m. Ampere demand (+0.2 percent full scale).
n. Watt demand (+0.4 percent full scale).
o. VAR demand (+0.4 percent full scale).
p. VA demand (+0.4 percent full scale).
q. Phaser diagram.
2. NEMA/ANSI C12.20, Class 0.2 revenue accuracy.
3. Communication ports and protocols: As specified herein and/or as required for a functioning system.
4. Supply voltage: 120 Vac.

2.3 ACCESSORIES

A. Personal Computer (PCs) as Operator Interfaces:
1. PCs with the most current hardware and following features:
a. Pentium 4 or Celeron processor.
b. 256 MB RAM.
c. USB, serial and parallel communication ports.
d. 80 GB hard drive.
e. 3 1/2 IN, 1.44 MB diskette drive.
f. CD-ROM drive.
g. Zip backup drive.
h. Video graphics card.
i. Keyboard.
j. Mouse.
k. Monitor:
1) Minimum refresh rate: 75 HZ.
2) Minimum size (nominal/actual viewing): 17 IN/15.6 IN.
3) Automatic and manual degaussing.
4) Resolution: 1280 X 1024 or higher.
5) No glare, flat screen.
6) Adjustable tilt.
7) Maximum dot pitch: 0.28 mm.
8) 256 user selectable colors for displays.
9) Adjustable brightness and contrast.
l. Software: MSWindows operating system.

B. Ink Jet Printers:
1. Rated color print speed: Minimum two (2) pages per minute.
2. Color graphics resolution: At least 720 x 720 dpi.
3. Minimum input tray capacity: 100 sheets.
4. Minimum output tray capacity: 30 sheets.
5. Capable of printing:
a. Letter size paper.
b. Legal size paper.

C. Communication Cable:
1. As recommended by manufacturer.
2. Standard: NFPA 262.

D. Software:
1. Power management and control software.

E. Retrofit Application Enclosure:
1. NEMA 12 rated for indoor locations.

2. NEMA 3R rated for outdoor locations.
3. Hinged front opening door with padlockable latch.
4. Input/output terminal blocks and wiring.
5. Separate control voltage source disconnect switch and wiring.
6. 600 Volt rated power voltage terminal blocks and wiring.
7. Current transformer shorting terminal blocks and wiring.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install as indicated and in accordance with manufacturer's recommendations and instructions.
   1. Provide all equipment as necessary to provide a compete and functioning system.
   2. Coordinate with the Owner on final computer screen layouts, trending requirements and printouts.

B. Meter Types:
   1. Type A meters: Not used.
   2. Type B meters: .Connected to 480V feeder breakers, unless otherwise indicated on the Drawings.
   3. Type C meters: Connected to 13.8kV breakers and 480V main breakers, unless otherwise indicated on the Drawings

C. Communication Configuration:
   1. Feeder breaker meters shall communicate with its associated main breaker meter.
   2. The main breaker meter shall be connected to the nearest plant control system Ethernet switch.
   3. Configure one (1) of the computers provided by the control system with the power management and control software.
      a. Provide technical assistance to the system integrator as necessary to provide a functioning system.

D. Computer Screen Configuration:
   1. Each Type A, B and C meter shall have a data screen with the following minimum data as applicable for the capabilities of that type of meter:
      a. Voltage line-to-line for each phase and an average.
      b. Voltage line-to-neutral for each phase and an average.
      c. Current for each phase, neutral and average and peak demands.
      d. Kilowatts (kW)for each phase, total, demand and peak demand.
      e. Kilovolt-amperes (kVA) for each phase, total, demand and peak demand.
      f. Kilovolt-amperes reactive (kVAR) for each phase, total, demand and peak demand.
      g. Power factor for each phase and total.
      h. Frequency.
      i. Voltage total harmonic distortion for each phase.
      j. Current total harmonic distortion for each phase.
      k. Energy (kWhr) for each phase and total.
      l. A seven (7) day kW, kVA and kVAR trend average.
      m. Peak demands shall be resetable by the operator.
   2. Meter Types shall have the following 15 minute trending graphs.
      a. Duration: Adjustable, with a seven (7) day default.
      b. Phase A current: Minimum, maximum and average.
      c. Phase B current: Minimum, maximum and average.
      d. Phase C current: Minimum, maximum and average.
      e. Neutral current: Minimum, maximum and average.

f. Phase A Watts: Minimum, maximum and average.
g. Phase B Watts: Minimum, maximum and average.
h. Phase C Watts: Minimum, maximum and average.
i. Watts total.
j. Phase A Voltamps: Minimum, maximum and average.
k. Phase B Voltamps: Minimum, maximum and average.
l. Phase C Voltamps: Minimum, maximum and average.
m. Voltamps total.
n. Phase A power factor: Minimum, maximum and average.
o. Phase B power factor: Minimum, maximum and average.
p. Phase C power factor: Minimum, maximum and average.
q. Power factor total.

3.2 FIELD QUALITY CONTROL

A. Acceptance Testing: See Specification Section 26 08 13.

3.3 TRAINING

A. A qualified factory-trained manufacturer's representative shall provide the Owner with 8 HRS of on-site training in the operation and maintenance of the metering system and its components.

END OF SECTION

SECTION 26 09 16

CONTROL EQUIPMENT ACCESSORIES

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Operator control devices (selector switches, pushbuttons, indicator lights, etc.).
   2. Control devices (timers, relays, contactors, etc.).
   3. Control panels and operator stations.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.
   2. Section 01 25 13 - Product Substitution.
   3. Section 26 05 00 - Electrical: Basic Requirements.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. National Electrical Manufacturers Association (NEMA):
      a. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
      b. ICS 2, Industrial Control and System Controllers, Contactors and Overload Relays Rated 600 Volts.
   2. Underwriters Laboratories, Inc. (UL):
      a. 508, Standard for Safety Industrial Control Equipment.
      b. 508A, Standard for Safety Industrial Control Panels.

B. Miscellaneous:
   1. Supplier of Industrial Control Panels shall build control panel under the provisions of UL 508A.
      a. Entire assembly shall be affixed with a UL 508A label "Listed Enclosed Industrial Control Panel" prior to shipment to the jobsite.

1.3 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
   2. Product technical data:
      a. Provide submittal data for all products specified in PART 2 of this Specification:
      b. Control panel bill of material.
      c. See Specification Section 26 05 00 for additional requirements.
   3. Fabrication and/or layout drawings.
      a. Control panel interior and exterior layout.
      b. Control panel wiring diagrams.

B. Operation and Maintenance Manuals:
   1. See Specification Section 26 05 00 for requirements for:
      a. The mechanics and administration of submittal process.
      b. The content of Operation and Maintenance Manuals.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following manufacturers are acceptable:
   1. Pilot devices and relays:
      a. Idec.
      b. Potter & Brumsfield.
      c. Time Mark.
      d. ATC Diversified Electronics.
   2. Contactors:
      a. Automatic Switch Company (ASCO).
      b. Cutler-Hammer.
      c. General Electric Company.
      d. Square D Company.
      e. Siemens.
      f. Allen Bradley.
   3. Photocells and time clocks:
      a. Grasslin.
      b. Tork.
      c. Intermatic.
      d. Paragon.
   4. Alarm devices:
      a. Edwards Signaling.
      b. Federal Signal Corp.
   5. Terminal blocks:
      a. Phoenix Contact.
      b. Allen-Bradley.
   6. Enclosures:
      a. Hoffman Engineering Co.
      b. Wiegmann.
      c. B-Line Circle AW.
      d. Adalet.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 PILOT DEVICES

A. General Requirements:
   1. Standards: NEMA ICS 2, UL 508.
   2. Heavy-duty NEMA 4/13 watertight/oiltight.
   3. Heavy-duty NEMA 4/4X corrosion resistant.
   4. Heavy-duty factory sealed, explosion-proof and dust ignition-proof (Class I and II).
   5. Mounting hole: 30.5 mm.
   6. Contact blocks: 10 amp, NEMA A600 rated, number as required to fulfill functions shown or specified.
   7. Legend plate marked as indicated on Drawings or specified.

B. Selector Switches:
   1. Two, three- or four-position rotary switch as required to fulfill functions shown or specified.
   2. Maintained contact type.
   3. Knob or lever type operators.

C. Pushbuttons:

1. Non-illuminated type:
    a. Protective boot.
    b. Momentary contact.
    c. Standard flush and mushroom operators.
    d. Emergency stop pushbuttons: Mushroom head operator and maintained contact.
2. Illuminating type:
    a. Protective boot.
    b. Momentary contact.
    c. Standard flush operator.
    d. Serves as both pushbutton control and indicating light.
    e. Resistor-type full voltage light unit with lens and panel gasket.

D. Indicating Lights:
1. Allowing replacement of bulb without removal from control panel.
2. Lamp: LED, 120 V or 24 V as required.
3. Full voltage type.
4. Push-to-test indicating lights.
5. Glass lens.
6. Color code lights as follows:
    a. Green: OFF or stopped.
    b. Amber: Standby; auto mode; ready.
    c. Red: ON or running.

2.3 RELAYS

A. General Requirements:
1. Standards: NEMA ICS 2, UL 508.

B. Control Relays:
1. General purpose (ice cube) type:
    a. Plug-in housing.
    b. Clear polycarbonate dust cover with clip fastener.
    c. Coil voltage: 120 Vac or as required.
    d. Contacts:
        1) 10 amp continuous.
        2) Silver cadmium oxide.
        3) Minimum of 3 SPDT contacts.
    e. Sockets: DIN rail mounted.
    f. Internal neon or LED indicator is lit when coil is energized.
    g. Manual operator switch.
2. Industrial type:
    a. Coil voltage: 120 Vac or as required.
    b. Contacts:
        1) 10 amp, NEMA A600 rated.
        2) Double break, silver alloy.
        3) Convertible from normally open to normally closed or vice versa, without removing any wiring.
        4) Expandable from 2 poles to 12 poles.
    c. Provide contacts for all required control plus two spares.

C. Time Delay Relays:
1. General purpose type:
    a. Timing modes: On and Off delay, interval, one shot and repeat cycle.
    b. Plug-in housing.

c. Polycarbonate dust cover with clip fastener.
d. Coil voltage: 120 Vac or as required.
e. Contacts:
    1) 10 amp continuous.
    2) Silver cadmium oxide.
    3) Two normally open and two normally closed DPDT contacts.
f. Sockets: DIN rail mounted.
g. External timing adjustment knob.
h. Timing ranges: 0.05 seconds to 16.65 HRS.
i. Repeat accuracy: +1 percent.

2. Solid State industrial type:
    a. Timing modes: On and Off delay and repeat cycle.
    b. Industrial housing.
    c. Coil voltage: 120 Vac or as required.
    d. Contacts:
        1) 5 amp, NEMA B150 rated.
        2) Silver alloy.
        3) Convertible On Delay and Off Delay contacts.
        4) One normally open and one normally closed timed contacts.
        5) One normally open and one normally closed instantaneous contacts.
    e. Furnish with "on" and "timing out" indicators.
    f. External timing adjustment knob.
    g. Timing ranges: 0.05 seconds to 10 HRS.
    h. Repeat accuracy: +1 percent.
3. Mechanical industrial type:
    a. Timing modes: On and Off delay.
    b. Coil voltage: 120 Vac or as required.
    c. Contacts:
        1) 10 amp, NEMA A600 rated.
        2) Double break, silver alloy.
        3) Convertible On Delay and Off Delay contacts.
        4) Convertible normally open and normally closed timed contacts.
        5) Convertible normally open instantaneous contacts.
    d. External timing adjustment knob.
    e. Timing ranges: 0.2 - 60 sec or 5 - 180 sec.
    f. Repeat accuracy: Greater than +10 percent.

2.4 CONTACTORS

A. General Requirements:
    1. Standards: NEMA ICS 2, UL 508.

B. Lighting and Remote Control Switches:
    1. Electrically operated, electrically held.{Electrically operated, mechanically held.}
    2. Coil voltage: 120 Vac or as required.
    3. Contacts: Totally enclosed, double-break silver-cadmium-oxide.
    4. Rated for ballasted lighting, tungsten and general use loads.
    5. Number of poles, continuous ampere rating and voltage, as indicated on Drawings or as specified.
    6. Auxiliary control relays, as indicated on Drawings or as specified.
    7. Auxiliary contacts, as indicated on Drawings or as specified.

C. Definite Purpose:
    1. Coil voltage: 120 Vac or as required.

2. Contacts: Totally enclosed, double-break silver-cadmium-oxide.
3. Resistive load and horsepower rated.
4. Number of poles, continuous ampere rating and voltage, as indicated on Drawings or as specified.
5. Auxiliary contacts, as indicated on Drawings or as specified.

2.5 PHOTOCELLS AND TIME CLOCKS

A. Photocells:
   1. Weatherproof enclosure.
   2. Adjustable turn-on range, initially set at 1.0 footcandles.
      a. Turn-off level approximately three times turn-on.
   3. Provide time delay device to eliminate nuisance switching.
   4. Voltage, amperage and/or wattage ratings as required for the application.

B. General Requirements for Time Clocks:
   1. Separate manual on-off operation without disturbing automatic settings.
   2. Enclosure:
      a. NEMA 1 for indoor locations.
      b. Stand alone or DIN rail for mounting in control panel.
      c. NEMA 3R or 4 for exterior locations.
   3. Voltage, amperage and/or wattage ratings as required for the application.

C. Electromechanical:
   1. 24 HR dial powered by a self-starting synchronous motor.
   2. Minimum of 16 HR carryover power utilizing a spring-driven reserve with automatic rewind or rechargeable battery.
   3. Minimum of 12 pairs of on-off trippers and a skip-a-day device.

D. Electromechanical:
   1. Seven (7) day dial powered by a self-starting synchronous motor.
   2. Minimum of 24 HR carryover power utilizing a spring-driven reserve with automatic rewind or rechargeable battery.
   3. Minimum of one (1) pair of on-off trippers per day.

E. Electronic:
   1. 24 HR and seven (7) day programmable using solid state technology.
   2. Minimum of 72 HR carryover power utilizing rechargeable battery or capacitor.
   3. Minimum of seven (7) on and seven (7) off set points.

F. Electronic:
   1. 365 day programmable using solid state technology with block programming.
   2. Minimum of 72 HR carryover power utilizing rechargeable battery or capacitor.
   3. Minimum of 48 events per week, 16 individual holiday overrides, daylight savings or standard time selectable, automatic leap year correction.

G. Astronomical Clocks:
   1. Adjustable for the installed latitude.
      a. Settings for astro on/astro off, astro on/time off or time on/astro off.
   2. 365 day programmable using solid state technology with block programming.
   3. Minimum of 72 HR carryover power utilizing rechargeable battery or capacitor.
   4. Minimum of 48 events per week, 16 individual holiday overrides daylight savings or standard time selectable, automatic leap year correction.

2.6 ALARM DEVICES

A. Alarm Horns:

1. Vibrating horn type.
2. PLC compatible as required.
3. Heavy-duty die cast housing with corrosion resistant finish.
4. Adjustable volume: 78 to 103 dB at 10 FT.
5. Voltage: 120 Vac or as required.
6. Enclosures/mountings:
   a. Flush wall or panel mounting in dry areas.
   b. NEMA 4X panel mounting in wet areas.
   c. Surface mounting in dry areas.
   d. NEMA 4X surface mounting in wet areas.
   e. NEMA 4X, hazardous location surface mounting in wet and hazardous areas.
      1) Fixed volume: 97 dB at 10 FT.

B. Alarm Lights:
1. Panel mounted:
   a. Strobe type.
   b. Shatter resistant polycarbonate lens and base.
   c. Lens color as indicated on Drawings.
   d. NEMA 4X enclosure.
   e. PLC compatible.
   f. Voltage: 120 Vac.
2. Wall mounted:
   a. Heavy-duty strobe type.
   b. Weatherproof shatter resistant polycarbonate lens and cast base.
   c. Optically designed fresnel lens with color as indicated on Drawings.
   d. Immune to shock and vibration, no moving parts.
   e. Xenon flash tube providing a minimum of 65 single flashes per minute.
   f. Mounting: Wall or corner wall brackets.
3. Hazardous and corrosive locations:
   a. Heavy-duty strobe type.
   b. Weatherproof and rated for the indicated hazardous location.
   c. Body: Zinc plated cast iron or cast copper free aluminum and/or coated with 20 mils of PVC.
   d. High impact glass dome with guard.
   e. Shatter resistant polycarbonate lens with color as indicated on Drawings.
   f. Immune to shock and vibration, no moving parts.
   g. Xenon flash tube providing a minimum of 65 single flashes per minute.
   h. Mounting: Wall bracket or pendant.

2.7 MISCELLANEOUS DEVICES

A. Run Time Meters:
1. Six-digit wheels including a 1/10 digit.
2. Non-reset type.
3. Time range in hours.
4. Automatic recycle at zero.
5. Accuracy: 1 percent.
6. Sealed against dirt and moisture.
7. Tamperproof.

2.8 TERMINATION EQUIPMENT

A. General Requirements:
1. Modular type with screw compression clamp.

2. Screws: Stainless steel.
3. Current bar: Nickel-plated copper alloy.
4. Thermoplastic insulation rated for -40 to +90 DegC.
5. Wire insertion area: Funnel-shaped to guide all conductor strands into terminal.
6. End sections and end stops at each end of terminal strip.
7. Machine-printed terminal markers on both sides of block.
8. Spacing: 6 mm.
9. Wire size: 22-12 AWG.
10. Rated voltage: 600 V.
11. DIN rail mounting.

B. Standard-type block:
   1. Rated current: 30 A.
   2. Color: Gray body.

C. Bladed-type disconnect block:
   1. Terminal block with knife blade disconnect which connects or isolated the two sides of the block.
   2. Rated current: 10 A.
   3. Color:
      a. Panel control voltage leaves enclosure - normal: Gray body, orange switch.
      b. Foreign voltage entering enclosure: Orange body, orange switch.

D. Grounded-type block:
   1. Electrically grounded to mounting rail.
   2. Terminal ground wires and analog cable shields.
   3. Color: Green and yellow body.

E. Fuse Holders:
   1. Blocks can be ganged for multi-pole operation.
   2. Spacing: 9.1 mm.
   3. Wire size: 30-12 AWG.
   4. Rated voltage: 300 V.
   5. Rated current: 12 A.
   6. Fuse size: 1/4 x 1-1/4.
   7. Blown fuse indication.
   8. DIN rail mounting.

2.9 ENCLOSURES

A. Control Panels:
   1. NEMA 4 rated:
      a. Seams continuously welded and ground smooth.
      b. No knockouts.
      c. External mounting flanges.
      d. Hinged or non-hinged cover held closed with stainless steel screws and clamps.
      e. Cover with oil resistant gasket.
   2. NEMA 4X rated:
      a. Body and cover: 14 GA Type 304 or 316 stainless steel.
      b. Seams continuously welded and ground smooth.
      c. No knockouts.
      d. External mounting flanges.
      e. Hinged door and stainless steel screws and clamps.
      f. Door with oil-resistant gasket.
   3. NEMA 7 and 9 rated:

a. Cast gray iron alloy or copper-free aluminum.
b. Drilled and tapped openings or tapered threaded hub.
c. Cover bolted-down with stainless steel bolts or threaded cover with neoprene gasket.
d. External mounting flanges.
e. Grounding lug.
f. Accessories: 40 mil PVC exterior coating and 2 mil urethane interior coating.

4. NEMA 12 enclosure:
   a. Body and cover: 14 GA steel finished with rust inhibiting primer and manufacturers standard paint inside and out.
   b. No knockouts.
   c. External mounting flanges.
   d. Non-hinged stainless steel cover held closed with captivated cover screws threaded into sealed wells or hinged cover held closed with stainless steel screws and clamps.
   e. Flat door with oil resistant gasket.
5. Control panel miscellaneous accessories:
   a. Back plane mounting panels: Steel with white enamel finish or Type 304 stainless steel.
   b. Interiors shall be white or light gray in color.
   c. Wire management duct:
      1) Bodies: PVC with side holes.
      2) Cover: PVC snap-on.
      3) Size as required.
   d. Rigid handles for covers larger than 9 SF or heavier than 25 LBS.
   e. Split covers when heavier than 25 LBS.
   f. Floor stand kits made of same material as the enclosure.
   g. Weldnuts for mounting optional panels and terminal kits.
   h. Ground bonding jumper from door, across hinge, to enclosure body.
6. Standards: NEMA 250, UL 508.

B. Operator Control Stations:
1. NEMA 4/13 rated:
   a. Die cast aluminum body with manufacturers standard finish.
   b. Gasketed die cast aluminum cover with manufacturers standard finish.
   c. Number of device mounting holes as required.
2. NEMA 4X rated:
   a. Type 304 or 316 stainless steel body.
   b. Gasketed Type 304 or 316 stainless steel cover.
   c. Number of device mounting holes as required.
3. NEMA 7 and 9 rated:
   a. Zinc plated cast iron or die-cast copper free aluminum, with threaded hubs, grounding screw and with manufacturers standard finish.
   b. "EDS" or "EFS" style.
   c. Single or multiple gang or tandem.
   d. Accessories: 40 mil PVC exterior coating and two (2) mil urethane interior coating.

2.10 MAINTENANCE MATERIALS

A. Provide 100 percent replacement lamps for indicating lights.

B. Provide 10 percent replacement caps for indicating lights.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install as indicated and in accordance with manufacturer's recommendations and instructions.

B. Control Panels:
1. Size as required to mount the equipment.
2. Permitted uses of NEMA 4 enclosure:
   a. Surface mounted in areas designated as wet.
3. Permitted uses of NEMA 4X enclosure:
   a. Surface mounted in areas designated as wet and/or corrosive or highly corrosive.
4. Permitted uses of NEMA 7 enclosure:
   a. Surface mounted in areas designated as Class I hazardous.
5. Permitted uses of NEMA 12 enclosure:
   a. Surface mounted in areas designated as dry and/or dusty architecturally or non-architecturally finished areas.

C. Operator Control Stations:
1. Permitted uses of NEMA 4/13 enclosure:
   a. Surface mounted in areas designated as dry and/or dusty architecturally or non-architecturally finished areas and wet.
2. Permitted uses of NEMA 4X enclosure:
   a. Surface mounted in areas designated as wet and/or corrosive or highly corrosive.
3. Permitted uses of NEMA 7 enclosure:
   a. Surface mounted in areas designated as Class I hazardous with PVC coating in corrosive and highly corrosive areas when PVC coated conduit is used.

3.2 FIELD QUALITY CONTROL

A. See Specification Section 26 05 00.

END OF SECTION

SECTION 26 12 19
DISTRIBUTION TRANSFORMERS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Distribution pad-mounted transformers.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.
   2. Section 01 25 13 - Product Substitution.
   3. Section 26 05 00 - Electrical: Basic Requirements.
   4. Section 26 08 13 - Acceptance Testing.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. American National Standards Institute (ANSI).
   2. Institute of Electronic and Electronics Engineers, Inc. (IEEE):
      a. 386, Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V.
      b. C57.12.00, Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.
      c. C57.12.34, Standard Requirements for Pad-Mounted, Compartmental-Type, Self-Cooled, Three-Phase Distribution Transformers (2500 kVa and Smaller) - High-Voltage: 34 500 GrdY/19 920 Volts and Below; Low-Voltage: 480 Volts and Below.
      d. C57.12.70, Standard Terminal Markings and Connections for Distribution and Power Transformers.
      e. C57.12.80, Standard Terminology for Power and Distribution Transformers.
      f. C57.12.90, Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers.
      g. C62.11, Standard for Metal-Oxide Surge Arresters for Alternating Current Power Circuits (>1 kV).
   3. National Electrical Manufacturers Association (NEMA).

1.3 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
   2. Product technical data:
      a. Provide submittal data for all products specified in PART 2 of this Specification Section.
      b. See Specification Section 26 05 00 for additional requirements.
   3. Fabrication and/or layout drawings.
      a. Nameplate drawing.
   4. Test reports:
      a. Factory tests.

B. Operation and Maintenance Manuals:
   1. See Specification Section 26 05 00 for requirements for:
      a. The mechanics and administration of the submittal process.

b. The content of Operation and Maintenance Manuals.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following manufacturers are acceptable:
1. ABB.
2. Cooper Power Systems.
3. General Electric Company.
4. Square D Company.
5. Cutler Hammer.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 THREE-PHASE TRANSFORMER

A. General:
1. Transformer to be designed and constructed in accordance with:
    a. IEEE C57.12.00, IEEE C57.12.34, IEEE C57.12.70, IEEE C57.12.80.

B. Ratings:
1. Type: Outdoor, pad-mounted, liquid-immersed, self-cooled, compartmental type.
2. Operation and application: Step-down operation.
3. Configuration:
    a. Dead-front, loop-feed primary.
4. Voltage and kVA Ratings: As specified on the Drawings.
5. Number of phases: Three (3).
6. Frequency: 60 Hz.
7. Polarity: ANSI standard.
8. Percent impedance: ANSI standard.
9. Basic impulse level (BIL): As indicated on the plans.
10. Temperature rise: 65 DegC.
11. Connections:
    a. Delta or Wye: As indicated on the Drawings.
    b. Primary: {200 ampere bushing wells and insert for loadbreak elbows.}{600 ampere one-piece bushing/well for deadbreak elbows.}
    c. Secondary:
        1) Less than 750 kVA: Six-hole, spade-type minimum or as required.
        2) 750 kVA and greater: 12-hole, spade-type minimum or as required.
12. Tap-changer: De-energized type on H-winding, five (5) total with:
    a. Two (2)2.5 percent above and two (2) 2.5 percent below nominal tap.
13. Sectionalizing oil immersed load break primary switch:
    a. Two (2) position, with the switch positions labeled:
        1) "XFMR OPEN" when the coil is de-energized.
        2) "XFMR CLOSED" when the coil is energized.
    b. Four (4) position, 'V' blade, with the switch positions labeled:
        1) "SOURCE A" (Loop is open and the coil is energized by Source A).
        2) "SOURCE B" (Loop is open and the coil is energized by Source B).
        3) "SOURCE A & B" (Loop is closed and the coil is energized by both sources).
        4) "LOOP & XFMR OPEN" (Loop is open and the coil is de-energized).
    c. Four (4) position, 'T' blade, with the switch positions labeled:
        1) "SOURCE A" (Loop is open and the coil is energized by Source A).

2) "SOURCE B" (Loop is open and the coil is energized by Source B).
3) "SOURCE A & B" (Loop is closed and the coil is energized by both sources).
4) "LOOP CLOSED & XFMR OPEN" (Loop is closed and the coil is de-energized).

C. Components:
1. Windings: Aluminum or copper.
2. Tank:
   a. Sealed-tank construction with welded main cover and bolted tamper-resistant handhole.
   b. Steel divider between high-voltage and low-voltage compartments.
   c. No exposed screws, bolts, or other fastening devices that are externally removable.
   d. No openings through which foreign objects such as sticks, rods, or wires may contact live parts.
   e. 24 IN deep cabinet (minimum)
   f. 1 IN upper fill plug.
   g. 1 IN drain valve with sampling device.
   h. Automatic pressure relief device.
   i. Stainless steel NEMA 2-hole ground pads.
3. Door:
   a. Each compartment will have removable, three-point latching hinged doors equipped for latching in the open position.
   b. The high-voltage compartment door will have a fastening device that is accessible only through the low-voltage compartment.
   c. The hinge assemblies made of corrosion-resistant material.
      1) Provide stainless-steel hinge pins of 3/8 IN minimum diameter.
   d. Both compartment doors capable of securing with a single padlock having a maximum 1/2 IN DIA shackle.
4. Unit protection:
   a. Provide unit protection with a partial-range current limiting fuse on each primary phase (under oil, factory replaceable only).
   b. Provide an expulsion-type, bayonet fuse (under oil, user serviceable) in series with the current limiting fuse.
5. Finish:
   a. Manufacturer's standard corrosion protection system.
   b. Dark "padmount" green.
6. Insulating oil:
   a. Less Flammable liquid.
   b. Permanently affix nameplate to outside of tank stamped "Non PCB".
7. Accessories:
   a. Liquid level indication.
   b. Dial-type thermometer.
   c. Provisions for pressure vacuum gage.
   d. Stainless steel or laser-scribed anodized aluminum nameplate, with date of manufacturer.

2.3 SURGE ARRESTORS

A. Standards: IEEE 386 and IEEE C62.11.

B. MOV gapless elbow type.

C. Elbow Connector:
1. One-piece design, comprised of an insulation layer and outer shield constructed of EPDM rubber.
2. 200A, dead front, load break type with hot stick pulling eye and grounding tab.

D. Voltage Class: As indicated on the Drawings.

E. Arrestor MCOV Rating: As indicated on the Drawings.

2.4 SOURCE QUALITY CONTROL

A. Factory Tests: Test transformers in accordance with IEEE C57.12.90.

2.5 MAINTENANCE MATERIALS

A. Touch-up paint, two (2) separate one (1) quart containers.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install on pad as detailed on the Drawings and in accordance with manufacture's instructions.

B. Transformer locations as shown on the Drawings are intended to be used as a guide.
   1. Field conditions may affect actual transformer location.
   2. Coordinate final location with Owner.

C. Install three-phase transformers on concrete pad per detail on the Drawings.

3.2 FIELD QUALITY CONTROL

A. Acceptance Testing: See Specification Section 26 08 13.

END OF SECTION

SECTION 26 22 13

DRY-TYPE TRANSFORMERS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Dry-type transformers, 1000 kVA and less.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.
   2. Section 01 25 13 - Product Substitution.
   3. Section 26 05 00 - Electrical: Basic Requirements.
   4. Section 26 05 26 - Grounding.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
      a. C57.96, Guide for Loading Dry-Type Distribution and Power Transformers.
   2. National Electrical Manufacturers Association (NEMA):
      a. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
      b. ST 20, Dry-Type Transformers for General Applications.
      c. TP 1, Guide for Determining Energy Efficiency for Distribution Transformers.
   3. Underwriters Laboratories, Inc. (UL):
      a. 506, Standard for Safety Specialty Transformers.
      b. 1561, Standard for Safety Dry-Type General Purpose and Power Transformers.

1.3 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
   2. Product technical data:
      a. Provide submittal data for all products specified in PART 2 of this Specification:
      b. See Specification Section 26 05 00 for additional requirements.
   3. Fabrication and/or layout drawings.
      a. Nameplate drawing.
   4. Certifications:
      a. Sound level certifications.

B. Operation and Maintenance Manuals:
   1. See Specification Section 26 05 00 for:
      a. The mechanics and administration of the submittal process.
      b. The content of Operation and Maintenance Manuals.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following manufacturers are acceptable:

1. Cutler-Hammer.
2. General Electric Company.
3. Square D Company.
4. Siemens.
5. Sola/Hevi-Duty.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 GENERAL PURPOSE DRY-TYPE TRANSFORMERS

A. Ventilated or non-ventilated, air cooled, two (2) winding type.

B. Cores:
1. High grade, non-aging silicon steel with high magnetic permeability, and low hysteresis and eddy current losses.
2. Magnetic flux densities are to be kept well below the saturation point.

C. Coils: Continuous wound with electrical grade aluminum.

D. Ventilated Units:
1. Core and coils assembly impregnated with non-hygroscopic, thermosetting varnish and cured to reduce hot spots and seal out moisture and completely isolated from the enclosure by means of vibration dampening pads.
2. Dripproof, NEMA 1, steel enclosure finished with a weather-resistant enamel and ventilation openings protected from falling dirt.

E. Furnish Taps for Transformers as follows:
1. 1 PH, 2 kVA and below: None.
2. 1 PH, 3 to 25 kVA: Two (2) 5 percent FCBN.
3. 1 PH, 25 kVA and above: Two (2) 2.5 percent FCAN and four (4) 2.5 percent FCBN.
4. 3 PH, 3 to 15 kVA: Two (2) 5 percent FCBN.
5. 3 PH, 15 kVA and above: Two (2) 2.5 percent FCAN and four (4) 2.5 percent FCBN.

F. Sound Levels:
1. Manufacturer shall guarantee not to exceed the following:
   a. Up to 9 kVA: 40 dB.
   b. 10 to 50 kVA: 45 dB.
   c. 51 to 150 kVA: 50 dB.
   d. 151 to 300 kVA: 55 dB.

G. Efficiency:
1. Ventilated, 15 kVA and larger: Energy efficient meeting NEMA TP 1 requirements.

H. Insulating Material (600 V and below):
1. 3 to 15 kVA units: 185 DegC insulation system with a 115 DegC rise.
2. 15 kVA and above units: 220 DegC insulation system with a 150 DegC rise.

I. Ratings: 60 Hz, voltage, KVA and phase, as indicated on the Drawings.

J. Finish: Rust inhibited primer and manufacturers standard paint inside and out.

K. Standards: IEEE C57.96, NEMA ST 20, NEMA TP 1, UL 506, UL 1561.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install products in accordance with manufacturer's instructions.

B. Indoor Locations:
   1. Provide ventilated type for 15 kVA units and above.
   2. Provide non-ventilated type for 9 kVA units and below and were indicated on the Drawings.
   3. Mount 9 kVA units and below on wall.
   4. Mount 15 kVA units and above on chamfered 4 IN high concrete housekeeping pad or from wall and/or ceiling, at 7 FT above finished floor, using equipment support brackets per Specification Section 26 05 00.
   5. Provide rubber vibrations isolation pads.

C. Enclosures: Painted steel in all areas except stainless steel in highly corrosive areas.

D. Ground in accordance with Specification Section 26 05 26.

END OF SECTION

SECTION 26 24 16
PANELBOARDS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Lighting and appliance panelboards.
   2. Power distribution panelboards.
   3. Panelboards mounted in Motor Control Centers.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.
   2. Section 01 25 13 - Product Substitution.
   3. Section 26 05 00 - Electrical: Basic Requirements.
   4. Section 26 28 00 - Overcurrent and Short Circuit Protective Devices.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. National Electrical Manufacturers Association (NEMA):
      a. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
      b. PB 1, Panelboards.
   2. National Fire Protection Association (NFPA):
      a. 70, National Electrical Code (NEC).
   3. Underwriters Laboratories, Inc. (UL):
      a. 50, Enclosures for Electrical Equipment, Non-Environmental Considerations.
      b. 67, Standard for Panelboards.

1.3 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
   2. Product technical data.
      a. Provide submittal data for all products specified in PART 2 of this Specification Section.
      b. See Specification Section 26 05 00 for additional requirements.
   3. Fabrication and/or layout drawings:
      a. Panelboard layout with alphanumeric designation, branch circuit breakers size and type, as indicated in the panelboard schedules.

B. Operation and Maintenance Manuals:
   1. See Specification Section 26 05 00 for requirements for:
      a. The mechanics and administration of the submittal process.
      b. The content of Operations and Maintenance Manuals.
   2. Panelboard schedules with as-built conditions.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following manufacturers are acceptable:
   1. Cutler-Hammer.
   2. General Electric Company.
   3. Square D Company.
   4. Siemens.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 MANUFACTURED UNITS

A. Standards: NEMA PB 1, NFPA 70, UL 50, UL 67.

B. Ratings:
   1. Current, voltage, number of phases, number of wires as indicated on the Drawings.
   2. Panelboards rated 240 Vac or less: 10,000 amp minimum short circuit rating or as indicated in the schedule.
   3. Panelboards rated 480 Vac: 14,000 amp minimum short circuit rating or as indicated in the schedule.
   4. Service Entrance Equipment rated when indicated on the Drawings.

C. Construction:
   1. Interiors factory assembled and designed such that switching and protective devices can be replaced without disturbing adjacent units and without removing the main bus connectors.
   2. Multi-section panelboards: Feed-through or sub-feed lugs.
   3. Main lugs: Solderless type approved for copper and aluminum wire.

D. Bus Bars:
   1. Main bus bars:
      a. Plated aluminum or copper sized to limit temperature rise to a maximum of 65 DegC above an ambient of 40 DegC.
      b. Drilled and tapped and arranged for sequence phasing of the branch circuit devices.
   2. Ground bus and isolated ground bus, when indicated on the Drawings: Solderless mechanical type connectors.
   3. Neutral bus bars: Insulated 100 percent rated or 200 percent rated, when indicated on the Drawings and with solderless mechanical type connectors.

E. Enclosure:
   1. Boxes: Code gage galvanized steel, furnish without knockouts.
   2. Trim assembly: Code gage steel finished with rust inhibited primer and manufacturers standard paint inside and out.
   3. Lighting and appliance panelboard:
      a. Trims supplied with hinged door over all circuit breaker handles.
      b. Trims for surface mounted panelboards, same size as box.
      c. Trims for flush mounted panelboards, overlap the box by 3/4 IN on all sides.
      d. Doors lockable with corrosion resistant chrome-plated combination lock and catch, all locks keyed alike.
      e. Nominal 20 IN wide and 5-3/4 IN deep with gutter space in accordance with NFPA 70.
      f. Clear plastic cover for directory card mounted on the inside of each door.
      g. NEMA 3R or NEMA 12 rated: Door gasketed.
   4. Power distribution panelboard:
      a. Trims cover all live parts with switching device handles accessible.

   b. Less than or equal to 12 IN deep with gutter space in accordance with NFPA 70.
   c. Clear plastic cover for directory card mounted front of enclosure.
   d. NEMA 3R or NEMA 12 rated: Doors gasketed and lockable with corrosion resistant chrome-plated combination lock and catch, all locks keyed alike.

F. Overcurrent and Short Circuit Protective Devices:
   1. Main overcurrent protective device:
      a. Molded case circuit breaker.
   2. Branch overcurrent protective devices:
      a. Mounted molded case circuit breaker.
   3. See Specification Section 26 28 00 for overcurrent and short circuit protective device requirements.
   4. Factory installed.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install as indicated on the Drawings, in accordance with the NFPA 70, and in accordance with manufacturer's instructions.

B. Support panelboard enclosures from wall studs or modular channels support structure, per Specification Section 26 05 00.

C. Provide NEMA 1, NEMA 3R or NEMA 12 rated enclosure as indicated on the Drawings.

D. Provide each panelboard with a typed directory:
   1. Identify all circuit locations in each panelboard with the load type and location served.
   2. Mechanical equipment shall be identified by Owner-furnished designation if different than designation indicated on the Drawings.
   3. Room names and numbers shall be final building room names and numbers as identified by the Owner if different than designation indicated on the Drawings.

END OF SECTION

SECTION 26 24 19

MOTOR CONTROL EQUIPMENT

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Motor control centers.
   2. Separately mounted motor starters (including those supplied with equipment).
   3. Manual motor starters.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.
   2. Section 01 25 13 - Product Substitution.
   3. Section 26 05 00 - Electrical: Basic Requirements.
   4. {Section 26 08 13 - Acceptance Testing.}
   5. Section 26 29 23 - Variable Frequency Drives - Low Voltage.
   6. Section 26 28 00 - Overcurrent and Short Circuit Protective Devices.
   7. Section 26 43 13 - Low Voltage Surge Protective Devices (SPD).
   8. Section 26 09 13 - Electrical Metering Devices.
   9. Section 26 09 16 - Control Equipment Accessories.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. International Electrotechnical Commission (IEC).
   2. National Electrical Manufacturers Association (NEMA):
      a. 250, Enclosures for Electrical Equipment (1000 Volt Maximum).
      b. ICS 2, Controllers, Contactors and Overload Relays Rated 600 V.
      c. ICS 3, Medium-Voltage Controllers Rated 2001 to 7200 V AC.
   3. Underwriters Laboratories, Inc. (UL):
      a. 508, Standard for Industrial Control Equipment.
      b. 845, Motor Control Centers.

B. Miscellaneous:
   1. Verify motor horsepower loads, other equipment loads, and controls from approved shop drawings and notify Engineer of any discrepancies.
   2. Verify the required instrumentation and control wiring for a complete system and notify Engineer of any discrepancies.

1.3 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
   2. Product technical data:
      a. Provide submittal data for all products specified in PART 2 of this Specification Section.
      b. See Specification Section 26 05 00 for additional requirements.
   3. Fabrication and/or layout drawings:
      a. Motor control center:

1) Elevation drawing with overall dimensions.
2) Starter and component schedule.
3) Identification of units and their location in the MCC.
4) Location of incoming line terminals.
5) Mounting dimensions.
6) Available conduit entrance areas.
7) Nameplate schedule.
8) Assembly ratings (amps, volts, short circuit, etc.).
9) Unit ladder logic wiring for each unit depicting electrical interlocking and wiring between units (NEMA ICS 3 Class II) and identification of terminals where field devices or remote control signals are to be terminated (NEMA ICS 3 Class II-S) as indicated on the Drawings and/or loop descriptions.

b. Separately mounted combination starters:
   1) Unit ladder logic wiring for each unit depicting electrical wiring and identification of terminals where field devices or remote control signals are to be terminated as indicated on the Drawings and/or loop descriptions.

B. Operation and Maintenance Manuals:
   1. See Specification Section 26 05 00 for requirements for:
      a. The mechanics and administration of the submittal process.
      b. The content of Operation and Maintenance Manuals.
      c. Fabrication and/or layout drawings updated with as-built conditions.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following manufacturers are acceptable:
   1. Allen-Bradley.
   2. Cutler Hammer.
   3. General Electric Company.
   4. Square D Company.
   5. Siemens.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 MOTOR CONTROL CENTERS

A. Ratings:
   1. 600 V class, 3 PH, 60 Hz with operating voltage and number of wires as indicated on the Drawings.
   2. Assembly short circuit current and interrupting device rating as indicated on the Drawings.
   3. Service Entrance Equipment rated when indicated on the Drawings.

B. Construction:
   1. Standards: UL 845.
   2. Totally enclosed, dead front, free standing assemblies, bolted together to form a single assembly.
   3. Fabricate of not less than 14 GA steel with 16 GA steel doors in standardized units.
   4. Nominal size per section: 20 IN wide, 20 or 21 IN deep, and 90 IN high.
   5. Enclosure:
      a. NEMA 1 gasketed.

- b. NEMA 12:
  - 1) Dust-tight and drip-proof.
  - 2) Gasketed material round all doors, door cutouts, cover plates, side, top and back sheets.
  - 3) Gasketed bottom plate.
- c. NEMA 3R non-walk-in:
  - 1) Rainproof and sleet resistant.
  - 2) NEMA 1 gasketed enclosure with an outdoor house erected around it.

6. Horizontal wireways:
   - a. At the top, isolated from the main bus
   - b. At the bottom.
   - c. Easily accessible.
   - d. Full length of the MCC.
7. Vertical wireway:
   - a. Located in each MCC section that accepts plug-in units.
   - b. Connect to top and bottom wireways.
   - c. Isolated from the unit interiors.
   - d. Accessible through a separate hinged door.
   - e. Cable tie supports to hold wiring in place.
8. Unit doors:
   - a. Formed round corners and rolled edges.
   - b. Minimum of two (2) heavy-duty hinges or continuous piano hinge.
   - c. Held closed by means of captive fasteners.
   - d. Fabricate to be a part of the structure and not part of the starter.
9. Unit cubicles:
   - a. Draw-out type for motor starters through NEMA Size 5.
   - b. Guide rails for supporting and aligning starters.
   - c. Operating handle:
     - 1) With the unit stabs engaged and door closed the handle mechanism allows complete ON/OFF control of the unit disconnect and clear indication of the disconnect status.
     - 2) Circuit breaker and MCP operators includes a separate TRIPPED position.
     - 3) Mechanical interlock to prevent the opening of the door when the disconnect is in the ON position with a defeater mechanism.
     - 4) Mechanical interlock to prevent the placement of the disconnect in the ON position with the door open with a defeater mechanism.
     - 5) Non-defeatable interlock to prevent the installation or removal of a unit unless the disconnect is in the OFF position.
     - 6) Padlockable in the OFF position.
   - d. Control panel:
     - 1) Provide control devices (selector switch, indicating devices, etc.) as indicated on the Drawings per Specification Section 26 09 16.
   - e. Control power:
     - 1) Control power transformer:
       - a) 120 V secondary.
       - b) Fused on primary and secondary side.
       - c) Sized for 140 percent of required load.
   - f. Minimum of one (1) full size space unit (12 IN) for any combination magnetic motor starter or starter without overload relay.
   - g. One-half full size space unit (6 IN) for circuit breakers 100 A and less.
   - h. Effectively baffled to isolate any ionized gases which may occur within unit starter.
10. Externally mounted overload relay pushbutton.

11. Assemblies effectively ventilated to allow relocation of starters and other components:
    a. Within the assembly and with the same load.
    b. Without having to compensate for changes in location.
12. Finish: Rust inhibited primer and manufacturer's standard paint inside and out.
13. Provide ample unrestricted space for conduit entry from the bottom.
14. Wiring: NEMA ICS 3 Class II, Type B-D.

C. Buses:
1. Material: Tin-plated copper.
2. Main horizontal bus:
    a. 600 A unless otherwise indicated on the Drawings.
    b. Extend the full-length of the MCC with provisions for splicing additional sections to either end.
3. Vertical buses:
    a. 300 A minimum.
    b. Securely bolted to the horizontal main bus with joint easily accessible for maintenance.
    c. Completely isolated and insulated by means of a barrier.
    d. Extended full length of vertical section to distribute incoming power to each circuit breaker and starter in structure.
        1) Starters NEMA Size 5 and larger and certain other components may be cable connected to the main bus with the approval of the Engineer.
    e. Extend Vertical bus to spaces provided for future equipment.
4. Ground bus:
    a. Extend the full-length of the MCC with provisions for splicing additional sections to either end.
    b. 300 A tin-plated copper.
    c. Solidly grounded to each structure.
    d. Locate near bottom of structure.
    e. Provide for lug connection of equipment ground wires.

D. Overcurrent and Short Circuit Protective Devices:
1. Main device:
    a. Molded case circuit breaker.
    b. Fusible switch.
2. Feeder devices:
    a. Molded case circuit breaker.
    b. Fusible switch.
3. Motor protection with full voltage starters:
    a. Motor circuit protector.
    b. Molded case circuit breaker.
    c. Class RK-1 fuse.
4. Motor protection with reduced voltage starters:
    a. Molded case circuit breaker.
    b. Motor circuit protector.
    c. Class RK-1 fuse.
5. See Specification Section 26 28 00 for overcurrent and short circuit protective device requirements.
6. Factory installed.

E. Motor Starters: See requirements within this Specification Section.

F. Surge Protective Device: Integrally mounted, see Specification Section 26 43 13.

G. Power Monitor Metering:

1. Separate compartment.
2. See Specification Section 26 09 13 for meter requirements.

H. Miscellaneous:
   1. See Drawings for items provided by other but factory installed (e.g., submersible motor temperature/leak controller, control system gateways or switches).

2.3 SEPARATELY MOUNTED COMBINATION STARTERS

A. Standards:
   1. NEMA 250, NEMA ICS 2.
   2. UL 508.

B. Enclosure:
   1. NEMA 4 rated:
      a. Body and cover: Sheet steel finished with rust inhibiting primer and manufacturer's standard paint inside and out.
      b. No knockouts, external mounting flanges, hinged and gasketed door.
   2. NEMA 4X rated:
      a. Body and cover: Type 304 or 316 stainless steel.
      b. No knockouts, external mounting flanges, hinged and gasketed door.
   3. NEMA 7 and NEMA 9 rated:
      a. Cast gray iron alloy or copper-free aluminum with manufacturer's standard finish.
      b. Drilled and tapped openings or tapered threaded hub.
      c. Gasketed cover bolted-down with stainless steel bolts.
      d. External mounting flanges.
      e. Front operating handle padlockable in the OFF position.
      f. Accessories: 40 mil PVC exterior coating.
   4. NEMA 12 rated:
      a. Body and cover: Sheet steel finished with rust inhibiting primer and manufacturer's standard paint inside and out.
      b. No knockouts, external mounting flanges, hinged and gasketed door.

C. Operating Handle:
   1. With the door closed the handle mechanism allows complete ON/OFF control of the unit disconnect and clear indication of the disconnect status.
   2. Circuit breaker and MCP operators includes a separate TRIPPED position.
   3. Mechanical interlock to prevent to prevent the opening of the door when the disconnect is in the ON position with a defeater mechanism for use by authorized personnel.
   4. Mechanical interlock to prevent the placement of the disconnect in the ON position with the door open with a defeater mechanism for use by authorized personnel.
   5. Padlockable in the OFF position.
   6. Exceptions: NEMA 7 and NEMA 9 enclosures.

D. External mounted overload relay pushbutton.

E. Control Devices:
   1. Provide control devices as indicated on the Drawings per Specification Section 26 09 16.
   2. Devices will be accessible with the door closed.

F. Control Power Transformer:
   1. 120V secondary.
   2. Fused on primary and secondary side.
   3. Sized for 140 percent of required load.

G. Fault Current Withstand Rating: Equal to the rating of the electrical gear from which it is fed.

H. Motor Starters: See requirements within this Specification Section.

I. Disconnect Switch, Overcurrent and Short Circuit Protective Devices:
   1. Motor circuit protector.
   2. See Specification Section 26 28 00 for overcurrent and short circuit protective device requirements.
   3. Factory installed.

2.4 MOTOR STARTERS

A. Standards:
   1. NEMA ICS 2.
   2. UL 508.

B. Full Voltage Non-Reversing (FVNR) Magnetic Starters:
   1. NEMA full size rated contactor.
      a. NEMA half sizes and IEC contactors are not permitted.
   2. Double-break silver alloy contacts.
   3. Overload relays:
      a. Ambient compensated, bimetallic type with interchangeable heaters, 24 percent adjustability, single phase sensitivity, an isolated arm contact and manual reset.
   4. Interlock and auxiliary contacts, wired to terminal blocks:
      a. Holding circuit contact, normally open.
      b. Overload alarm contact, normally open.
      c. Normally open auxiliary contact, for remote run status.
      d. Additional field replaceable auxiliary contacts as required per the Sequence of Operation.
      e. Two (2) additional normally open spare field replaceable auxiliary contacts.

C. Full Voltage Reversing (FVR) Magnetic Starters:
   1. Two (2) FVNR starters with one (1) overload relay assembled together.
   2. Mechanically and electrically interlocked to prevent line shorts and the energizing of both contactors simultaneously.
   3. See FVNR paragraph for additional requirements.

D. Full Voltage Two-Speed (FV2S) Magnetic Starters:
   1. Two (2) FVNR starters with two (2) overload relays assembled together.
   2. Configured for two (2) winding or one (1) winding consequent pole motors.
   3. See FVNR paragraph for additional requirements.

E. Reduced Voltage Autotransformer (RVAT) Starter:
   1. Closed transition design using three (3) contactors and two (2) or three (3) autotransformers.
   2. Transformer taps: 50, 65 and 80 percent, factory set at 65 percent.
   3. NEMA full size rated contactor.
      a. NEMA half sizes and IEC contactors are not permitted.
   4. Double-break silver alloy contacts.
   5. Overload relays:
      a. Ambient compensated, bimetallic type with interchangeable heaters, 24 percent adjustability, single phase sensitivity, an isolated arm contact and manual reset.
      b. Ambient insensitive, adjustable solid state type with phase loss protection, phase imbalance protection and manual reset.
   6. Interlock and auxiliary contacts, wired to terminal blocks:
      a. Holding circuit contact, normally open.
      b. Overload alarm contact, normally open.
      c. Normally open auxiliary contact, for remote run status.

d. Additional field replaceable auxiliary contacts as required per the Sequence of Operation.
e. Two (2) additional normally open spare field replaceable auxiliary contacts.

F. Variable Frequency Drives: See Specification Section 26 29 23.

2.5 MANUAL MOTOR STARTERS

A. Standards:
1. NEMA 250, NEMA ICS 2.
2. UL 508.

B. Quick-make, quick-break toggle mechanism that is lockable in the OFF position.

C. Types:
1. Horsepower rated, for ON/OFF control.
2. Horsepower rated, for ON/OFF control and thermal overload protection.
a. Switch to clearly indicate ON, OFF, and TRIPPED position.

D. Voltage and current ratings and number of poles as required for the connected motor.

E. Enclosures:
1. NEMA 1 rated:
a. Galvanized steel or steel finished with rust inhibiting primer and manufacturer's standard paint inside and out.
b. With or without concentric knockouts.
2. NEMA 4 rated:
a. Sheet steel finished with rust inhibiting primer and manufacturer's standard paint inside and out or cast gray iron alloy or copper-free aluminum with manufacturer's standard finish.
b. No knockouts, external mounting flanges.
3. NEMA 4X rated:
a. Type 304 or 316 stainless steel.
b. No knockouts, external mounting flanges.
4. NEMA 7 and NEMA 9 rated:
a. Cast gray iron alloy or copper-free aluminum with manufacturer's standard finish.
b. Drilled and tapped openings or tapered threaded hub, external mounting flanges.
c. Accessories: 40 mil PVC exterior coating.
5. NEMA 12 rated:
a. Body and cover: Sheet steel finished with rust inhibiting primer and manufacturer's standard paint inside and out.
b. No knockouts, external mounting flanges.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install as indicated on the Drawings and in accordance with manufacturer's recommendations and instructions.

B. Mounting height for surface mounted equipment: See Specification Section 26 05 00.

C. Mount MCC on 4 IN high concrete pad:
1. Install two (2) 4 IN wide channel sills flush in pads to support and maintain alignment of the MCC.

2. Align front of MCC with top edge of pad chamfer.

D. Overload Heaters:
   1. Size for actual motor full load current of the connected motor.
   2. For motors with power factor correction capacitors, size to compensate for the capacitors effect on load current.

E. Combination and Manual Starter Enclosures:
   1. Permitted uses of NEMA 1 enclosure:
      a. Surface or flush mounted in architecturally finished areas.
      b. Surface mounted above 10 FT in areas designated as dry in architecturally and non-architecturally finished areas.
   2. Permitted uses of NEMA 4 enclosure:
      a. Surface mounted in areas designated as wet.
   3. Permitted uses of NEMA 4X enclosure:
      a. Surface mounted in areas designated as wet and/or corrosive.
   4. Permitted uses of NEMA 7 enclosure:
      a. Surface mounted in areas designated as Class I hazardous.
      b. Provide PVC coating in corrosive and highly corrosive areas when PVC coated conduit is used.
   5. Permitted uses of NEMA 9 enclosure:
      a. Surface mounted in areas designated as Class II hazardous.
      b. Provide PVC coating in corrosive and highly corrosive areas when PVC coated conduit is used.
   6. Permitted uses of NEMA 12 enclosure:
      a. Surface mounted in areas designated as dry.

3.2 FIELD QUALITY CONTROL

A. {Acceptance Testing: See Specification Section 26 08 13.}{Test the ground fault protection system as indicated in Specification Section 26 28 00.}

END OF SECTION

SECTION 26 27 26
WIRING DEVICES

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Material and installation requirements for:
      a. Light switches.
      b. Receptacles.
      c. Device wallplates and coverplates.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.
   2. Section 01 25 13 - Product Substitution.
   3. Section 26 05 00 - Electrical: Basic Requirements.
   4. Section 26 05 33 - Raceways and Boxes.
   5. Section 26 24 19 - Motor Control Equipment.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. National Electrical Manufacturers Association (NEMA):
      a. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
      b. WD 1, General Color Requirements for Wiring Devices.
      c. WD 6, Wiring Devices - Dimensional Requirements.
   2. Underwriters Laboratories, Inc. (UL):
      a. 20, General-Use Snap Switches.
      b. 498, Standard for Attachment Plugs and Receptacles.
      c. 514A, Metallic Outlet Boxes.
      d. 894, Standard for Switches for Use in Hazardous (Classified) Locations.
      e. 943, Ground-Fault Circuit-Interrupters.
      f. 1010, Standard for Receptacle-Plug Combinations for Use in Hazardous (Classified) Locations.

1.3 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
   2. Product technical data:
      a. Provide submittal data for all products specified in PART 2 of this Specification Section.
      b. See Specification Section 26 05 00 for additional requirements.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following manufacturers are acceptable:
   1. Light switches and receptacles:

a. Bryant.
b. Cooper Wiring Devices.
c. Hubbell.
d. Leviton.
e. Pass & Seymour.
f. Crouse-Hinds.
g. Appleton Electric Co.
h. Killark.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 LIGHT SWITCHES

A. General requirements unless modified in specific requirements paragraph of switches per designated areas or types:
1. Toggle type, quiet action, Industrial Specification Grade.
2. Self grounding with grounding terminal.
3. Back and side wired.
4. Solid silver cadmium oxide contacts.
5. Rugged urea housing and one-piece switch arm.
6. Current and voltage rated as required.
7. Switch handle color: As indicated on the plans.
8. Types as indicated on the Drawings:
   a. Single-pole.
   b. Double-pole.
   c. 3-way.
   d. 4-way.
9. Standards: UL 20, UL 514A, NEMA WD 6.

B. Architecturally Finished Areas:
1. Wallplate:
   a. High impact thermoplastic or nylon.
   b. Single or multiple gang as required.

C. Dry Non-architecturally Finished Areas:
1. Coverplate:
   a. Zinc plated malleable iron or galvanized steel.
   b. Single or multiple gang as required.

D. Wet Non-architecturally Finished Areas:
1. Coverplate:
   a. Gasketed zinc plated malleable iron or aluminum with stainless steel screws utilizing rocker, front mounted toggle or pull type switch.
   b. Single or multiple gang as required.

E. Corrosive Areas:
1. Corrosion resistant nickel plated metal parts.
2. Coverplate:
   a. Gasketed zinc plated malleable iron or copper free aluminum with stainless steel screws utilizing rocker, front mounted toggle or pull type switch.
   b. Single or multiple gang as required.

F. Highly Corrosive Areas:
1. Corrosion resistant nickel plated metal parts.
2. Coverplate:
   a. PVC-RGS conduit system:

1) PVC coated zinc plated malleable iron or copper free aluminum with stainless steel screws utilizing rocker, front mounted toggle or pull type switch.
2) Single or multiple gang as required.

b. PVC conduit system:
1) Gray colored high impact thermoplastic.
2) Single or multiple gang as required.

G. Hazardous Areas:
1. Rated for Class I, Division 1 and 2, Groups B, C, and D; and Class II, Division 1 and 2 areas, Groups E, F, and G.
2. Switch enclosed in separate sealing chamber.
   a. Sealing chamber has prewired factory sealed pigtail leads.
3. Coverplate:
   a. Zinc plated malleable iron or copper free aluminum with stainless steel screws utilizing rocker or front mounted toggle type switch.
   b. Single or multiple gang as required.
4. Standards: UL 894.

2.3 RECEPTACLES

A. General requirements unless modified in specific requirements paragraph of receptacles per designated areas:
1. Straight blade, Industrial Specification Grade.
2. Brass triple wipe line contacts.
3. One-piece grounding system with double wipe brass grounding contacts and self grounding strap.
4. Back and side wired.
5. Current and voltage rated as required.
6. High impact nylon body.
7. Receptacle body color:
   a. Normal power: As indicated on the plans.
   b. Generator or UPS power: Red.
8. Types as indicated on the Drawings:
   a. Normal: Self grounding with grounding terminal.
   b. Ground fault circuit interrupter: Feed-through type with test and reset buttons.
9. Duplex or simplex as indicated on the Drawings.
10. Configuration: NEMA 5-20R.
11. Standards: UL 498, UL 514A, UL 943, NEMA WD 1, NEMA WD 6.

B. Architecturally Finished Areas:
1. Wallplate: high impact thermoplastic or nylon.

C. Dry Non-architecturally Finished Areas:
1. Coverplate:
   a. Zinc plated malleable iron or galvanized steel.
   b. Single or multiple gang as required.

D. Wet Non-architecturally Finished Areas:
1. Coverplate: Weatherproof (NEMA 3R) while in use, gasketed, copper-free aluminum, 2.5 IN minimum cover depth.

E. Exterior Locations:
1. Coverplate: Weatherproof (NEMA 3R) while in use, gasketed, copper-free aluminum, 2.5 IN minimum cover depth.

F. Corrosive Areas:

1. Corrosion resistant nickel plated metal parts.
2. Receptacle body color: Yellow.
3. Coverplate:
   a. Zinc plated malleable iron or galvanized steel.
   b. Single or multiple gang as required.

G. Highly Corrosive Areas:
1. Corrosion resistant nickel plated metal parts.
2. Receptacle body color: Yellow.
3. Coverplate:
   a. PVC-RGS conduit system:
      1) PVC coated zinc plated malleable iron or copper free aluminum.
      2) Single or multiple gang as required.
   b. PVC conduit system:
      1) Gray colored high impact thermoplastic.
      2) Single or multiple gang as required.

H. Hazardous Areas:
1. Rated for Class I, Division 1 and 2, Groups B, C, and D; and Class II, Division 1 and 2 areas, Groups F and G.
2. Factory-sealed receptacle/switch/coverplate.
   a. Zinc plated malleable iron or copper free aluminum with stainless steel screws and gasketed spring-loaded cover.
3. "Dead-front" construction requiring plug to be inserted and rotated to activate receptacle.
   a. Ordinary non-hazardous plug shall not activate the receptacle.
4. Standard: UL 1010.

I. Special Purpose Receptacles:
1. NEMA configuration as indicated on the Drawings.
2. Coverplate: See requirements per area designations herein.

2.4 MISCELLANEOUS WIRING DEVICES

A. Manual Motor Starters: Horsepower rated with or without thermal overloads, see Specification Section 26 24 19.

2.5 OCCUPANCY SENSORS

A. Low Voltage Passive Infrared Ceiling Sensor per the Drawings:
1. Detection of changes in the infrared energy: Sensor to respond only to those signals caused by human motion.
2. Analog and digital processing to provide immunity to RFI and EMI.
3. Temperature compensated, dual element sensor and a multi-element lens with a minimum field of view of 110 degrees.
4. Daylight filter or compensation for short wavelength infrared wave from the sun.
5. Cover up to 300 SF at normal mounting heights.
6. System voltage: 24 Vdc through power pack.
7. Load ON-OFF control through power pack.
8. Adjustable time delay set at 30 minutes
9. Adjustable sensitivity set at maximum.
10. Adjustments and mounting hardware under a removable cover.
11. Parallel wiring of multiple sensors to allow coverage of large areas.

B. Passive Infrared Wall Switch:
1. Self contained control system that replaces a standard toggle switch.

a. Latching air gap relay switching mechanism, compatible with electronic ballasts, compact fluorescent and inductive loads.
2. Detection of changes in the infrared energy: Sensor to respond only to those signals caused by human motion.
3. Analog and digital processing to provide immunity to RFI and EMI.
4. Temperature compensated, dual element sensor and a multi-element Fresnel lens.
5. Cover up to 300 SF for walking motion, with a field of view of 180 degrees.
6. System voltage: 120 Vac or 277 Vac.
7. No minimum load.
   a. 0 to 500 watts incandescent, 0 to 800 watts fluorescent or 1/6 HP at 120 Vac, 60 Hz.
   b. 0 to 1200 watts fluorescent or 1/3 HP at 277 Vac, 60 Hz.
8. DIP switch to control the following functions:
   a. Built-in light level feature adjustable from 8 to 180 foot candles.
   b. AUTOMATIC-ON or MANUAL-ON operation.
   c. Time delay adjustable from 30 seconds to 30 minutes.
   d. High/low sensitivity adjustments.
9. Adjustments and mounting hardware under a removable, tamper resistant cover.
10. Normal operation: OFF and AUTO.

C. Ultrasonic Ceiling Sensor:
1. Detection of Doppler shifts in transmitted ultrasound.
2. Ultrasonic sensing is volumetric in coverage with a frequency of 32 kHz and automatically adjust the detection threshold dynamically to compensate for constantly changing levels of activity and air flow throughout controlled areas.
3. Temperature and humidity resistant, 32 kHz tuned ultrasonic receivers.
   a. Receivers have less than a 6 dB shift in the humidity range of 10 percent to 90 percent and less than a 10 dB shift in the temperature range of -20 to 60 DegC.
4. DIP switch to control the following functions:
   a. Override-ON function for use in the event of failure.
   b. Time delay adjustable from 15 seconds to 30 minutes.
   c. High/low sensitivity adjustments.
5. Cover 360 degrees and hallway and corridor sensors shall cover up to 90 linear feet.
6. Additional single-pole, double-throw isolated relay with normally open, normally closed, and common outputs with current and voltage rated as required.
   a. The isolated relay is for use with HVAC control, data logging and other control options.

D. Power Pack:
1. Self contained transformer and relay module.
2. Dry contacts capable of switching:
   a. 20 amp ballast load, 13 amp incandescent, 1 HP at 120 Vac, 60 Hz.
   b. 20 amp ballast at 277 Vac, 60 Hz.
3. 24 Vdc, 100 mA output.
4. Capable of parallel wiring without regard to AC phases on primary.
5. Used as a stand alone, low voltage switch or wired to sensor for auto control.
6. Low voltage Teflon coated leads, rated for 300 V, suitable for use in plenum applications.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install products in accordance with manufacturer's instructions.

B. Mount devices where indicated on the Drawings and as scheduled in Specification Section 26 05 00.

C. See Specification Section 26 05 33 for device outlet box requirements.

D. Where more than one (1) receptacle is installed in a room, they shall be symmetrically arranged.

E. Provide blank plates for empty outlets.

END OF SECTION

SECTION 26 28 00

OVERCURRENT AND SHORT CIRCUIT PROTECTIVE DEVICES

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Low voltage circuit breakers.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.
   2. Section 01 25 13 - Product Substitution.
   3. Section 26 05 00 - Electrical: Basic Requirements.
   4. Section 26 08 13 - Acceptance Testing.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
      a. C37.13, Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures.
      b. C37.16, Low-Voltage Power Circuit Breakers and AC Power Circuit Protectors - Preferred Ratings, Related Requirements, and Application Recommendations.
      c. C37.17, Trip Devices for AC and General Purpose DC Low Voltage Power Circuit Breakers.
   2. National Electrical Manufacturers Association (NEMA):
      a. AB 1, Molded-Case Circuit Breakers, Molded Case Switches, and Circuit-Breaker Enclosures. (Equivalent to UL 489)
   3. National Fire Protection Association (NFPA):
      a. 70, National Electrical Code (NEC).
   4. Underwriters Laboratories, Inc. (UL):
      a. 489, Standard for Safety Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures.
      b. 943, Standard for Safety for Ground-Fault Circuit-Interrupters.
      c. 1066, Standard for Low-Voltage AC and DC Power Circuit Breakers Used in Enclosures.

1.3 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
   2. Product technical data including:
      a. Provide submittal data for all products specified in PART 2 of this Specification Section.
      b. See Specification Section 26 05 00 for additional requirements.

B. Operation and Maintenance Manual:
   1. See Specification Section 26 05 00 for requirements for:
      a. The mechanics and administration of the submittal process.
      b. The content of Operation and Maintenance Manuals.

C. Miscellaneous Submittals:

1. See Specification Section 26 05 00 for requirements for the mechanics and administration of the submittal process.
2. Reports:
    a. As-left condition of all circuit breakers that have adjustable settings.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following manufacturers are acceptable:
    1. Circuit breakers:
        a. Cutler-Hammer.
        b. General Electric Company.
        c. Square D Company.
        d. Siemens.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 CIRCUIT BREAKERS

A. Molded Case Type:
    1. General:
        a. Standards: NEMA AB 1, UL 489.
        b. Unit construction.
        c. Over-center, toggle handle operated.
        d. Quick-make, quick-break, independent of toggle handle operation.
        e. Manual and automatic operation.
        f. All poles open and close simultaneously.
        g. Three (3) position handle: On, off and tripped.
        h. Molded-in ON and OFF markings on breaker cover.
        i. One-, two- or three-pole as indicated on the Drawings.
        j. Current and interrupting ratings as indicated on the Drawings.
        k. Bolt on type.
    2. Thermal magnetic type:
        a. Inverse time overload and instantaneous short circuit protection by means of a thermal magnetic element.
        b. Frame size 150 amp and below:
            1) Non-interchangeable, non-adjustable thermal magnetic trip units.
        c. Frame sizes 225 to 400 amp (trip settings less than 400A):
            1) Interchangeable and adjustable instantaneous thermal magnetic trip units.
        d. Ground Fault Circuit Interrupter (GFCI) Listed:
            1) Standard: UL 943.
            2) One- or two-pole as indicated on the Drawings.
            3) Class A ground fault circuit.
            4) Trip on 5 mA ground fault (4-6 mA range).
    3. Solid state trip type:
        a. Inverse time overload, instantaneous short circuit and ground fault protection by means of a solid state trip element, associated current monitors and flux shunt trip mechanism.
        b. Frame size 400 amp to 1200 amp (trip settings between 400 and 1200A):
            1) Standard rating.
            2) Interchangeable current sensor or rating plug.
            3) Adjustable long time pick-up setting.
                a) Adjustable from 50 to 100 percent of the current sensor or rating plug.

4) Adjustable short time pick-up setting.
5) Adjustable instantaneous pick-up.
6) Fixed ground fault pick-up, when indicated on the Drawings.

c. Frame size 1600 amp and above:
1) 100 percent rated.
2) Interchangeable current sensor or rating plug.
3) Adjustable long time pick-up setting.
a) Adjustable from 50 to 100 percent of the current sensor or rating plug.
4) Adjustable long time delay setting.
5) Adjustable short time pick-up setting.
6) Adjustable instantaneous pick-up setting.
7) Adjustable ground fault pick-up setting, when indicated on the Drawings.
8) Adjustable ground fault delay setting, when indicated on the Drawings.

4. Motor circuit protector:
a. Adjustable instantaneous short circuit protection by means of a magnetic or solid state trip element.
b. Sized for the connected motor.

B. Insulated Case Type:
1. Inverse time overload, instantaneous short circuit and ground fault protection by means of a solid state trip element, associated current monitors and two-step stored energy trip mechanism.
2. Standards: NEMA AB 1, UL 489.
3. 100 percent rated.
4. Manually operated (MO) unless electrically operated (EO) is indicated on the Drawings.
5. Electrically operated breakers:
a. 120 Vac operators.
b. Close/open pushbuttons and Control switch.
c. Red and green indicators to indicated breaker position.
d. AC source: Control power transformer.
6. Motor driven operator for charging mechanism with open, close and charge push button.
7. Draw out construction:
a. Roll out type operated by removable crank handle and interlocked with the door.
b. Four (4) positions: Connected, test, disconnected and removed.
c. Cell switches to short out ground fault relay when main or tie breaker is drawn out.
8. Current and interrupting ratings as indicated on the Drawings.
9. Selective override circuit on breakers with short time settings and without instantaneous settings that allow selectivity up to the breakers RMS symmetrical short time rating.
a. The selective override circuit shall allow the breaker to ride through a fully offset (asymmetrical) fault equal to its RMS symmetrical short time rating in a system having an X/R ration of 6.6 with a maximum single phase peak current of 2.3 times the RMS symmetrical short time range.
10. Frame size 400 amp and above:
a. Interchangeable current sensor or rating plug:
b. Adjustable long time pick-up setting.
1) Adjustable from 50 to 100 percent of the current sensor or rating plug.
c. Adjustable long time delay setting.
d. Adjustable short time pick-up setting.
e. Adjustable instantaneous pick-up setting.
f. Adjustable ground fault pick-up setting, when indicated on the Drawings.
g. Adjustable ground fault delay setting, when indicated on the Drawings.

C. Low Voltage Power Type:

1. Inverse time overload, instantaneous short circuit and ground fault protection by means of a solid state trip element, associated current monitors and two-step stored energy trip mechanism.
2. Standards: IEEE C37.13, IEEE C37.16, IEEE C37.17, UL 1066.
3. 100 percent rated.
4. Electrically operated (EO) or manually operated (MO) as indicated on the Drawings.
5. Manually operated breakers:
   a. Close/Open pushbuttons.
   b. Red and green indicators to indicate breaker position.
   c. Trip unit power: Internal CPT of the electrical gear.
6. Motor driven operator for charging mechanism with open, close and charge push button.
7. Stored energy mechanism position indicator.
8. Contact position indicator: Reversible 52a/52b contacts, quantity as indicated on the Drawings.
9. Truck operated cell switch (52TOC) when indicated on the Drawings.
10. Bell alarm with manual reset when indicated on the Drawings.
11. Draw out construction:
    a. Roll out type operated by removable crank handle and interlocked with the door.
    b. Four (4) positions: Connected, test, disconnected and removed.
    c. Cell switches to short out ground fault relay when main or tie breaker is drawn out.
12. Current and interrupting ratings as indicated on the Drawings and a 30-cycle short-time withstand ratings equal to their symmetrical interrupting ratings, regardless of whether equipped with instantaneous trip protection or not.
13. Current limiters:
    a. Integrally mounted on 2000 amp frames and less and separate draw-out limiter on 3200 amp and larger.
    b. Coordinated with the trip unit to avoid unnecessary blowing of the current limiters.
    c. Anti-single-phasing device to trip breaker in the event of a blown limiter, indicator to indicate which limiter is blown and prevent breaker from being re-closed on a single-phase condition.
    d. Current limiting fuses: 200,000 amp RMS symmetrical interrupting capacity.
14. Frame size 800 amp and above:
    a. Interchangeable current sensor or rating plug:
    b. Adjustable long time pick-up setting.
       1) Adjustable from 50 to 100 percent of the current sensor or rating plug.
    c. Adjustable long time delay setting.
    d. Adjustable short time pick-up setting.
    e. Adjustable instantaneous pick-up setting.
    f. Adjustable ground fault pick-up setting.
    g. Adjustable ground fault delay setting.
    h. Unit status indicator.
    i. Cause of trip indicator.
    j. Current display.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Current and interrupting ratings as indicated on the Drawings.

B. Series rated systems not acceptable.

C. Devices shall be ambient temperature compensated.

D. Circuit Breakers:
   1. Molded case circuit breakers shall incorporate the following, unless indicated otherwise on the Drawings:
      a. Frame sizes 400 amp and less with trip setting less than 400A shall be thermal magnetic type.
      b. Frame sizes 400 amp and larger shall be solid state trip type.
      c. Frame sizes 1000 amp and above shall include integral ground fault protection, when indicated on the Drawings.
      d. Motor circuit protectors sized for the connected motor.
   2. Insulated case circuit breakers shall incorporate the following, unless indicated otherwise on the Drawings:
      a. Set current sensor or rating plugs long time pick-up setting so that the indicated trip level is near the 75 percent trip point.
      b. Frame sizes 1000 amp and above shall include integral ground fault protection, when indicated on the Drawings.

3.2 FIELD QUALITY CONTROL

A. Adjustable Circuit Breakers:
   1. Set all circuit breaker adjustable taps as defined on the Drawings, except adjust motor circuit protectors per the motor nameplate and NFPA 70 requirements.

B. Ground Fault Protection System:
   1. Single source system:
      a. Main breaker using the residual sensing method system {coordinated with individual feeder breakers using the residual sensing method}.
      b. Main and feeder breakers: Utilize four (4) individual current sensors; the phase sensors are integral to the circuit breaker and the neutral sensor is external to the circuit breaker.

C. Testing:
   1. Acceptance testing: See Specification Section 26 08 13.

END OF SECTION

SECTION 26 28 16

SAFETY SWITCHES

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Safety switches.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.
   2. Section 01 25 13 - Product Substitution.
   3. Section 26 05 00 - Electrical: Basic Requirements.
   4. Section 26 28 00 - Overcurrent and Short Circuit Protective Devices.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. National Electrical Manufacturers Association (NEMA):
      a. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
      b. KS 1, Enclosed and Miscellaneous Distribution Equipment Switches (600 Volts Maximum).
   2. Underwriters Laboratories, Inc. (UL):
      a. 98, Enclosed and Dead-Front Switches.

1.3 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
   2. Product technical data:
      a. Provide submittal data for all products specified in PART 2 of this Specification Section.
      b. Provide a table that associates safety switch model number with connected equipment tag number.
      c. See Specification Section 26 05 00 for additional requirements.

B. Operation and Maintenance Manuals:
   1. See Specification Section 26 05 00 for requirements for:
      a. The mechanics and administration of the submittal process.
      b. The content of Operation and Maintenance Manuals.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following safety switch manufacturers are acceptable:
   1. Cutler-Hammer.
   2. General Electric Company.
   3. Square D Company.
   4. Siemens.
   5. Appleton Electric Company.

6. Crouse-Hinds.
7. Killark.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 SAFETY SWITCHES

A. General:
1. Non-fusible or fusible as indicated on the Drawings.
2. Suitable for service entrance when required.
3. NEMA Type HD heavy-duty construction.
4. Switch blades will be fully visible in the OFF position with the enclosure door open.
5. Quick-make/quick-break operating mechanism.
6. Deionizating arc chutes.
7. Manufacture double-break rotary action shaft and switchblade as one (1) common component.
8. Clear line shields to prevent accidental contact with line terminals.
9. Operating handle (except NEMA 7 and NEMA 9 rated enclosures):
   a. Red and easily recognizable.
   b. Padlockable in the OFF position
   c. Interlocked to prevent door from opening when the switch is in the ON position with a defeater mechanism.

B. Ratings:
1. Horsepower rated of connected motor.
2. Voltage and amperage: As indicated on the Drawings.
3. Short circuit withstand:
   a. Non-fused: 10,000A.
   b. Fused: 200,000A.

C. Accessories, when indicated in PART 3 of this Specification Section or on the Drawings:
1. Neutral kits.
2. Ground lug kits.
3. Auxiliary contact kits with 1 N.O. and 1 N.C. contact.

D. Enclosures:
1. NEMA 1 rated:
   a. Body and cover: Sheet steel finished with rust inhibiting primer and manufacturers standard paint inside and out.
   b. With or without knockouts, hinged and lockable door.
2. NEMA 3R rated:
   a. Body and cover: Sheet steel finished with rust inhibiting primer and manufacturers standard paint inside and out.
   b. With or without knockouts, hinged and lockable door.
3. NEMA 4 rated:
   a. Body and cover: Sheet steel finished with rust inhibiting primer and manufacturers standard paint inside and out.
   b. No knockouts, external mounting flanges, hinged, gasketed and lockable door.
4. NEMA 4X rated (metallic):
   a. Body and cover: Type 304 or 316 stainless steel.
   b. No knockouts, external mounting flanges, hinged and gasketed door.
5. NEMA 4X rated (non-metallic):
   a. Body and cover: Ultraviolet light protected fiberglass-reinforced polyester boxes.
   b. No knockouts, external mounting flanges, hinged, gasketed and lockable door.
6. NEMA 7 and NEMA 9 rated:

a. Cast gray iron alloy or copper-free aluminum with manufacturers standard finish.
b. Drilled and tapped openings or tapered threaded hub.
c. Gasketed cover bolted-down with stainless steel bolts.
d. External mounting flanges.
e. Operating handle padlockable in the OFF position.

7. NEMA 12 rated:
   a. Body and cover: Sheet steel finished with rust inhibiting primer and manufacturers standard paint inside and out.
   b. No knockouts, external mounting flanges, hinged and gasketed door.

E. Overcurrent and short circuit protective devices:
   1. Fuses.
   2. See Specification Section 26 28 00 for overcurrent and short circuit protective device requirements.

F. Standards: NEMA KS 1, UL 98.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install as indicated and in accordance with manufacturer's instructions and recommendations.

B. Install switches adjacent to the equipment they are intended to serve unless otherwise indicated on the Drawings.

C. Provide auxiliary contact kit on local safety switches for motors being controlled by a variable frequency drive.
   1. The VFD is to be disabled with the switch is in the open position.

D. Permitted uses of NEMA 1 enclosure:
   1. Surface or flush mounted in areas designated dry in architecturally finished areas.

E. Permitted uses of NEMA 3R enclosure:
   1. Surface mounted in exterior location for HVAC equipment only.

F. Permitted uses of NEMA 4 enclosure:
   1. Surface mounted in areas designated as wet.

G. Permitted uses of NEMA 4X metallic enclosure:
   1. Surface mounted in areas designated as wet and/or corrosive.

H. Permitted uses of NEMA 4X non-metallic enclosure:
   1. Surface mounted in areas designated as corrosive.
   2. Surface mounted in areas designated as highly corrosive.

I. Permitted uses of NEMA 7 enclosure:
   1. Surface mounted in areas designated as Class I hazardous.
   2. Provide PVC coating in corrosive and highly corrosive areas when PVC coated conduit is used.

J. Permitted uses of NEMA 9 enclosure:
   1. Surface mounted in areas designated as Class II hazardous.
   2. Provide PVC coating in corrosive and highly corrosive areas when PVC coated conduit is used.

K. Permitted uses of NEMA 12 enclosure:
   1. Surface mounted in areas designated as dry in non-architecturally finished areas.

END OF SECTION

SECTION 26 29 23

VARIABLE FREQUENCY DRIVES: LOW VOLTAGE

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Variable frequency drives (VFDs) for operation of inverter duty motors.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.
   2. Section 01 25 13 - Product Substitution.
   3. Section 10 14 00 - Identification Devices.
   4. Section 26 05 00 - Electrical: Basic Requirements.
   5. Section 40 05 05 - Equipment: Basic Requirements.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. American National Standards Institute (ANSI).
   2. ETL Testing Laboratories (ETL).
   3. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
      a. 399, Recommended Practice for Industrial and Commercial Power Systems Analysis.
      b. 519, Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems.
      c. C62.41, Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits.
   4. National Electrical Manufacturer's Association (NEMA):
      a. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
      b. MG 1, Motors and Generators.
   5. National Fire Protection Association (NFPA):
      a. 70, National Electrical Code (NEC):
         1) Article 430, Motors Motor Circuits, and Controllers..
   6. Occupational Safety and Health Administration (OSHA).
   7. Underwriters Laboratory, Inc. (UL):
      a. 508, Standard for Industrial Control Equipment.
      b. 508A, Standard for Industrial Control Panels.

B. Qualifications:
   1. Provide drives that are listed and labeled by UL, ETL, or other Nationally Recognized Testing Laboratory (NRTL) as defined by OSHA regulations, or that have been inspected and subsequent field-labeled by such NRTL.
   2. Where listed drives and other components are installed in a common enclosure, the assembly shall be listed and labeled per UL 508 and UL 508A or equivalent NRTL standard.
      a. Entire assembly shall be affixed with a UL 508A label "Listed Enclosed Industrial Control Panel" or equivalent NRTL label prior to shipment to the jobsite.
   3. VFD Supplier shall maintain an authorized service organization within 100 miles of the Project Site.

C. Coordination:

1. The intent of this Specification Section is to allow the VFD manufacturer to provide the best solution for the harmonic and motor protection outlined herein.
   a. This solution shall include, but not be limited to, all aspects of the distribution system including standby generation, motor feeder cable type and available floor space.
2. Motor and VFD coordination: See Specification Section 40 05 05 and Specification Section 26 05 09
3. VFD shall be supplied complete with all required control components.
   a. Provide control as indicated:
      1) On the electrical drawings.
      2) As specified in this Specification Section.
      3) As specified in the process control system loop descriptions.
         a) The control loop descriptions provide the functional requirements of the control loops represented in the Contract Documents.
            (1) Descriptions are provided as follows:
               (a) Control system overview and general description.
               (b) Major equipment to be controlled.
               (c) Major field mounted instruments (does not include local gages).
               (d) Manual control functions.
               (e) Automatic control functions/interlocks.
               (f) Major indications provided at local control panels and motor starters/VFD's.
               (g) Remote indications and alarms.
         b) The control loop descriptions are not intended to be an inclusive listing of all elements and appurtenances required to execute loop functions, but are rather intended to supplement and complement the Drawings and other Specification Sections.
            (1) The control loop descriptions shall not be considered equal to a bill of materials.
         c) Provide instrumentation hardware and software as necessary to perform control functions specified herein and shown on Drawings.
   b. VFD manufacturer shall review the application and provide, at no additional cost to the Owner, the hardware and software necessary to allow the VFD to control the driven equipment motor over its required operating range.
      1) These may include, but are not limited to, analog and digital interface modules, communication interface modules, switches, lights and other devices.
   c. Coordinate control devices with devices furnished with driven equipment such as vibration switches, thermal sensors, leak detectors, etc.
4. Verify plan dimensions with equipment space requirements as indicated on the Drawings.
   a. Equipment which exceeds the allotted maximum dimensions may not be acceptable.
   b. Equipment which reduces clear work space below the minimums established by the NFPA 70 will not be acceptable.

1.3 DEFINITIONS

A. Variable Torque (VT):
   1. Defines a load characteristic in which the torque delivered from the motor to the load is reduced as speed is reduced below full rated.
   2. This type of load permits the VFD and the motor to operate at reduced output current at reduced speed.

B. Constant Torque (CT):
   1. Defines a load characteristic in which the torque delivered from the motor to the load remains constant as speed is varied.

2. This type of load requires the VFD to be able to continuously deliver rated output current over the entire speed range.

C. Constant Horsepower:
   1. Defines a load characteristic in which the torque delivered from the motor to the load is reduced as the speed is increased.
   2. This characteristic is required for operation of the VFD and motor above rated frequency to maintain output current within the rated value.

D. Inverter Duty Motor: An AC induction motor complying with all requirements of NEMA MG 1 Part 31 for definite-purpose inverter-fed motors.

E. Standard Motor: An AC induction motor that fails to comply with one (1) or more requirements of NEMA MG 1 Part 31.

F. Low Voltage: 600 Vac or less.

1.4 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
   2. Provide a schedule for each VFD including the following information:
      a. Equipment Tag Number.
      b. VFD Complete Catalog Number.
      c. VFD Amp Frame Size.
      d. Variable or Constant Torque Rating Basis.
      e. 7Rated Input Current.
      f. Rated Continuous Output Current.
      g. Rated Short Circuit Current.
      h. VFD cable type specified (shielded or non-shielded).
      i. VFD Maximum Motor Lead Length for the type of cable used.
      j. Motor Manufacturer.
      k. Motor Frame Size.
      l. Motor Full Load Amps.
      m. Motor Service Factor.
      n. As installed motor Lead Length.
      o. VFD options provided to meet harmonic or motor protection specifications.
   3. Submit VFD Shop Drawings concurrently with driven equipment and motor Shop Drawings.
   4. Product technical data:
      a. Complete electrical ratings and performance specifications confirming compliance with specified ratings and performance.
      b. Maximum rate of heat rejection from VFD and all related components and associated cooling requirements.
      c. Manufacturer’s installation instructions.
      d. Manufacturer’s programming and operating instructions.
      e. See Specification Section 26 05 00 for additional requirements.
   5. Fabrication and/or layout drawings:
      a. Top, front and side exterior views, with details showing maximum overall dimensions of enclosure, mounting provisions and conduit/cable entry provisions.
      b. Identify minimum clearances from other VFDs or electrical equipment required for proper cooling at top, bottom, side and back of enclosure.
      c. Three-line diagrams showing AC schematic of VFD, input, output and bypass devices including device ratings.

d. Interior layout drawings showing location of all components within enclosure, field wiring terminal boards, and power and grounding connections.
e. Field wiring diagrams showing locations and sizes of all electrical connections, ground terminations, and requirements for shielded wire usage or any other special installation considerations.

6. Certifications:
   a. Submit with Shop Drawings:
      1) Identification and location of closest authorized service organization.
      2) Harmonic analysis at each PCC per Harmonic Protection Requirements Article.
   b. Submit prior to shipment:
      1) Certified factory test reports confirming compliance with specified requirements.
   c. Submit after installation:
      1) Certified field service reports showing:
         a) Each VFD is operational.
         b) Each VFD and its driven equipment motor are compatible.
         c) Each VFD responds correctly to the input control signals.
         d) Critical frequencies of the drive system and that the VFD has been set to lockout these frequencies.
         e) Measured harmonic levels per Harmonic Protection Requirements Article.
         f) Measured motor terminal peak voltages per Motor Protection Requirements Article.

B. Operations and Maintenance Manuals:
   1. See Specification Section 26 05 00 for requirements for:
      a. The mechanics and administration of the submittal process.
      b. The content of Operation and Maintenance Manuals.
   2. Approved copy of VFD schedule per Submittals Article.
   3. Manufacturer’s instruction manuals.
   4. Troubleshooting procedures with a cross-reference between symptoms and corrective recommendations.
   5. Connection data to permit removal and installation of recommended smallest field-replaceable parts.
   6. Recommended spare parts list.
   7. Commissioning sheets showing “as-left” values of all user-programmable or adjustable drive parameters.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following manufacturers are acceptable:
   1. Allen Bradley.
   2. ASEA Brown Bovari (ABB).
   3. Square D Company.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 GENERAL

A. VFDs shall consist of a rectifier-DC bus-inverter combination producing a sine-coded pulse-width-modulated (PWM) output voltage waveform.

B. VFDs, whether installed in motor control center (MCC) construction or separately-mounted, shall constitute a complete combination motor controller per NFPA 70, Article 430 and shall provide the following per the requirements of that article without the addition of any external components or devices.
   1. Motor control.
   2. Motor overload protection.
   3. Motor and motor branch circuit short circuit and ground fault protection.
   4. Motor and controller disconnecting means.

C. It is the intent of this Specification that VFDs shall be an “engineered” or “configured” drive package in which the VFD chassis, all input, output and bypass power devices, VFD accessories, ancillary switches, contactors, relays, and related control devices are selected, furnished, factory-assembled and -tested by the VFD manufacturer in a single enclosure requiring only connection of the power supply circuit, motor branch circuit, and external control wiring in the field.

2.3 PERFORMANCE AND DESIGN REQUIREMENTS

A. Application:
   1. VFD(s) shall be sized to handle the maximum required torque to operate the movable span.
   2. VFD(s) shall be of sufficient capacity and shall provide a quality of output waveform for stepless motor control from 10 to 100 percent of base speed of the driven equipment.
   3. VFDs shall be compatible with:
      a. Inverter duty induction motors.
   4. VFDs shall be suitable for Constant Torque (CT) or Variable Torque (VT) applications.
      a. VFD manufacturer shall coordinate with the manufacturer of the driven equipment to identify CT and VT applications.
   5. VFDs shall be designed to operate successfully under the following site conditions:
      a. Ambient:
         1) Temperature: 0-50 DegC.
         2) 95 percent non-condensing relative humidity.
      b. Elevation: Less than 3,300 FT above MSL.
      c. Power supply characteristics:
         1) 480Vac, 3 PH, 60 Hz, 3 wire, (+/- 10 percent).
         2) Effectively grounded.

B. Ratings and Performance Specifications:
   1. Voltage rating:
      a. As required.
      b. Range for continuous full load operation: +/-10 percent of nominal.
      c. Voltage imbalance tolerance for full load operation: 3 percent minimum.
   2. Current ratings:
      a. Continuous:
         1) Equal to or greater than the motor nameplate full load.
      b. Short-term overload:
         1) VT: 110 percent for 1 minute.
         2) CT: 150 percent for 1 minute.
         3) Permissible for 1 minute every 10 minutes continuously.
      c. Short circuit:
         1) As indicated on the Drawings.
         2) Where a short circuit rating is not indicated or specified for individual VFDs, each VFD shall have a rating not less than indicated on the Drawings for the MCC, switchboard or panelboard the VFD is supplied from.

    3) Where specified short circuit rating indicates additional input impedance is required to protect semiconductors, provide input AC line reactors, whether required to meet harmonic performance specifications or not.
3. Efficiency:
    a. 97 percent, minimum, at full speed and full load.
    b. 93 percent, minimum at 1/2 speed and full load.
4. Displacement power factor:
    a. 95 percent, minimum from 50 percent to 100 percent speed and load.
5. Efficiency and power factor criteria apply from the input terminals to the output terminals of the VFD alone, excluding losses of input and output power circuit accessories.
6. Frequency drift:
    a. +0.5 percent of set frequency.
7. Speed regulation (motor dependent): 3 percent.
8. Speed range: 10:1.
9. Control type:
    a. Volts/Hertz ratio; constant over the entire operating range of the VFD except:
        1) When operating under voltage boost.
        2) At frequencies over 60 Hz.
    b. Closed Loop with feed back.

C. Operational Features:
1. Insensitive to input phase sequence.
2. Continued operation with momentary voltage dips of 25 percent of rated voltage, or single phase condition: 4 second, minimum.
3. Controls power loss ride-through: 500 msec, minimum.
4. Electronic reversing.
5. DC injection braking.
6. Anti-windmilling: Synchronization of VFD starting frequency with spinning or coasting load, forward or reverse.
7. Critical frequency band lockout:
    a. Minimum of three (3) settings.
    b. Adjustable bandwidth, 1 - 5 Hz.
8. Capable of operating without the motor connected for start-up and troubleshooting.

D. The VFD shall be provided with the following minimum user-programmable parameters:
1. Carrier frequency.
2. Independent maximum and minimum speeds for forward and reverse operation.
3. Start frequency and hold time.
4. Independent linear acceleration and deceleration time.
5. Preset “jog” speed.
6. Three (3) critical frequency bands.
7. One (1) preset speed selectable by logic input.
8. Volts/Hertz ratio.
9. Voltage boost, magnitude and frequency range.
10. Process controller gain, offset and bias.
11. Current limit.
12. Overcurrent pickup.
13. Overcurrent delay.
14. Ground fault pickup.
15. DC injection level and time.

E. The VFD shall be designed such that the power circuit components are fully protected from line side disturbances and load side faults:

1. General:
    a. Shutdown conditions associated with supply circuit conditions which can be corrected external to the VFD-motor system shall be provided with automatic reset, with shutdown cause logged in memory:
        1) Input under voltage.
        2) Input over voltage.
        3) Input under frequency.
        4) Input over frequency.
        5) Input Phase loss.
        6) DC Bus under voltage.
    b. Shutdown conditions which indicate overload or fault within the VFD, the output circuit, or the motor shall require local manual reset at the VFD, requiring operator intervention.
        1) Over temperature.
        2) Blown fuse.
        3) Component failure.
        4) Overload.
        5) Short circuit.
        6) Ground fault.
        7) DC Bus over voltage.
        8) External safety input (e.g., motor thermal protection).
        9) Logic fault.
    c. When automatic shutdown occurs, VFD shall restart only when remote run signal is removed and reapplied.
    d. VFD shall hold cause of trip data for a minimum of four (4) shutdowns in memory.
        1) Data to be accessible through the keypad, local communication link and remotely.
2. Input protection:
    a. Input circuit breaker or current-limiting fuses with externally operable disconnect.
        1) Fault current interrupting rating equal to or greater than the specified withstand rating of the VFD.
        2) Handle padlockable in the OFF position.
    b. Provide full protection for semiconductors integral to the VFD; units requiring current-limiting fuses or circuit breakers in the supply circuit are not acceptable.
    c. Incoming line transient suppression.
        1) 6000V peak per IEEE C62.41.
        2) Phase-to-phase and phase-to-ground protection.
    d. Sustained over voltage trip.
3. Internal protection:
    a. Surge suppression and power device snubbers.
    b. Power devices rated at 2.5 times line voltage.
    c. Instantaneous over current trip.
    d. DC bus over voltage trip.
    e. Power device over temperature trip.
    f. Control logic circuit malfunction trip.
4. Output protection:
    a. Inverse-time overload trip:
        1) UL Class 10 characteristic.
    b. Over voltage trip.
    c. Over frequency trip.
    d. Short circuit trip.
        1) Line to line and line to ground.
    e. Ground fault trip.

2.4 OPERATOR AND REMOTE CONTROL INTERFACE

A. Drive controls shall be microprocessor-based with on-board human machine interface and both local and remote digital communications capability.
   1. All monitoring and control functions, other than those shutdowns specified to be manual reset only, shall be available both locally and remotely.

B. Control circuits shall be 120 Vac or 24 Vac or 24 Vdc.
   1. 120 Vac supplied by CPT in the VFD.
      a. CPT shall have minimum additional capacity of 60 VA greater than that required by control devices.
      b. CPT shall have two (2) fuses on the primary side and one (1) fuse on the secondary side.
      c. CPT shall have surge protection on the primary side independent of any other surge protection in the VFD.
   2. 24 Vac or 24 Vdc supplied by Class 2 power supply in the VFD.
      a. Power supply shall have minimum additional capacity of 33 percent greater than that required by control devices.
      b. Provide two (2) current-limiting fuses on the AC supply to the power supply.
      c. Power supply shall have surge protection on the primary side independent of any other surge protection in the VFD.

C. Operator Interface:
   1. Door mounted sealed keypad, membrane type with LED or LCD display.
      a. Messages shall be in English and engineering units.
      b. Drive operating parameters shall be programmable.
      c. Menu driven.
      d. Password security.
      e. Display fault and diagnostic data.
      f. Operating parameters, fault and diagnostic data maintained in non-volatile memory with historic log of fault and diagnostic data.
      g. Gold plated plug-in contacts.
   2. Provide indication and control interface, integral in the keypad, as required in the sequence of operation and Drawings.
      a. Minimum indications:
         1) Run.
         2) Stop.
         3) Ready.
         4) Alarm.
         5) Fault.
         6) Local control.
         7) Remote control.
         8) Control source local.
         9) Control source remote.
         10) Speed indication.
      b. Minimum control functions:
         1) Local/Remote switch.
         2) Stop button.
         3) Start button.
         4) Reset button.
         5) Speed control buttons.
   3. Diagnostic indicators located externally on the face of the drive shall show the type of fault responsible for drive warning, shutdown or failure.

a. On occurrence of more than one (1) condition, each shall be recorded or indicated by the diagnostics.

D. Remote Control Interface:
1. Local portable computer interface via RS232/RS242 serial communications port:
   a. Capability to:
      1) Start-Stop VFD.
      2) Control VFD Speed.
      3) Access fault and diagnostic data.
2. Analog and discrete inputs:
   a. Speed reference (setpoint) signal 4-20 mA.
   b. Isolated process PID controller with user-programmable setpoint, gain, rate, reset and span for accepting a remote 4-20 mA process variable signal.
3. Analog and discrete outputs:
   a. {4-20 mA} {0-10 V} DC output for remote speed indication, as a function of frequency, calibrated 0 to 100 percent.
   b. Drive FAULT contacts.
   c. Drive RUNNING contacts.
   d. Drive selector switch in REMOTE status contacts.
4. Contacts:
   a. Contacts shall be rated as required.
   b. All contacts shall be wired to field wiring terminal boards.
5. Drive shutdown on external fault input:
   a. Provide isolated input for dry contact from external motor or system safety devices to cause immediate shutdown of VFD.
   b. Safety shutdown to be operable in all operating modes of drive, including local operation from keypad.
   c. Local safety switch, to driven equipment, auxiliary contact to lock-out VFD from running when safety switch is open.
6. Network communications capability:
   a. Provide VFD with communication card, protocol and required programming for digital communication of all VFD program and operational parameters to plant control system via:
      1) As recommended by the drive manufacturer and approved by the Engineer.

2.5 HARMONIC PROTECTION REQUIREMENTS

A. All VFDs shall be capable of satisfactory operation from a source having voltage distortion and notch characteristics identified as acceptable for a “dedicated system” in IEEE 519 Table 10.2.

B. With all VFDs operating under worst-case harmonic current conditions, and the facility supplied from either or both the utility and generator sources, the VFDs shall not produce harmonic effects in excess of the following limits at any point of common coupling (PCC).
1. Voltage distortion and notch characteristics: IEEE 519 Table 10.2 for General System.
2. Current distortion: IEEE 519 Table 10.3.

C. PCC shall be considered:
1. Building service entrance switchgear, switchboard or MCC.
2. Each MCC, switchboard, switchgear, or panelboard supplying a VFD branch circuit.

D. The Design-Builder shall perform preliminary calculations based on typical VFD data and indicate the minimum mitigation measures required to meet the specified harmonic criteria.

E. VFD manufacturer shall determine, for their proposed equipment, uncorrected harmonic distortion levels and mitigation techniques required to meet the specified limits and shall furnish the VFD types and all accessory items and equipment necessary to do so, whether specified herein or not.

F. VFD manufacturer shall provide a harmonic analysis of the distribution system based on their proposed specific equipment characteristics and mitigation techniques confirming that the specified levels are not exceeded.
   1. Analysis shall be based on the methodology of IEEE 519 and IEEE 399.
   2. Power system data for analysis shall be taken from the electrical drawings and approved equipment submittals.
      a. VFDs provided in a package with equipment specified elsewhere, shall be included in the analysis.

G. Following start-up, with facility at full load operation, provide measurement of harmonic voltage, current and notch characteristics at each PCC according to the requirements of IEEE 519 Section 9.
   1. Values in excess of specified limits require correction by Design-Builder and re-measurement.
   2. Provide certification of compliant measurements as part of Field Service Engineer’s final report.

2.6 MOTOR PROTECTION REQUIREMENTS

A. The VFD shall produce a quality of output waveform adequate to allow the motor to produce rated torque at rated RPM continuously without exceeding the temperature rise given in NEMA MG 1 Table 31-2.

B. Provide motor overload, short circuit and ground fault protection integral to drive electronics.

C. The VFD shall not produce voltage spikes in excess of the following values at the motor terminals when operated with the feeder types shown on the Drawings and the actual installed feeder lengths.
   1. If unmitigated voltage peaks exceed the specified limits, provide output line reactors, filters, or other devices as required to meet the specified limits:
      a. Inverter duty motors: rated as required.
      b. Rise time shall be greater than or equal to 0.1 microsecond.
      c. Motor lead length and data shall be determined by the Design-Builder based on the actual routing of the conductors.

D. Following start-up, provide measurement of peak voltage at the terminals of each motor, unless the lead lengths are 10 percent shorter than the manufacturers published literature for maximum lead length for the type of cable installed.
   1. Values in excess of specified limits require correction by Design-Builder and re-measurement.
   2. Provide certification of compliant measurements as part of Field Service Engineer’s final report.

2.7 EQUIPMENT CONSTRUCTION

A. Fabrication and Assembly:
   1. Each VFD system shall be factory-assembled in an enclosure for remote mounting, and shall utilize interchangeable plug-in printed circuit boards and power conversion components wherever possible.

a. Factory assembly shall be performed by the VFD manufacturer or authorized agent.
b. Systems fabricated or assembled in whole or in part by parties other than the VFD manufacturer or authorized agent will not be acceptable.
2. Reactors and/or filters, where required, shall be mounted within or in an ancillary enclosure adjacent to the drive enclosure, or with the Engineer's permission may be mounted in a separate enclosure.
3. Cooling fans, as required, shall be provided to run when drive is running.
4. Enclosures for separately mounted VFD's:
   a. NEMA Type 1 for installation in Electrical Rooms.
   b. NEMA Type 12 for installation in other unclassified areas.

B. Wiring:
1. The wiring in the VFD shall be neatly installed in wire ways or with wire ties where wire ways are not practical.
   a. Where wire ties are used, the wire bundles are to be held at the back panel with a screw-mounted wire tie mounting base.
   b. Bases with a self-sticking back will not be allowed.
2. All plug-in contacts shall be gold-plated.
3. Provide terminal boards for all field wiring and inter-unit connections, including analog signals.
   a. Provide terminals for shield continuity where required.
4. Terminal blocks shall be complete with marking strip, covers and pressure connectors.
   a. Non-brittle, interlocking, track-mounted type.
   b. Screw terminals will not be allowed.
   c. A terminal for each conductor of external circuits plus one (1) ground for each shielded cable.
   d. For free-standing panels, 8 IN of clearance shall be provided between terminals and the panel base for conduit and wiring space.
   e. Not less than 25 percent spare terminals shall be provided.
   f. Terminals shall be labeled to agree with identification indicated on the suppliers submittal drawings.
   g. Individually fuse each control loop or system and all fuses or circuit breakers shall be clearly labeled and located for easy maintenance.
5. All grounding wires shall be attached to the enclosure sheet metal with a ring tongue terminal.
   a. The surface of the sheet metal shall be prepared to assure good conductivity and corrosion protection.
6. Wiring shall not be kinked or spliced and shall have markings on both ends or be color coded.
   a. Markings or color code shall match the manufacturer's drawings.
7. With the exception of electronic circuits, all interconnecting wiring and wiring to terminals for external connection shall be stranded copper, type MTW or SIS, insulated for not less than 600 V, with a moisture-resistant and flame-retardant covering rated for not less than 90 DegC.

C. Nameplates:
1. All devices mounted on the face of the drive shall be provided with a suitable nameplate as specified in Specification Section 10 14 00.
2. Push buttons, selector switches, and pilot lights shall have the device manufacturer's standard legend plate.
3. Relays, terminals and special devices inside the control enclosure shall have permanent markings to match identification used on manufacturer's wiring diagrams.

D. Painting: Enclosure, after being phosphate washed, shall be thoroughly cleaned and given at least one (1) coat of rust-inhibiting primer on all inner surfaces prior to fabrication.

2.8 COMPONENTS AND ACCESSORIES

A. Reactors:
  1. Impedance: As required.
  2. Continuous current: Not less than drive rating.
  3. Current overload: 150 percent for 1 minute.
  4. Insulation temperature rating: 180 DegC.
  5. Copper windings.
  6. Saturation current rating: 3.5 to 5 times rated current.
  7. Hi-potential rating: 2500 Vac line to ground and line to line, for 1 minute.
  8. Noise reduction features:
     a. Epoxy over cast coil.
     b. Extra dips and bakes of varnish over continuous wound coil.

2.9 SOURCE QUALITY CONTROL

A. Factory Tests:
  1. Conduct all standard tests in accordance with NEMA and ANSI standards to ensure conformance to Specification requirements.
  2. Prior to final assembly:
     a. Inspect incoming components.
     b. Test and inspect power devices.
     c. Circuit cards:
        1) Component and functional tests:
        2) Burn-in chamber or temperature cycling test.
        3) System test after burn-in or temperature cycling.
  3. After final assembly:
     a. Continuity and insulation test of 480 power control circuits.
     b. Drive tests:
        1) Burn-in complete drive at full load for 24 HRS.
        2) Verify all auxiliary circuits operation.
        3) Monitor output variables.
     c. Systems test:
        1) Provide inputs to field connections and simulate on-site operation.
        2) Test all auxiliary equipment.

2.10 MAINTENANCE MATERIALS

A. Provide manufacturer's recommended renewable spare parts (e.g., power and control fuses).

B. Spare parts utilized during pre-start-up or start-up and demonstration testing shall be immediately restocked, at no cost to the Owner.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install products in accordance with manufacturer's instructions and as indicated on the Drawings.

B. Verify the installed motor nameplate electrical requirements do not exceed the VFD capacity.

C. Provide services of manufacturer's representative to perform start-up services.

D. The selection of input and output harmonic and voltage spike protection shall also be made on the available physical space.
   1. The space available on the Drawings shall not be exceeded.

3.2 START UP

A. Pre-start-up Services:
   1. Shall be completed a minimum of 30 days prior to the start-up and demonstration period described in Specification Section 26 05 00.
   2. Shall consist of:
      a. Physical and electrical installation check.
      b. Final adjustments and calibration of drive parameters.
      c. VFD operation from simulated input signals.
   3. Shall be complete when VFD(s) are fully operational.

B. Field Quality Control:
   1. Perform field measurement of harmonics at each PCC per Harmonic Protection Requirements Article.
      a. For each individual VFD.
      b. For the maximum number of VFDs that will be operational at the same time.
      c. When all loads are at 75 percent load minimum.
      d. Duration: 1 HR minimum.
   2. Perform field measurement of the maximum voltage peak at the terminals of each motor fed from a VFD per Motor Protection Requirements Article.
      a. Use a high speed oscilloscope to produce a plot of Voltage (Y axis) versus Time (X axis).
         1) Time shall be measured in microseconds.
      b. Tests shall be performed at full:
         1) Full voltage and speed.
         2) Loaded to 75 percent minimum.
         3) Duration: 1 HR minimum.
   3. Record all data necessary for the preparation of required test reports.

C. Start-up and Demonstration Services:
   1. Supervise start-up of all units including recheck of settings made during the pre-start-up tests.
      a. Perform all work in the presence of the Owner's designated representatives.
   2. Setup all VFDs with carrier frequency at minimum value consistent with proper operation; inform Engineer of carrier frequencies set in excess of 5 kHz and reason for setting.
   3. Simulate operation of the VFD and its associated control and instrumentation system in both the manual and automatic modes.
      a. Ensure compatibility of VFD with associated control and instrumentation signals.
   4. Simulate VFD failures and demonstrate troubleshooting aids.

D. Instruct Owner's designated personnel:
   1. Minimum of 8 HRS at the jobsite.
   2. Include both field and classroom instruction.
   3. Instructions shall include proper operation and maintenance procedures including, but not limited to:
      a. Lubrication.
      b. Troubleshooting.
      c. Repair and replacement.
      d. Parts inventory.
      e. Maintenance records.

3.3 SCHEDULES

A. Several motors may have full load amps (FLA) greater than that listed in NFPA 70.
   1. The Design-Builder shall provide a schedule of all the motors, as shown below, for review and approval by the Engineer:

EQUIPMENT TAG	HP	RPM	ESTIMATED FLA

END OF SECTION

SECTION 26 32 14

ENGINE GENERATOR: DIESEL

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Engine generator set and accessories.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.
   2. Section 01 25 13 - Product Substitution.
   3. Section 26 05 00 - Electrical: Basic Requirements.
   4. Section 26 05 48 - Seismic Bracing Systems.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. Environmental Protection Agency (EPA):
      a. 40 CFR Part 60, Subpart IIII, Protection of Environment, Standards of Performance for New Stationary Sources, Standards for Performance for Stationary Compression Ignition Internal Combustion Engines.
   2. National Electrical Manufacturers Association (NEMA):
      a. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
      b. MG 1, Motors and Generators.
   3. National Fire Protection association (NFPA):
      a. 70, National Electrical Code (NEC):
         1) Article 700, Emergency Systems.
         2) Article 701, Legally Required Standby Systems.
         3) Article 702, Optional Standby Systems.
   4. Underwriters Laboratories, Inc. (UL):
      a. 2200, Standard for Stationary Engine Generator Assemblies.

B. The engine generator set manufacturer or authorized supplier is designated to have single source responsibility for the supply of all components and installation of the unit.

1.3 SYSTEM DESCRIPTION

A. The engine generators will be used and rated for:
   1. Emergency power during a power outage, NFPA 70, Article 700.
   2. Legally required standby power during a utility power outage, NFPA 70, Article 701.
   3. Optional standby power during a utility power outage, NFPA 70, Article 702.

1.4 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
   2. Product technical data:
      a. Provide submittal data for all products specified in PART 2 of this Specification Section.
      b. See Specification Section 26 05 00 for additional requirements.
      c. Engine/generator performance curves.
   3. Fabrication and/or layout drawings.

a. Dimensional plan and elevation drawings.
b. Wire interconnection drawings.
4. Test reports:
a. Factory test reports.

B. Operations and Maintenance Manuals:
1. See Specification Section 26 05 00 or requirements for:
a. The mechanics and administration of the submittal process.
b. The content of Operation and Maintenance Manuals.

C. Miscellaneous Submittals:
1. Unit installation, startup and operational statement.
2. Field Quality Control test reports.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following manufacturers are acceptable:
1. Engine generator unit:
a. Cummins Onan.
b. Caterpillar.
c. Kohler.
2. Silencers:
a. Maxim.
b. GT Exhaust Systems.
c. Nelson.
3. Battery charger:
a. Manufacturer's standard.
4. Governor:
a. Manufacturer's standard.
5. Radiator:
a. Manufacturer's standard.
6. Vibration isolators:
a. Caldyne.
b. Mason Inds.
c. Ace.
7. Day tank:
a. Pryco.
b. Simplex Access Controls.
c. Tramont.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 EQUIPMENT

A. Emissions Requirements:
1. A single units emissions shall meet all Federal, State and Local government requirements, including but not limited too:
a. Environmental Protection Agencies (EPA) New Source Performance Standards (NSPS), 40 CFR Part 60, Subpart IIII.

2.3 COMPONENTS

A. Engine Generator Unit General:

1. Diesel engine direct-connected to alternating current generator mounted on suitable rigid steel skid supports.
2. Mount unit on skid suitable for installation on concrete foundation.
3. Base rating on operation at rated RPM when equipped with all operating accessories.
4. Standards: UL 2200.

B. Engine:
1. Four-cycle, full compression ignition, single acting, solid-injection unit, either vertical or V-type pistons turbo charged with inner and after cooling.
2. Fuel supply: No. 2 Diesel.
3. Removable full wet-type cylinder liners of close grained alloy iron, heat treated for proper hardness to obtain maximum life.
4. Capable of operating at idle or light loads for extended periods of time.

C. Injection Pumps and Valves:
1. Type not requiring adjustment in service, which may be individually removed and replaced.
2. Individual injection pump and valve for each cylinder.
3. Fuel injection pumps: Positive action, constant-stroke, actuated by cam driven by gears from engine crankshaft.
4. Fuel lines between injection pumps and valves: Heavy seamless steel tubing.
5. Flexible fuel line connectors for supply and return connections at pump.

D. Oil Pump:
1. Gear-type lubricating oil pump to supply oil under pressure to main bearings, crank pin bearings, pistons, timing gears, camshaft bearings and valve rocker mechanism.
2. Spray cool and lubricate pistons.
3. Oil filters so located that lubricating oil is continuously filtered, except during periods when oil is automatically by-passed to protect vital parts when filters are clogged.
4. Filter elements accessible and easily removable.
5. Filter elements: Effective full flow, replaceable resin-impregnated cellulose type.
6. Equip filter system with spring-loaded by-pass valve.
7. Oil cooler: Water-cooled, engine-mounted.

E. Fuel System:
1. Fuel pump: Built-in gear-type, engine-driven fuel transfer pump.
2. Equip fuel system with replaceable fuel filter elements arranged for easy removal without breaking any fuel line connections or disturbing fuel pumps or any other part of engine.
3. Locate all fuel filters in an accessible housing, ahead of injection pumps to thoroughly filter fuel before it reaches the pump.
4. Use no screens or filters requiring cleaning or replacement of injection pumps or valve assemblies.

F. Governor: Fully enclosed electronic type governor with actuator capable of providing accurate speed control within 1 percent of rated speed, complete with panel-mounted electronic assembly with ramp generator and speed-sensing modules.

G. Air Cleaners: Engine-mounted, dry type air cleaners of sufficient capacity.

H. Electric Starting System:
1. Sufficient capacity to crank at speed which will start engine under normal operating conditions.
2. Controls to provide automatic cranking of engine when generator is called to start.
3. Prevent excessive cranking which could damage cranking motor.
4. Automatic stop controls.
5. Starter motors with positive-engagement feature.

I. Cooling System:
  1. Capacity for cooling engine at the specified operating conditions.
  2. Engine driven, centrifugal type water circulating pump and thermostatic valve to maintain the engine at recommended temperature level.
  3. Unit mounted radiator.
     a. Core guard flexible duct adapter.
     b. Site glass at top of unit.
     c. Engine driven blower fan.
     d. Low water level cutoff switch.
  4. Provide fan guards.

J. Heater:
  1. Thermostatically controlled jacket water heater(s) to maintain cooling jacket at the manufacturer's recommended temperature at the specified low ambient temperature.
  2. Rated as required.

K. Silencer:
  1. Suitable type for residential silencing.
  2. Seamless, stainless steel, flexible, exhaust adapter for exhaust outlet to silencer.

L. Engine Instruments and Controls:
  1. Engine-mounted instruments:
     a. Oil pressure gage.
     b. Water temperature gage.
     c. Run time meter.
     d. Battery voltage meter.
  2. Automatic cycle cranking and over-crank protection.
  3. Safety controls: Equip engine with automatic safety controls to shut down engine in event of low lubricating oil pressure, high jacket water temperature, overspeed or overcrank.
  4. Auxiliary control devices: Either integral with specified engine instruments, control, and safety devices or as separate devices as required to operate various signal circuits specified for remote annunciator panel.
  5. Three (3) NO auxiliary contacts for interface with louvers, fans or other miscellaneous equipment.
     a. Contacts shall close when generator is started.

M. Fuel Day Tank:
  1. Double wall sub-base day tank mounted underneath engine generator unit.
  2. Steel construction, top and bottom baffles, steel channel side supports, weatherproof secondary containment, rust preventive interior coating, rust proofed and finish painted exterior.
  3. Tank connections: Fuel level gauge, fuel lines to generator, fill, vent, drain and pressure relief.
  4. Manual overfill protection.
  5. Low level warning with contacts for remote alarm.
     a. Set to alarm at 50 percent of capacity.
  6. Critical low level shutoff with contacts for remote alarm.
  7. Leak detection alarm with contacts for remote alarm.
  8. Capacity: As indicated on the plans..

N. Batteries:
  1. Nickel cadmium type.
  2. Furnish electrolyte separately for use when installation is complete and unit is ready for testing.

O. Battery Charger:
   1. Output current rating of at least 1/20th of ampere hour capacity of battery and capable of automatically switching between low rate (float) mode and high rate (equalize) mode.
   2. Solid state rectifiers, DC voltmeter and ammeter, fuse input and output, and 115 Vac input.
   3. Malfunction alarm contacts (minimum): low and high battery voltage, weak battery and charger failure.

P. Generator:
   1. Brushless, 6-pole drip-proof revolving field type with permanent magnet, 2/3 pitch stator, direct-coupled rotor, Class H insulation.
   2. Minimum continuous standby ratings:
      a. As indicated on the Drawings substantiated by manufacturer's standard published curves and conform to NEMA MG 1 specification.
      b. Special ratings or maximum ratings are not acceptable.
   3. Rated to serve up to 50 percent non-linear load without exceeding rated temperature rise.
   4. Minimum efficiency: 92 percent at 50 to 110 percent of nominal standby rating, less than 30 percent instantaneous voltage dip at full load and rated power factor and suitable for simultaneous operation with other future units connected in parallel.
   5. Stator and rotor: 125 DegC temperature rise with minimum Class F insulated with 100 percent epoxy impregnation and overcoat of resilient insulating material to reduce possible fungus and/or abrasive deterioration.
   6. Directly connect stator to engine flywheel housing.
   7. Drive rotor through semiflexible driving flange to ensure permanent alignment.
   8. Self ventilating with suitable blower, air inlet and outlet openings.
   9. Provide terminal box of adequate size for entrance of conduit and termination of conductors.
   10. Generator drive free from critical torsional vibration within operating range.
   11. Provide generator mounted main circuit breaker:
      a. Solid state molded case type.
      b. Ratings as indicated.

Q. Voltage Regulator:
   1. SCR type, to maintain 2 percent voltage regulation from 0 to full load with steady state modulation not exceeding plus 1/2 percent including cross-current compensation to provide maximum of 5 percent unbalance in kVA load sharing between this unit and possible future generators.
   2. Automatic protection against short circuits on system.
   3. Permit unit to operate at no load below rated frequency for engine start up and shut down procedures.
   4. Provide voltage level and gain controls for normal operating adjustments.
   5. Provide voltage level control with minimum range of plus or minus 5 percent from rated voltage.
   6. Mount regulator, volts per hertz type, in generator housing on suitable vibration isolators.

R. Generator Instruments and Controls:
   1. Generator mounted NEMA 1 type, illuminated vibration isolated instrument and control panel(s).
   2. AC voltmeter and phase selector switch.
   3. AC ammeter and phase selector switch.
   4. Frequency meter.
   5. Run-off-auto engine, start-stop control switch.
   6. Emergency stop.
   7. Run time meter.
   8. Governor control rheostat.

9. Voltage level adjustment rheostat.
10. Cool down time delay 0-15 minute adjustable.
11. Cycle cranking control.
12. Minimum red shut down indicating lights as follows:
    a. Overcrank.
    b. Overspeed.
    c. Low lubricating oil pressure.
    d. High engine water temperature.
13. Minimum amber alarm indicator lights as follows:
    a. Control switch not in auto position.
    b. Low engine water temperature (less than 70 DegF).
    c. Low fuel in day tank.
    d. Day tank leak.
    e. Battery charger malfunctioning.
    f. Low battery voltage.
14. Minimum amber prealarm indicator lights as follows:
    a. High engine water temperature.
    b. Low lubricating oil pressure.
15. Common dry contact and audible alarm to indicate when one (1) or more alarm or prealarm conditions exist.

S. Vibration Isolators: Vibration system shall consist of engine and generator mount isolators with or without additional mechanical spring isolators rubber pads to control both high and low frequency vibrations between major components, sub-base and structural foundation and to provide required vibration isolation for the seismic zone of the Project.

2.4 ACCESSORIES

A. Provide interposing relays (24 Vdc to 120 Vac) as required for interfacing with customer's 120 Vac monitoring system.

B. Generator remote annunciator panel:
1. Surface mounted NEMA 1 enclosure. {Flush mounted enclosure with flush plate} {Flush mounted with flush plate on ATS enclosure.}
2. Circuits:
    a. 24 Vdc powered from starting batteries.
    b. Verify circuit voltage to match battery voltage.
3. Provide red and green signal lamps, buzzer, silencing switch, lamp test switch, relays, solid-state components, and engraved function identifications.
4. Annunciator functions:
    a. Green light "ON" to indicate generator is operating to supply power to load.
    b. Separate red light for each shutdown or alarm condition and amber light for each prealarm condition and common buzzer with silence/ acknowledge switch.
    c. Shut down indicating lights as follows:
        1) Overcrank.
        2) Overspeed.
        3) Low lubricating oil pressure.
        4) High engine water temperature.
    d. Alarm indicator lights as follows:
        1) Control switch not in auto position.
        2) Low engine water temperature (less than 70 DegF).
        3) Low fuel in day tank.
        4) Fuel in day tank rupture basin.
        5) Battery charger malfunctioning.

6) Low battery voltage.

e. Prealarm indicator lights as follows:
1) High engine water temperature.
2) Low lubricating oil pressure.

C. Generator set non-walk-in weather protective enclosure:
1. Sheet steel with side servicing panels, air intake louvers and rear control panel access door.
2. Side servicing panels shall have two (2) locking points; all panels and doors are key lockable.
3. Pitched roof with silencing exhaust muffler mounted {inside} {or} {outside} the enclosure.
4. Completely install enclosure on generator set mounting base.

2.5 SOURCE QUALITY CONTROL

A. Individually test each prime mover.
1. Apply derating factors for the proposed site to test data.
2. Continuously test for a period no less than 2 HRS.
3. Test procedure shall be as follows:
a. Start prime mover and upon reaching rated RPM, pick up 100 percent of nameplate KW rating at rated power factor in one (1) step.
b. Observe and record the cranking time(s) required to start and run for each prime mover.
c. Observe and record the time required to come up to operating speed for each prime mover.
d. Record voltage and frequency overshoot for each prime mover.
e. Record voltage, frequency and amperes.
f. Record oil pressure, water temperature where applicable and battery charge rate at first load acceptance and at 15 minute intervals thereafter for each prime mover.

2.6 MAINTENANCE MATERIALS

A. Spare Parts:
1. Provide manufacturer's recommended spare parts.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install all components as indicated and in accordance with manufacturer's recommendations and instructions {and Specification Section 26 05 48}.

B. Fill cooling system with solution of 50-50 water and ethylene glycol anti-freeze to prevent freezing at temperatures as low as minus 30 DegF.

C. Provide fuel for a full day tank.

D. Install all wiring to engine in conduit.
1. Control wiring on engine may be factory installed in high temperature loom.

E. Provide control wiring in conduit between generator control panel {, remote annunciator panel(s)} and remote devices as described under generator instrument and controls paragraph and remote annunciator paragraph of this Specification.

F. Mount on concrete pad utilizing vibration/seismic isolators, see structural drawings for pad detail.

3.2 FIELD QUALITY CONTROL

A. Employ and pay for services of equipment manufacturer's field service representative(s) to:

1. Inspect equipment covered by this Specification Section.
2. Supervise pre-startup adjustments and installation checks.
3. Conduct initial startup of equipment and perform operational checks.
4. Provide Owner written statement that manufacturer's equipment has been installed properly, started up, tested, and is ready for operation by Owner's personnel.
5. Provide 4 HRS of the manufacturer's technical representative's time for on-site training of Owner's personnel.

B. Provide two (2) load tests and one (1) cycle crank test.
   1. Tests one (1) and two (2) shall be for continuous period of no less than 2 HRS each.
   2. Engineer and Owner shall be notified seven (7) days prior to testing.
   3. Test number one:
      a. With prime mover(s) in a "cold start" condition and emergency load at normal operating level, initiate a normal power failure by opening all switches or breakers supplying normal power to facility.
      b. Observe and record the time delay on engine start.
      c. Observe and record the cranking time(s) required to start and run for each prime mover.
      d. Observe and record the time required to come up to operating speed for each prime mover.
      e. Record voltage and frequency overshoot for each prime mover.
      f. Observe and record time required to achieve steady-state condition with all switches transferred to emergency position.
      g. Record voltage, frequency and amperes.
      h. Record oil pressure, water temperature where applicable and battery charge rate at 5-minute intervals for the first 15 minutes and at 15 minute intervals thereafter for each prime mover.
      i. Return normal power to facility, record time delay on retransfer to normal for each switch and cooldown time delay for each prime mover.
   4. Test number two:
      a. Immediately after completion of test number one, start prime mover and upon reaching rated RPM, pick up 100 percent of nameplate KW rating in one (1) step.
         1) Unity power factor is acceptable for on-site testing
      b. Observe and record the cranking time(s) required to start and run for each prime mover.
      c. Observe and record the time required to come up to operating speed for each prime mover.
      d. Record voltage and frequency overshoot for each prime mover.
      e. Observe and record time required to achieve steady-state condition.
      f. Record voltage, frequency and amperes.
      g. Record oil pressure, water temperature where applicable and battery charge rate at first load acceptance and at 15 minute intervals thereafter for each prime mover.
   5. Cycle crank test:
      a. Perform test for each prime mover.
         1) Utilize any method recommended by manufacturer to prevent prime mover(s) from running.
         2) Put control switch into "run" position to cause prime mover to crank.
      b. A complete cranking cycle shall consist of an automatic crank period of approximately 15 seconds duration followed by a rest period of approximately 15 seconds duration.
         1) Upon starting and running of the prime mover, further cranking shall cease.
         2) Two (2) means of cranking termination shall be utilized so that one (1) will act as a backup to the other to prevent inadvertent starter engagement.
         3) Cranking limiter time shall be 75 seconds for cycle crank.
   6. Furnish load banks of required ratings necessary for tests.

7. Record engine fuel consumption by means of test equipment.
8. Test all safeties specified for generator instruments and controls {and generator remote annunciator panel} as recommended by manufacturer and as required to verify proper operation.
9. Design-Builder shall be responsible for fuel and all consumables use during the test.

END OF SECTION

SECTION 26 36 00
TRANSFER SWITCHES

PART 1 - GENERAL

1.1 GENERAL

A. Section Includes:
   1. Manual transfer switches.
   2. Automatic transfer switches.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.
   2. Section 01 25 13 - Product Substitution.
   3. Section 26 05 00 - Electrical: Basic Requirements.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. National Electrical Manufacturers Association (NEMA):
      a. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
      b. KS 1, Enclosed and Miscellaneous Distribution Equipment Switches (600 Volts Maximum).
   2. Underwriters Laboratories, Inc. (UL):
      a. 98, Standard for Safety Enclosed and Dead-Front Switches.
      b. 1008, Standard for Safety Switch Equipment.

1.3 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
   2. Product technical data:
      a. Provide submittal data for all products specified in PART 2 of this Specification:
      b. See Specification Section 26 05 00 for additional requirements.

B. Operation and Maintenance Manuals:
   1. See Specification Section 26 05 00 for requirements for:
      a. The mechanics and administration of the submittal process.
      b. The content of Operation and Maintenance Manuals.

1.4 DELIVERY, STORAGE, AND HANDLING

A. See Specification Section 26 05 00.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the listed manufacturers are acceptable:
   1. Automatic transfer switches:
      a. Automatic Switch Company.
      b. Kohler.
      c. Onan.
      d. Russelectric.

        e. Zenith Products.
    2. Manual transfer switches:
        a. Automatic Switch Company.
        b. Cutler-Hammer.
        c. General Electric Company.
        d. Russelectric.
        e. Square D Company.
        f. Siemens.
        g. Zenith Products.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 MANUAL TRANSFER SWITCH

A. Double throw load break rated with:
    1. Quick-make/quick-break operating mechanism.
    2. Deionizating arc chutes.
    3. Double-break rotary action shaft and switchblade shall be manufactured as one (1) common component.
    4. Clear line shields to prevent accidental contact with line terminals.

B. Operating handle: Easily recognizable and padlockable in both positions.

C. Wiring configuration to allow single load to be supplied by a normal or alternate source.

D. Ratings:
    1. Voltage and amperage: As indicated on Drawings.
    2. Short circuit withstand: Equal to or greater than the upstream equipment.

E. Multiple switches shal be interlocked both mechanically and electrically.

F. Enclosure:
    1. NEMA 4X rated:
        a. Body and cover: Type 304 or 316 stainless steel.
        b. No knockouts, external mounting flanges, hinged, gasketed and lockable door.

G. Standards: NEMA KS 1, UL 98.

2.3 AUTOMATIC TRANSFER SWITCH

A. Construction:
    1. Electrically operated mechanically held, double throw, air-break type.
    2. Silver-surface main contacts and protect by arcing contacts.
    3. Switch shall have provisions for visual inspection of switch blades and contacts.
    4. Mechanical design will positively open all ungrounded conductors from normal source before connection is made to alternate source and will positively open alternate source before connection is made to normal source.
    5. Mechanical interlock to ensure the switch cannot be readily disabled, disconnected, improperly adjusted, removed or otherwise made inoperative.
    6. Make all contacts and coils readily accessible for replacement from front of panel without major disassembly.
    7. Ratings:
        a. Continuous duty in both normal and emergency.
        b. Three-phase, four-pole, four-wire.
        c. Voltage and current ratings as indicated on the Drawings.
        d. Short circuit withstand rating equal to or greater than the normal source electrical gear.
    8. Standards: UL 1008.

B. Operation:
   1. Microprocessor based control module.
   2. Closed transition.
   3. Red and green indicating lights with fuses, identification nameplates, and test switch on front to simulate normal power failure at switch.
   4. Engine starting contacts and all other auxiliary contacts and accessory devices for functions to be performed.
   5. Supervisory voltage relays on each phase of normal source and single phase supervisory voltage and frequency relay for emergency source.
      a. Normal source voltage sensing.
         1) Adjustable pickup from 85-100 percent of rated voltage, factory set 90 percent.
         2) Adjustable dropout from 75-98 percent of pickup setting, factory set 85 percent.
      b. Emergency source voltage and frequency sensing:
         1) Adjustable pickup from 85-100 percent of rated voltage, factory set 90 percent.
         2) Fixed voltage dropout at 85 percent of pickup setting.
         3) Adjustable pickup from 90-100 percent of rated frequency, factory set 95 percent.
         4) Fixed frequency dropout at 88 percent of pickup setting.
   6. Time delays:
      a. Engine start, adjustable from 0 to 10 seconds, factory set at 4 seconds, to avoid unnecessary starting caused by short time outages.
      b. Transfer to generator, adjustable from 0 to 120 seconds, factory set at 10 seconds.
      c. Retransfer to normal, adjustable from 2 to 30 minutes, factory set at 15 minutes to avoid erratic operation caused by short time reestablishment of normal source.
         1) Automatically bypassed when emergency source fails and normal source is available.
      d. Generator cool down, adjustable from 0 to 60 minutes, factory set at 10 minutes.
   7. Exerciser timer:
      a. Enable and disable function.
      b. Selectable to exercise with or without transferring load.
      c. Adjustable exercise duration from 1 minute to 24 HRS, factory set at 15 minutes.
      d. Adjustable day of the week exercise setting, factory set for Monday.
   8. Inphase monitor:
      a. Compare the phase relationship and frequency difference between the normal and emergency sources and permit transfer the first time the sources are within 15 electrical degrees and only if transfer can be accomplished within 60 electrical degrees as determined by monitoring the frequency differences.
      b. Inphase transfer accomplished if both sources are within 2 Hz of rated frequency and 70 percent or more of rated voltage.
   9. Multiple transfer switches shall be interlocked both mechanically and electrically.

C. Enclosure:
   1. NEMA 4X rated:
      a. Body and cover: Type 304 or 316 stainless steel.
      b. No knockouts, external mounting flanges, hinged, gasketed and lockable door.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install as indicated and in accordance with manufacturer's recommendations and instructions.

B. Connect as indicated in one-line diagram.

C. Mounting of manual transfer switches: Wall-mounted.

D. Mounting of automatic transfer switches:
   1. Wall-mounted or floor mounted on 4 IN high concrete pad.

E. Manual Transfer Switch Enclosure:
   1. Permitted uses of NEMA 1 rated enclosure:
      a. Surface mounted in areas designated as dry.
   2. Permitted uses of NEMA 4X rated enclosure:
      a. Surface mounted in areas designated as wet and/or corrosive.

3.2 FIELD QUALITY CONTROL

A. Automatic Transfer Switch Testing:
   1. Simulate power outage by opening normal source overcurrent device.
      a. Verify engine generator starts and switch transfers in the specified time.
   2. Close normal source overcurrent device to simulate the return of normal power.
      a. Verify the switch retransfers and engine generator shuts down in the specified time.
   3. Perform a manual transfer and retransfer.
   4. Verify the indicator lights function properly.
   5. Verify all safety interlocks.

END OF SECTION

SECTION 26 41 13
LIGHTNING PROTECTION SYSTEM

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Material, design and installation requirements for:
      a. Lightning protection system.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.
   2. Section 01 25 13 - Product Substitution.
   3. Section 26 05 26 - Grounding.
   4. Section 26 05 33 - Raceways and Boxes.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. Lightning Protection Institute (LPI):
      a. 175, Standard of Practice for the Design - Installation - Inspection of Lightning Protection Systems.
   2. National Fire Protection Association (NFPA):
      a. 780, Standard for the Installation of Lightning Protection Systems.
   3. Underwriters Laboratories, Inc. (UL):
      a. 96A, Standard for Installation Requirements for Lightning Protection Systems.

1.3 DEFINITIONS

A. Classification of Buildings per NFPA 780:
   1. Class I: Any commercial, industrial, or residential building less than 75 FT in height.
   2. Class II: Any commercial, industrial, or residential building 75 FT or taller.
   3. Heavy-duty stacks: Any smoke or vent stack with a flue cross-section area greater than 500 SQ IN and a stack height greater than 75 FT.

1.4 SYSTEM DESCRIPTION

A. Provide a complete lightning protection system on the following:
   1. Towers.
   2. As required to render a complete code compliant lightning protection system.

1.5 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
   2. Product technical data:
      a. Provide submittal data for all products specified in PART 2 of this Specification Section.
      b. Provide manufacturer's technical information on products to be used, including product descriptive bulletin.

c. Include data sheets that include manufacturer's name and product model number. Clearly identify all optional accessories.
d. Acknowledgement that products submitted are in compliance with LPI or UL.
e. Manufacturer's delivery, storage, handling and installation instructions.
f. Equipment installation details.
3. Fabrication and/or layout drawings:
a. Plan drawing showing type, size, and locations of all lightning protection hardware. Roof penetration details.
c. Verification that the installation shall comply with the requirements of, and shall qualify for the UL Master Label Certificate.

B. Operation and Maintenance Manuals:
1. See Specification Section 26 05 00 for requirements for:
a. The mechanics and administration of submittal process.
b. The content of Operation and Maintenance Manuals.
2. Product data and as-built layout drawings.
3. Requirements for, and frequency of, periodic inspections.

C. Miscellaneous Submittals:
1. UL Master Label Certificate.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following manufacturers are acceptable:
1. A-C Lightning Security, Inc.
2. Harger Lightning Protection.
3. Heary Brothers.
4. National Lightning Protection (NLP).
5. Robbins Lightning Protection Company.
6. Thompson Lightning Protection, Inc.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 MATERIALS

A. Standards: NFPA 780, UL 96A.

B. Material for air terminals, main conductors and bonding conductors: Copper or aluminum.

C. Size of air terminals, main conductors and bonding conductors: In accordance with Tables 3-1.1(a) and 3-1.1(b) of NFPA 780.

D. Ground rods: In accordance with Specification Section 26 05 26.

E. Material for conductor fasteners, connector fittings, bonding fittings, conductor splicers and thru-wall or thru-roof assemblies: Cast bronze, brass or copper with bolt pressure connectors.

F. Material for bolts, nuts, and screws: Stainless steel.

G. Raceways: In accordance with Specification Section 26 05 33.

PART 3 - EXECUTION

3.1 INSTALLATION

A. General:
1. Design and installation standards: LPI 175, NFPA 780, UL 96A.
2. Lightning protection material selected shall be compatible with the material of construction for the structure being protected.

B. Structures and/or Buildings:
1. The protection system shall utilize Class I or Class II materials as defined by NFPA 780.
2. The system shall include:
    a. Roof mounted air terminals.
    b. Interconnecting conductors.
    c. Downleads:
        1) Conductors encased in rigid non-metallic conduit concealed within the exterior wall.
    d. Ground terminations.
    e. Bonding of other grounded structure/building systems.
3. Connect down leads to individual ground rods.
4. Connection to grounding electrode system shall be made in accordance with Specification Section 26 05 26.

3.2 FIELD QUALITY CONTROL

A. Installation shall be performed in accordance with UL and NFPA.

B. The completed installation shall qualify for and receive the UL Master Label Certificate.

C. Provide a nameplate, attached to the structure, which includes the name and address of the Design-Builder responsible for the installation of the lightning protection system.

END OF SECTION

SECTION 26 43 13

LOW VOLTAGE SURGE PROTECTION DEVICES (SPD)

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Type 1 SPD - High exposure locations (switchgear, switchboard, panelboard or motor control center), integrally mounted.
   2. Type 2 SPD - High exposure locations (switchgear, switchboard, panelboard or motor control center), externally mounted.
   3. Type 3 SPD - Medium exposure locations (switchboard, panelboard and motor control center), integrally mounted.
   4. Type 4 SPD - Medium exposure location (switchboard, panelboard and motor control center), externally mounted.
   5. Type 5 SPD - Medium or low exposure locations at individual equipment locations, external, parallel connection.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.
   2. Section 26 05 00 - Electrical: Basic Requirements.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
      a. C62.41, Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits.
      b. C62.41.1, Guide on the Surge Environment in Low-Voltage (1000V and Less) AC Power Circuits.
      c. C62.41.2, Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and Less) AC Power Circuits.
      d. C62.45, Recommended Practice on Surge Testing For Equipment Connected to Low-Voltage (1000V and Less) AC Power Circuits.
   2. Military Standard:
      a. MIL-STD-220B, Method of Insertion-Loss Measurement.
   3. National Electrical Manufacturers Association (NEMA):
      a. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
      b. LS 1, Low Voltage Surge Protective Devices.
   4. National Fire Protection Association (NFPA):
      a. 70, National Electrical Code (NEC).
   5. Underwriters Laboratories, Inc. (UL):
      a. 1283, Standard for Electromagnetic Interference Filters.
      b. 1449, Standard for Safety Transient Voltage Surge Suppressors.

B. Qualifications:
   1. Provide devices from a manufacturer who has been regularly engaged in the development, design, testing, listing and manufacturing of SPDs of the types and ratings required for a period of 10 years or more and whose products have been in satisfactory use in similar service.
      a. Upon request, suppliers or manufacturers shall provide a list of not less than three (3) customer references showing satisfactory operation.

1.3 DEFINITIONS

A. Clamping Voltage:
   1. The applied surge shall be induced at the 90 degree phase angle of the applied system frequency voltage.
   2. The voltage measured at the end of the 6 IN output leads of the SPD and from the zero voltage reference to the peak of the surge.

B. Let-Through Voltage:
   1. The applied surge shall be induced at the 90 degree phase angle of the applied system frequency voltage.
   2. The voltage measured at the end of the 6 IN output leads of the SPD and from the system peak voltage to the peak of the surge.

C. Maximum Continuous Operating Voltage (MCOV): The maximum steady state voltage at which the SPD device can operate and meet its specification within its rated temperature.

D. Maximum Surge Current:
   1. The maximum 8 x 20 microsecond surge current pulse the SPD device is capable of surviving on a single-impulse basis without suffering either performance degradation or more than 10 percent deviation of clamping voltage at a specified surge current.
   2. Listed by mode, since number and type of components in any SPD may very by mode.

E. MCC: Motor Control Center.

F. Protection Modes: This parameter identifies the modes for which the SPD has directly connected protection elements, i.e., line-to-neutral (L-N), line-to-line (L-L), line-to-ground (L-G), neutral-to-ground (N-G).

G. Surge Current per Phase:
   1. The per phase rating is the total surge current capacity connected to a given phase conductor.
      a. For example, a wye system surge current per phase would equal L-N plus L-G; a delta system surge current per phase would equal L-L plus L-G.
      b. The N-G mode is not included in the per phase calculation.

H. System Peak Voltage: The electrical equipment supply voltage sine wave peak (i.e., for a 480/277 V system the L-L peak voltage is 679V and the L-N peak voltage is 392 V).

1.4 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
   2. Product technical data including:
      a. Manufacturer's qualifications.
      b. Standard catalog cut sheet.
      c. Electrical and mechanical drawing showing unit dimensions, weights, mounting provisions, connection details and layout diagram of the unit.
      d. Testing procedures and testing equipment data.
      e. Create a Product Data Sheet for each different model number of SPD provided (i.e., Model XYZ with disconnect and Model XYZ without disconnect, each require a Product Data Sheet).
         1) Data in the Product Data Sheet heading:
            a) SPD Type Number per PART 2 of the Specification.
            b) Manufacturer’s Name.
            c) Product model number.

2) Data in the Product Data Sheet body:
   a) Column one: Specified value/feature of every paragraph of PART 2 of the Specification.
   b) Column two: Manufacturer’s certified value confirming the product meets the specified value/feature.
   c) Name of the nationally recognized testing laboratory that preformed the tests.
   d) Warranty information.
3) Data in the Product Data Sheet closing:
   a) Signature of the manufacturer’s official (printed and signed).
   b) Title of the official.
4) Date of signature.

B. Operation and Maintenance Manual:
   1. See Specification Section 26 05 00 for requirements for:
      a. The mechanics and administration of submittal process.
      b. The content of the Operation and Maintenance Manuals.
   2. Warranty.

1.5 WARRANTY

A. Minimum of a five (5) year Warranty from date of shipment against failure when installed in compliance with applicable national/local electrical codes and the manufacturer's installation, operation and maintenance instructions.

PART 2 - PRODUCTS

2.1 GENERAL

A. Standards: IEEE C62.41.1, IEEE C62.41.2, IEEE C62.45, NEMA LS 1, MIL-STD 220B, UL 1283, UL 1449.

2.2 TYPE 1 SPD

A. Product:
   1. SPD tag number or electrical equipment tag number SPD is connected to.
   2. Integrally mounted in switchgear, switchboards or MCCs.
   3. Hybrid solid-state high performance suppression system.
      a. Do not use a suppression system with gas tubes, spark gaps or other components which might short or crowbar the line resulting in interruption of normal power flow to connected loads.
   4. Do not connect multiple SPD modules in series to achieve the specified performance.
   5. Designed for parallel connection.
   6. Field connection: Use mechanical or compression lugs for each phase, neutral and ground that will accept bus bar or conductors sized as required.
   7. Device monitor:
      a. Long-life, solid state, externally visible indicators and Form C dry contact(s) that monitors the on-line status of each mode of the units suppression filter system and power loss in any of the phases.
      b. A fuse status only monitor system is not acceptable.

B. Operating Voltage: The nominal unit operating voltage and configuration as indicated on Drawings.

C. Modes of Protection: All modes.
   1. Three phase (delta): L-L, L-G.
   2. Three phase (wye): L-N, L-L, L-G and N-G.

3. Single phase (2 pole): L-L, L-N, L-G and N-G.
4. Single phase: L-N, L-G and N-G.

D. Maximum Continuous Operating Voltage: Less than 130 percent of system peak voltage.

E. Operating Frequency: 45 to 65 Hz.

F. Short Circuit Rating: Equal to or greater than rating of equipment SPD is connected to.

G. Maximum Surge Current: 240,000 A per phase, 120,000 A per mode minimum.

H. Minimum Repetitive Surge Current Capacity: 4000 IEEE C High waveform impulses with no degradation greater than 10 percent deviation of the clamping voltage.

I. SPD Protection:
1. Integral unit level and/or component level overcurrent fuses and sustained overvoltage thermal cutout device.
2. An IEEE C High waveforms shall not cause the fuse to open and render the SPD inoperable.

J. Maximum Clamping Voltages: Dynamic test at the 90 degree phase angle including 6 IN lead length and measured from the zero voltage reference:

		IEEE C62.41		
System Voltage	**Test Mode**	**C High V & I Wave**	**B Combination Wave**	**UL 1449**
L-L < 250 V	L-L	1470 V	1000 V	800 V
L-N < 150 V	L-N	850 V	600 V	500 V
	L-G	1150 V	800 V	600 V
	N-G	1150 V	800 V	600 V
L-L > 250 V	L-L	2700 V	2000 V	1800 V
L-N > 150 V	L-N	1500 V	1150 V	1000 V
	L-G	2000 V	1550 V	1200 V
	N-G	2000 V	1550 V	1200 V

K. EMI-RFI Noise Rejection: Attenuation greater than 30 dB for frequencies between 100 kHz and 100 MHz.

2.3 TYPE 2 SPD

A. Product:
1. SPD tag number or electrical equipment tag number SPD is connected to.
2. Externally mounted next to switchgear, switchboards or MCCs.
3. Hybrid solid-state high performance suppression system.
    a. Do not use suppression system with gas tubes, spark gaps or other components which might short or crowbar the line resulting in interruption of normal power flow to connected loads.
4. Do not connect multiple SPD modules in series to achieve the specified performance.
5. Designed for parallel connection.
6. Enclosure:
    a. Metallic NEMA 4 or 12 for interior locations.
    b. Metallic NEMA 4 or 4X for exterior locations.
7. Field connection:
    a. Mechanical or compression lugs for each phase, neutral and ground that will accept #10 through #1/0 conductors.
8. Device monitor:

a. Long-life, solid state, externally visible indicators and Form C dry contact(s) that monitor the on-line status of each mode of the units suppression filter system or power loss in any of the phase.
b. A fuse status only monitor system is not acceptable.

9. Accessories (when specifically specified): Unit mounted disconnect switch.

B. Operating Voltage: Nominal unit operating voltage and configuration as indicated on the Drawings.

C. Modes of Protection: All modes.
1. Three phase (delta): L-L, L-G.
2. Three phase (wye): L-N, L-L, L-G and N-G.
3. Single phase (2 pole): L-L, L-N, L-G and N-G.
4. Single phase: L-N, L-G and N-G.

D. Maximum Continuous Operating Voltage: Less than 130 percent of system peak voltage.

E. Operating Frequency: 45 to 65 Hz.

F. Short Circuit Rating: Equal to or greater than rating of equipment SPD is connected to.

G. Maximum Surge Current: 240,000 A per phase, 120,000 A per mode minimum.

H. Minimum Repetitive Surge Current Capacity: 4000 IEEE C High waveform impulses with no degradation of more than 10 percent deviation of the clamping voltage.

I. SPD Protection:
1. Integral unit level and/or component level overcurrent fuses and sustained overvoltage thermal cutout device.
2. An IEEE C High waveforms shall not cause the fuse to open and render the SPD inoperable.

J. Maximum Clamping Voltages: Dynamic test at the 90 degree phase angle including 6 IN lead length and measured from the zero voltage reference:

		IEEE C62.41		
System Voltage	**Test Mode**	**C High V & I Wave**	**B Combination Wave**	**UL 1449**
L-L < 250 V	L-L	1470 V	1000 V	800 V
L-N < 150 V	L-N	850 V	600 V	500 V
	L-G	1150 V	800 V	600 V
	N-G	1150 V	800 V	600 V
L-L > 250 V	L-L	2700 V	2000 V	1800 V
L-N > 150 V	L-N	1500 V	1150 V	1000 V
	L-G	2000 V	1550 V	1200 V
	N-G	2000 V	1550 V	1200 V

K. EMI-RFI Noise Rejection: Attenuation greater than 30 dB for frequencies between 100 kHz and 100 MHz.

2.4 TYPE 3 SPD

A. Product:
1. SPD tag number or electrical equipment tag number SPD is connected to.
2. Integrally mounted in a switchboard, panelboards or motor control centers.
3. Hybrid solid state high performance suppression system.

a. Do not use gas tubes, spark gaps or other components in suppression system which might short or crowbar the line resulting in interruption of normal power flow to connected loads.

4. Do not connect multiple SPD modules in series to achieve the specified performance.
5. Designed for parallel connection.
6. Field connection: Use mechanical or compression lugs for each phase, neutral and ground that will accept bus bar or #10 through #1/0 conductors.
7. Device monitor:
   a. Long-life, solid state, externally visible indicators and Form C contact(s) that monitor the on-line status of each mode of the units suppression filter system or power loss in any of the phases.
   b. A fuse status only monitor system is not acceptable.

B. Operating Voltage: The nominal unit operating voltage and configuration as indicated on the Drawings.

C. Modes of Protection: All modes.
1. Three phase (delta): L-L, L-G.
2. Three phase (wye): L-N, L-L, L-G and N-G.
3. Single phase (2 pole): L-L, L-N, L-G and N-G.
4. Single phase: L-N, L-G and N-G.

D. Maximum Continuous Operating Voltage: Less than 130 percent of system peak voltage.

E. Operating Frequency: 45 to 65 Hz.

F. Short Circuit Rating: Equal to or greater than rating of equipment SPD is connected to.

G. Maximum Surge Current: 160,000 A per phase, 80,000 A per mode minimum.

H. Minimum Repetitive Surge Current Capacity: 4000 IEEE C High or B combination waveform impulses with no degradation of more than 10 percent deviation of the clamping voltage.

I. SPD Protection:
1. Integral unit level and/or component level overcurrent fuses and sustained overvoltage thermal cutout device.
2. An IEEE B combination wave shall not cause the fuse to open and render the SPD inoperable.

J. Maximum Clamping Voltages: Dynamic test at the 90 degree phase angle including 6 IN lead length and measured from the zero voltage reference:

System Voltage	Test Mode	IEEE C62.41 B Comb. Wave	IEEE C62.41 B3 Ring Wave	UL 1449
L-L < 250 V	L-L	1000 V	700 V	800 V
L-N < 150 V	L-N	600 V	400 V	500 V
	L-G	800 V	550 V	600 V
	N-G	800 V	550 V	600 V
L-L > 250 V	L-L	2000 V	1400 V	1800 V
L-N > 150 V	L-N	1150 V	800 V	1000 V
	L-G	1550 V	1000 V	1200 V
	N-G	1550 V	1000 V	1200 V

K. EMI-RFI Noise Rejection: Attenuation greater than 30 dB for frequencies between 100 kHz and 100 MHz.

2.5 TYPE 4 SPD

A. Product:
1. SPD tag number or electrical equipment tag number SPD is connected to.
2. Externally mounted next to Switchgear, Switchboards or Motor Control Centers.
3. Hybrid solid state high performance suppression system.
    a. Do not use gas tubes, spark gaps or other suppression system components which might short or crowbar the line resulting in interruption of normal power flow to connected loads.
4. Do not connect multiple SPD modules in series to achieve the specified performance.
5. Designed for parallel connection.
6. Enclosure:
    a. Metallic NEMA 4 or 12 for interior locations.
    b. Metallic NEMA 4 or 4X for exterior locations.
7. Field connection:
    a. Mechanical or compression lugs for each phase, neutral and ground that will accept conductors sized as required.
8. Device monitor:
    a. Long-life, solid state, externally visible indicators and Form C dry contact(s) that monitor the on-line status of each mode of the units suppression filter system or power loss in any of the phase.
    b. A fuse status only monitor system is not acceptable.
9. Accessories (when specifically specified): Unit mounted disconnect switch.

B. Operating Voltage: Nominal unit operating voltage and configuration as indicated on the Drawings.

C. Modes of Protection: All modes.
1. Three phase (delta): L-L, L-G.
2. Three phase (wye): L-N, L-L, L-G and N-G.
3. Single phase (2 pole): L-L, L-N, L-G and N-G.
4. Single phase: L-N, L-G and N-G.

D. Maximum Continuous Operating Voltage: Less than 130 percent of system peak voltage.

E. Operating Frequency: 45 to 65 Hz.

F. Maximum Surge Current: 160,000 A per phase, 80,000 A per mode minimum.

G. Minimum Repetitive Surge Current Capacity: 4000 IEEE C High or B combination waveform impulses with no degradation of more than 10 percent deviation of the clamping voltage.

H. SPD Protection:
1. Integral unit level and/or component level overcurrent fuses and sustained overvoltage thermal cutout device.
2. An IEEE B combination wave shall not cause the fuse to open and render the SPD inoperable.

I. Maximum Clamping Voltages: Dynamic test at the 90 degree phase angle including 6 IN lead length and measured from the zero voltage reference:

System Voltage	Test Mode	IEEE C62.41 B Comb. Wave	IEEE C62.41 B Ring Wave	UL 1449
L-L < 250 V	L-L	1000 V	700 V	800 V
L-N < 150 V	L-N	600 V	400 V	500 V
	L-G	800 V	550 V	600 V

	N-G	800 V	550 V	600 V
L-L > 250 V	L-L	2000 V	1400 V	1800 V
L-N > 150 V	L-N	1150 V	800 V	1000 V
	L-G	1550 V	1000 V	1200 V
	N-G	1550 V	1000 V	1200 V

J. EMI-RFI Noise Rejection: Attenuation greater than 30 dB for frequencies between 100 kHz and 100 MHz.

2.6 TYPE 5 SPD

A. Product:
1. SPD tag number or electrical equipment tag number SPD is connected to.
2. Externally mounted next to equipment or internally to control panel for point-of-use loads.
3. Hybrid solid state high performance suppression system.
   a. Do not use gas tubes, spark gaps or other suppression system components which might short or crowbar the line resulting in interruption of normal power flow to connected loads.
4. Designed for parallel connection.
5. Enclosure:
   a. Metallic NEMA 4 or 12 for interior locations.
   b. Metallic NEMA 4 or 4X for exterior locations.
6. Field connection:
   a. Mechanical or compression lugs for each phase, neutral and ground that will accept #10 through #1/0 conductors.
7. Device monitor:
   a. Long-life, solid state, externally visible indicators and Form C dry contact(s) that monitor the on-line status of each mode of the units suppression filter system or power loss in any of the phase.
   b. A fuse status only monitor system is not acceptable.
8. Accessories (when specifically specified): Unit mounted disconnect switch.

B. Operating Voltage: Nominal unit operating voltage and configuration as indicated on the Drawings.

C. Modes of Protection: All modes.
1. Three phase (delta): L-L, L-G.
2. Three phase (wye): L-N, L-L, L-G and N-G.
3. Single phase (2 pole): L-L, L-N, L-G and N-G.
4. Single phase: L-N, L-G and N-G.

D. Maximum Continuous Operating Voltage: Less than 130 percent of system peak voltage.

E. Operating Frequency: 45 to 65 Hz.

F. Short Circuit Rating: Equal to or greater than rating of equipment SPD is connected to.

G. Maximum Surge Current: 120,000 A per phase, 60,000 A per mode minimum.

H. Minimum Repetitive Surge Current Capacity: 4000 IEEE C High or B combination waveform impulses with no degradation of more than 10 percent deviation of the clamping voltage.

I. SPD Protection:
1. Integral unit level and/or component level overcurrent fuses and sustained overvoltage thermal cutout device.

2. An IEEE B combination wave shall not cause the fuse to open and render the SPD inoperable.

J. Maximum Clamping Voltages: Dynamic test at the 90 degree phase angle including 6 IN lead length and measured from the zero voltage reference:

		IEEE C62.41		
System Voltage	**Test Mode**	**B Comb. Wave**	**B Ring Wave**	**UL 1449**
L-L < 250 V	L-L	1000 V	700 V	800 V
L-N < 150 V	L-N	600 V	400 V	500 V
	L-G	800 V	550 V	600 V
	N-G	800 V	550 V	600 V
L-L > 250 V	L-L	2000 V	1400 V	1800 V
L-N > 150 V	L-N	1150 V	8000 V	1000 V
	L-G	1550 V	1000 V	1200 V
	N-G	1550 V	1000 V	1200 V

K. EMI-RFI Noise Rejection: Attenuation greater than 30 dB for frequencies between 100 kHz and 100 MHz.

2.7 SOURCE QUALITY CONTROL

A. SPD approvals and ratings shall be obtained by manufacturers from nationally recognized testing laboratories.

B. The SPD are to be tested as a complete SPD system including:
1. Integral unit level and/or component level fusing.
2. Neutral and ground shall not be bonded during testing.
3. 6 IN lead lengths.
4. Integral disconnect switch when provided.

C. The “as installed” SPD system including the manufacturers recommended circuit breaker, the SPD is connected to, will not open when tested with a IEEE C3 combination waveform.

D. Tests to be performed in accordance with IEEE C62.45:
1. Clamping voltage performance testing using IEEE C62.41 Category waveforms.
2. Single pulse surge current capacity test.
3. Repetitive surge current capacity testing.
4. Spectrum analysis for EMI-RFI noise rejection.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install products in accordance with manufacturer's instructions.

B. Type 1 and 3 SPD:
1. Connected in parallel to the equipment.
2. Install in dedicated electrical equipment compartment, bucket or panelboard box at the factory before shipment.
3. Provide leads that are as short and straight as possible.
4. Maximum lead length: 12 IN.
5. Minimum lead size: #2 stranded AWG or bus bar.
6. Connect leads to the equipment to be protected by one (1) of the following means:
   a. Through a circuit breaker or molded case switch mounted in the equipment.

b. Use manufacturer recommended circuit breaker size.
c. Circuit breaker or switch to be operable from the equipment exterior or from behind a hinged door.

C. Type 2, 4 and 5 SPD:
1. Mounting options:
   a. On wall or support structure adjacent to the equipment to be protected with leads routed through conduit.
2. Install leads as short and straight as possible.
3. Maximum lead length: 5 FT.
4. Minimum lead size:
   a. Type 2 and 4 SPD: #2 stranded AWG.
   b. Type 5: #10 stranded AWG.
5. When conduit connection is used, provide a minimum of four (4) twists per foot in the lead conductors and install in NFPA 70 sized conduit.
6. Connect leads to the equipment to be protected by one (1) of the following means:
   a. Through a circuit breaker or molded case switch mounted in the equipment.
      1) Use manufacturer recommended circuit breaker size.
   b. Directly to the protected equipment bus, when SPD has integral disconnect switch.
   c. To the load side of field mounted equipment's local disconnect switch.
      1) Provide taps or lugs as required to provide a UL and NFPA 70 compliant connection.

	Equipment to be Protected	*SPD Type*	*Integral Disconnect (Yes/No)*	*Voltage*	*Short Circuit Rating*
1					
2					
3					
4					

END OF SECTION

SECTION 26 50 00

INTERIOR AND EXTERIOR LIGHTING

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Material and installation requirements for:
      a. Interior building lighting fixtures.
      b. Exterior building and site lighting fixtures.
      c. Lamps.
      d. Ballasts.
      e. Light poles.
      f. Lighting control.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.
   2. New Hampshire Department of Transportation Division 500 - Structures.
   3. Section 01 25 13 - Product Substitution.
   4. Section 26 05 00 - Electrical: Basic Requirements.
   5. Section 26 05 19 - Wire and Cable - 600 Volt and Below.
   6. Section 26 09 16 - Control Equipment Accessories.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. American National Standards Institute (ANSI).
   2. Certified Ballast Manufacturers (CBM).
   3. Federal Communications Commission (FCC):
      a. Code of Federal Regulations (CFR), 47 CFR 18, Industrial, Scientific and Medical Equipment.
   4. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
      a. C62.41, Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits.
   5. National Electrical Manufacturers Association (NEMA):
      a. 250, Enclosures for Electrical Equipment (1000Volts Maximum).
      b. LE 4, Recessed Luminaires, Ceiling Compatibility.
   6. National Electrical Manufacturers Association/American National Standards Institute (NEMA/ANSI):
      a. C82.1, Lamp Ballasts - Line Frequency Fluorescent Lamp Ballast.
      b. C82.4, Ballasts for High-Intensity Discharge and Low-Pressure Sodium (LPS) Lamps (Multiple-Supply Type).
      c. C82.11, High-Frequency Fluorescent Lamp Ballasts - Supplements.
   7. National Fire Protection Association (NFPA):
      a. 70, National Electrical Code (NEC).
      b. 101, Life Safety Code.
   8. Underwriters Laboratories, Inc. (UL):
      a. 248-4, Low-Voltage Fuses - Part 4: Class CC Fuses.
      b. 924, Standard for Emergency Lighting and Power Equipment.
      c. 935, Standard for Fluorescent-Lamp Ballasts.
      d. 1029, Standard for High-Intensity-Discharge Lamp Ballasts.
      e. 1598, Luminaires.

9. United States Department of Energy (USDOE):
    a. EPAct, the National Energy Policy Act.

1.3 SUBMITTALS

A. Shop Drawings:
    1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
    2. Product technical data:
        a. Provide submittal data for all products specified in PART 2 of this Specification Section.
        b. Identify fixtures by Fixture Schedule number.
        c. Fixture data sheet including:
            1) Photometric performance data including candlepower distribution and coefficient of utilization (CU) table.
            2) Fixture effective projected areas for pole mounted fixtures.
        d. Pole data shall include:
            1) Pole wind loading.
            2) Anchor bolt template.
        e. UL nameplate data for fixtures used in Class 1 Division 1 and 2 areas.
        f. See Specification Section 26 05 00 for additional requirements.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following manufacturers are acceptable:
    1. Lighting fixtures: See Fixture Schedule.
    2. Lamps:
        a. Osram/Sylvania.
        b. General Electric.
        c. Philips.
        d. Venture.
    3. Ballasts: Fixture manufacturer's standard.
    4. Emergency ballasts: Bodine.
    5. Emergency transfer devices: Bodine.
    6. Poles: Fixture manufacturer's standard.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 GENERAL REQUIREMENTS

A. All lighting fixtures and electrical components:
    1. UL labeled.
    2. Fixtures complete with lamps and ballasts.
    3. Rated for area classification as indicated on the Drawings.
        a. In Class I, Division 1 and 2 areas, the temperature rating of the luminaires and lamp combination shall not exceed the auto-ignition temperature of the atmosphere in which the fixture is used.

B. Provide all recessed fixtures with gaskets of rubber, fiberglass, or equivalent material to prevent light leaks around flush trim.
    1. Provide recessed fixtures with trim gaskets cemented in proper position.

C. Provide standard plaster frame for all recessed lighting fixtures installed in plaster walls or ceilings.
   1. Design, finish and fabricate material to preclude possibility of rust stain in plaster.

D. No live parts normally exposed to contact.

E. When intended for use in wet areas: Mark fixtures "Suitable for wet locations."

F. When intended for use in damp areas: Mark fixtures "Suitable for damp locations" or "Suitable for wet locations."

2.3 LIGHT FIXTURES

A. Incandescent:
   1. UL 1598.
   2. Lamp base.
      a. Less than or equal to 300W: Medium base.
      b. Greater than 300W: Mogul base.
   3. Visibly marked to indicate maximum lamp wattage that can be used with the fixture.

B. Fluorescent:
   1. UL 1598.
   2. NEMA LE 4 for recessed locations.
   3. Lenses: As indicated in Fixture Schedule, with the following minimums:
      a. Troffer: 100 percent virgin acrylic, conical shaped, female 0.1875 IN, square based prisms, aligned 45 degrees to the length and width, 0.125 IN nominal thickness.
   4. Finish:
      a. Manufacturer's standard polyester, acrylic enamel or epoxy powder coating applied after fabrication.
      b. Manufacturer's standard color or special color specified in Fixture Schedule.
   5. Prewired and provided with lamps that are properly mated to the ballast operating characteristics.

C. High Intensity Discharge:
   1. UL 1598.
   2. Finish:
      a. Manufacturer's standard polyester, acrylic enamel or epoxy powder coating applied after fabrication.
      b. Manufacturer's standard color or special color specified in Fixture Schedule.
   3. Prewired and provided with lamps that are properly mated to the ballast operating characteristics.
   4. Provided with safety chain.

D. Exit Signs and Emergency Lighting Units:
   1. UL 924, NFPA 101.

2.4 LAMPS

A. Incandescent:
   1. Type as indicated in fixture schedule.
   2. Meet the current Federal Energy Standards (EPAct 1992).

B. Fluorescent:
   1. T12 (430 mA) instant or rapid-start medium bipin lamps.
      a. Correlated color temperature of 3500 degrees Kelvin.
      b. Minimum color rendering index (CRI) of 70.
      c. Minimum initial lumen ratings for each lamp type shall be:

1) 2025 lumens for 36 IN, 25 or 30 watt F30T12 lamp.
2) 2750 lumens for 48 IN, 34 watt F40T12 lamp.
3) 2730 lumens for 22.5 IN, 34 or 40 watt F40T12/U/6 lamp (U-shaped 6 IN leg spacing).

2. T8 (265 mA) instant or rapid-start medium bipin lamps.
   a. Correlated color temperature of 3500 degrees Kelvin.
   b. Minimum color rendering index (CRI) of 70.
   c. Minimum initial lumen ratings for each lamp type shall be:
      1) 1300 lumens for 24 IN, 17 watt F17T8 lamp.
      2) 2025 lumens for 36 IN, 25 watt F25T8 lamp.
      3) 2800 lumens for 48 IN, 32 watt F32T8 lamp.
      4) 5700 lumens for 96 IN, 59 watt F96T8 lamp.
      5) 2725 lumens for 22.5 IN, 32 watt F32T8/U/6 lamp (U-shaped 6 IN leg spacing).
3. T5 instant or rapid-start 4 pin (2G11 base) compact fluorescent lamps.
   a. Correlated color temperature of 3500 degrees Kelvin.
   b. Minimum color rendering index (CRI) of 80.
   c. Minimum initial lumen ratings for each lamp type shall be:
      1) 1250 lumens for 10.5 IN, 18 watt F18BX lamp.
      2) 1800 lumens for 12.8 IN, 24 or 27 watt F27BX lamp.
      3) 2850 lumens for 16.5 IN, 36 or 39 watt F39BX lamp.
      4) 3150 lumens for 22.5 IN, 39 watt F39BX lamp.
4. T4 twin-tube, quad-tube, and/or triple twin-tube compact fluorescent lamps.
   a. Correlated color temperature of 3500 degrees Kelvin.
   b. Minimum color rendering index (CRI) of 80.
   c. Minimum initial lumen ratings for preheat 2-pin twin-tube lamps with a G23 or GX23 base shall be:
      1) 580 lumens for 6.5 IN, 9 watt CF9TT lamp.
      2) 800 lumens for 7.1 IN, 13 watt CF13TT lamp.
   d. Minimum initial lumen ratings for rapid-start 4-pin quad-tube lamps with a G24q-1, G24q-2 or G24q-3 base shall be:
      1) 900 lumens for 5.2 IN, 13 watt CF13QT lamp.
      2) 1160 lumens for 5.8 IN, 18 watt CF18QT lamp.
      3) 1700 lumens for 6.5 IN, 26 watt CF26QT lamp.
   e. Minimum initial lumen ratings for rapid-start 4-pin triple twin-tube lamps with a GX24q-2 or GX24q-3 base shall be:
      1) 1120 lumens for 4.6 IN, 18 watt CF18TTT lamp.
      2) 1610 lumens for 5.2 IN, 26 watt CF26TTT lamp.
      3) 2200 lumens for 5.8 IN, 32 watt CF32TTT lamp.
      4) 3200 lumens for 6.3 IN, 42 watt CF42TTT lamp.

C. High Intensity Discharge (HID) Lamps:
1. Metal halide lamps:
   a. Metal halide lamps shall be pulse-start type.
      1) If used in an open luminaire, the lamp shall be rated for use in an open fixture and incorporate a protective arc tube shroud design.
   b. Clear lamps:
      1) Correlated color temperature of 4000 degrees Kelvin.
      2) Minimum color rendering index (CRI) of 65.
   c. Minimum initial lumen ratings for metal halide lamps with a medium base in a vertical position shall be:
      1) 3200 lumens for 50 watt, ED-17 (ANSI M110) clear lamp.
      2) 5600 lumens for 70 watt, ED-17 (ANSI M98) clear lamp.

3) 8500 lumens for 100 watt, ED-17 (ANSI M90) clear lamp.
4) 14250 lumens for 150 watt, ED-17 (ANSI M102) clear lamp.
5) 17500 lumens for 175 watt, ED-17 (ANSI M137) clear lamp.

d. Minimum initial lumen ratings for metal halide lamps with a mogul base in a vertical position shall be:
1) 14250 lumens for 150 watt, ED-28 (ANSI M102) clear lamp.
2) 17500 lumens for 175 watt, ED-28 (ANSI M137) clear lamp.
3) 20000 lumens for 200 watt, ED-28 (ANSI M136) clear lamp.
4) 25000 lumens for 250 watt, ED-28 (ANSI M138) clear lamp.
5) 32300 lumens for 320 watt, ED-28 or ED-37 (ANSI M132) clear lamp.
6) 36000 lumens for 350 watt, ED-28 or ED-37 (ANSI M131) clear lamp.
7) 42000 lumens for 400 watt, ED-28 or ED-37 (ANSI M135) clear lamp.
8) 47500 lumens for 450 watt, ED-37 (ANSI M144) clear lamp.

2. High pressure sodium lamps:
a. Correlated color temperature of 2100 degrees Kelvin.
b. Minimum color rendering index (CRI) of 21.
c. High pressure sodium lamps are designated on the lighting Fixture Schedule by the prefix HPS.

3. Uncoated (clear) unless identified as coated in the fixture schedule.
4. The specified fixture in the fixture schedule shall dictate the required lamp operating position and base type.
5. Provide lamps that have the correct bulb shape for the fixture specified.

2.5 BALLASTS

A. Fluorescent Electromagnetic Ballasts:
1. UL 935.
2. High-efficiency energy saving electromagnetic core and coil design.
3. CBM certification for full light output.
4. Operate lamps at a frequency of 60 Hz.
5. Power factor: Greater than 90 percent.
6. Input current with Total Harmonic Distortion (THD) of less than 32 percent.
7. Lamp current crest factor: Less than 1.7, in accordance with lamp manufacturer's recommendations and NEMA/ANSI C82.1.
8. Ballast factor: Greater than the following per NEMA/ANSI C82.1:
a. 0.925 for rapid start 265 mA (T8) and 430 mA (T12) ballasts.
9. Audible noise rating: Greater than or equal to the following:
a. Class A for rapid start 265 mA (T8) and 430 mA (T12) ballasts.
10. Coil temperature not to exceed 65 DegC (150 DegF) temperature rise over 40 DegC (105 DegF) ambient.
a. Maximum case temperature not to exceed 90 DegC (195 DegF).
11. Meet the requirements of the FCC 47 CFR 18, for non-consumer equipment for EMI and RFI.
12. Meet all applicable ANSI and IEEE standards regarding harmonic distortion and transient protection such as IEEE C62.41, Cat. A, for transient protection.
13. UL listed, Class P.
14. Fully encapsulated (potted) to ensure maximum thermal and structural integrity.
15. Contain no polychlorinated biphenyls (PCB's).

B. Fluorescent High Frequency Electronic Ballasts:
1. UL 935.
2. "High Frequency" electronic operating lamps at a frequency of 20 KHz or higher without visible flicker.

3. Power factor: Greater than 90 percent.
4. Input current total harmonic distortion (THD) of less than 20 percent.
5. Lamp current crest factor: Less than 1.7, in accordance with lamp manufacturer's recommendations and NEMA/ANSI C82.11.
6. Instant start with lamps wired in parallel.
7. Support a sustained short to ground or open circuit of any output leads without damage to the ballast.
8. Ballast Factor: Greater than 0.85 per NEMA/ANSI C82.11.
9. Audible noise rating: Class A or better.
10. Operation in ambient temperatures up to 40 DegC (105 DegF) without damage.
11. Light output to remain constant for a line voltage fluctuation of +5 percent.
12. Meet the requirements of the FCC 47 CFR 18, for non-consumer equipment for EMI and RFI.
13. Meet NEMA/ANSI C82.11 standards regarding harmonic distortion.
14. Meet IEEE C62.41 Cat. A for transient protection.
15. Comply with all applicable state and federal efficiency standards.
16. UL listed, Class P.
17. Contain no Polychlorinated Biphenyls (PCB's).

C. Fluorescent Emergency Ballasts:
   1. UL 924, NFPA 101.
   2. High temperature, 24 Watt-hour, maintenance-free nickel cadmium battery with charger.
   3. Charging indicator light (LED) to monitor the charger and battery.
   4. Double-pole test switch.
   5. Light one (1) lamp for 90 minutes in 1, 2 and 3-lamp fixtures.
      a. Light two (2) lamps for 90 minutes in 4-lamp fixtures.
   6. Dual input voltage (120/277V), 4 Watts input.
   7. Compatible with the install lamp type.
   8. Initial lumen output: 975 to 1400.
   9. Contain no Polychlorinated Biphenyls (PCB's).

D. High Intensity Discharge Ballasts:
   1. NEMA/ANSI C82.4, UL 1029.
   2. Metal halide:
      a. Input voltage variation: +10 percent.
      b. Maximum lamp regulation spread: 20 percent.
      c. Minimum power factor: 90 percent.
      d. Starting current: Not greater than operating current.
      e. Maximum input voltage dip: 40 percent.
      f. Crest factor: 1.5 to 1.8.
      g. Types:
         1) Lead-type regulators: Constant wattage autotransformer (CWA) and pulse start.
         2) Lag-type regulators: Magnetic regulator and pulse start.
      h. Contain no Polychlorinated Biphenyls (PCB's).
   3. High pressure sodium:
      a. Input voltage variation: +10 percent.
      b. Maximum lamp regulation spread: 30 percent.
      c. Minimum power factor: 90 percent.
      d. Starting current: Not greater than operating current.
      e. Maximum input voltage dip: 20 percent.
      f. Crest factor: 1.6 to 1.8.
      g. The Volts-Watts trace shall be within the lamp manufacturer's trapezoid.
      h. Types:

        1) Lead-type regulators: Constant wattage autotransformer (CWA).
        2) Lag-type regulators: Magnetic regulator and regulated lag.
    i. Ballast shall not contain Polychlorinated Biphenyls (PCB's).
4. Ballasts for interior use:
    a. Encased and potted type.
    b. Audible noise rating of B or better.
    c. Built-in automatic resetting thermal protection switch.
5. Ballasts for exterior use:
    a. Starting temperature: -20 DegF.

2.6 POLES

A. As scheduled or noted on the Drawings.

2.7 MAINTENANCE MATERIALS

A. Furnish a minimum of 2 or 10 percent of total of each type and wattage of lamps, whichever is greater.

B. Furnish a minimum of 10 percent of total of each type and amperage of fuses for fixtures indicated to be fused.

C. Spare parts are to be stored in a box clearly labeled as to its contents.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Coordinate fixture types with ceiling construction.
    1. Provide mounting hardware for the ceiling system in which the fixture is to be installed.

B. Fasten lighting fixtures supported by suspended ceiling systems to ceiling framing system with hold down clips.

C. Provide mounting brackets and/or structural mounting support for wall-mounted fixtures.
    1. Do not support fixture from conduit system.
    2. When fixtures are supported from outlet boxes, install per NFPA 70.
    3. Supports for fixtures mounted on exterior walls shall not be attached to exterior face of the wall.

D. Provide pendant incandescent, compact fluorescent, and/or HID fixtures with swivel hangers which will allow fixture to swing in any direction but will not permit stem to rotate.
    1. Provide hangers with enclosure rating (NEMA 1, 4, or 7) equal to enclosure requirements of area in which they are installed.
    2. Swivel hangers for fixtures in mechanical equipment areas: Shock absorbing type.
    3. Secure HID fixtures with safety chain.

E. Pendant mounted, open, industrial fluorescent fixtures:
    1. Not in continuous rows, shall be supported by conduit or by approved chains:
        a. Hardwired to ceiling mounted junction box.
    2. In continuous rows, shall be rigidly supported with conduit and fasten fixtures to each other or mount on continuous metal channel per Specification Section 26 05 00.
        a. Hardwired to ceiling mounted junction box.
        b. Provide reflector alignment clips.

F. Locate fixtures in accordance with reflected ceiling plans.

G. Locate in exact center of tile when indicated.

1. Relocate misplaced fixtures and replace damaged ceiling materials.

H. Mount lighting fixtures at heights indicated in Specification Section 26 05 00 or per fixture schedule or as indicted on the Drawings.

I. Install exterior fixtures so that water can not enter or accumulate in the wiring compartment.

J. Where indicated provide two-level control of three (3) and/or four (4) lamp fluorescent fixtures.
   1. Provide two (2) ballasts per fixture and control inside lamp(s) in each fixture by one (1) switch or set of switches and the outside two (2) lamps by a second switch or group of switches.

K. Ground fixtures and ballasts.

3.2 POLE INSTALLATION

A. Drawings indicate the intended location of light pole.
   1. Field conditions may affect actual location.
   2. Coordinate location with all existing or new utilities and pavement.

B. Steel and Aluminum Poles:
   1. Mounted on cast-in-place foundations, as detailed on the Drawings.
      a. Concrete and reinforcing steel, in accordance with Division 500 Specification Sections.
   2. Protect pole finish during installation.
      a. Repair damage to pole finish with manufacturer approved repair kit.

C. Ground poles as indicated on the Drawings.

D. Conductors:
   1. See Specification Section 26 05 19 for required underground conductors.
   2. Use interior building wire, as specified in Specification Section 26 05 19, from pole base to fixture, #12 AWG minimum.

E. Overcurrent and Short Circuit Protection:
   1. Protect each phase with a UL Class CC fuse:
      a. Size: Three (3) times load current.
      b. Standard: UL 248-4.
   2. Fuseholder:
      a. Watertight, in-line and break-a-way style.
      b. Accept up to a 30 A, 600 V fuse.
      c. Neutral conductor shall utilize a fuseholder with a solid copper rod.
      d. Conductor terminal: Adequate size for the installed conductors.

3.3 LIGHTING CONTROL

A. See Specification Section 26 09 16 for lighting control equipment.

B. Exterior wall mounted and pole mounted fixtures controlled as detailed on the Drawings.

3.4 ADJUST AND CLEAN

A. See Specification Section 26 05 00.

B. Replace all inoperable lamps with new lamps prior to final acceptance.

C. Aim all emergency lighting units, so that, the path of egress is illuminated.

END OF SECTION

SECTION 27 05 00
PASSIVE TELECOMMUNICATION SYSTEM

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Requirements for data and telephone signal distribution.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.
   2. Section 26 05 00 - Electrical: Basic Requirements.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. Building Industry Consulting Service International (BICSI).
   2. National Electrical Manufacturers Association (NEMA):
      a. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
   3. National Fire Protection Association (NFPA):
      a. 70, National Electrical Code (NEC).
   4. Telecommunications Industry Association/Electronic Industries Alliance/American National Standards Institute (TIA/EIA/ANSI):
      a. 568B-1, Commercial Building Telecommunications Cabling Standard, Part 1: General Requirements.
      b. 568B-2, Commercial Building Telecommunications Cabling Standard, Part 2: Balanced Twisted-Pair Cabling Components.
      c. 568B-3, Optical Fiber Cabling Components Standard.
      d. 569A, Commercial Building Standard for Telecommunications Pathways and Spaces.
      e. 606, Administration Standard for the Telecommunications Infrastructure of Commercial Buildings.
      f. J-STD-607, Commercial Building Grounding (Earthing) and Bonding Requirements for Telecommunications.

B. Qualifications:
   1. Design-Builder shall have a Registered Communications Distribution Designer (RCDD) on staff and a BICSI Certified Technician supervising each work crew on site.
      a. Bidding Contractors are pre-selected prior to bid based on Telecommunications Infrastructure installation experience.
      b. The Design-Builder shall include three (3) references of similar scope jobs completed in the last two (2) years.
   2. Manufacturer: Company specializing in manufacturing products specified in this Specification Section with minimum 10 years documented experience.

1.3 SYSTEM DESCRIPTION

A. The telecommunications passive infrastructure shall consist of the all passive components and ancillary equipment and devices, as required to complete the intended function of the voice and data system.
   1. All components required for the above shall be provided for a fully tested operational system per the latest TIA/EIA/ANSI Standards.

B. The Design-Builder shall provide and install all passive components per this Specification for the Passive Telecommunication System.

C. Active equipment including switched hubs, routers, data switch(es) for fiber/copper shall be provided by others under a separate contract.
   1. Patch cords connected to active equipment shall be installed by others.

1.4 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
   2. Product technical data including:
      a. Provide submittal data for all products specified in PART 2 of this Specification.
      b. See Specification Section 26 05 00 for additional requirements.
   3. Fabrication and/or layout drawings.
      a. Rack layouts.
   4. Test reports:
      a. Test procedures.
      b. Cable test results.

B. Miscellaneous:
   1. See Specification Section 26 05 00 for requirements for the mechanics and administration for the submittal process.
   2. Contractor and manufacturer qualifications.
   3. Labeling scheme.

PART 2 - PRODUCTS

2.1 MATERIALS AND EQUIPMENT

A. Materials and equipment shall be the standard products of a manufacturer regularly engaged in the manufacture of the products and shall be the manufacturer's latest standard design that has been in satisfactory use for at least one (1) year prior to installation.
   1. Materials and equipment shall conform to the respective publications and other requirements specified below and to the applicable requirements of NFPA 70.

2.2 UNSHIELDED TWISTED PAIR CABLE SYSTEM

A. Horizontal Voice and Data Cable:
   1. Category as required by the manufacturer.
   2. Cable shall be label-verified.
   3. Cable jacket shall be factory marked at regular intervals indicating verifying organization and performance level.
   4. Conductors shall be solid untinned copper 24 AWG.
   5. Cable shall be rated CMP per NFPA 70.

B. Outside Plane Cable:
   1. Same as horizontal cable except gel filled with UV resistant jacketed suitable for installation underground.

C. Connecting Hardware.
   1. Connecting and cross-connecting hardware shall be the same category as the cable it serves.
   2. Telecommunications outlets.
      a. General wall and desk outlet plates shall come equipped with two (2) modular jacks, with the top jack labeled "voice" and the bottom jack labeled "data".

b. Wall and pay telephone outlet plates shall come equipped with one (1) modular jack type.
c. Modular jacks shall be the same category as the cable they terminate.
d. Modular jack pin/pair configuration shall be T568B.
e. Modular jacks shall be unkeyed.
f. Wallplates:
   1) High impact thermoplastic or nylon.
   2) Color: as shown on the plans.

3. Patch panels:
   a. 48-port modular jack (2U maximum), with rear mounted type 110 insulation displacement connectors.
   b. Mounted in a 19 IN rack.
   c. Jack pin/pair configuration shall be T568B.
   d. Jacks shall be unkeyed.
   e. Panels shall be labeled with alphanumeric x-y coordinates.
4. Patch cords:
   a. Assemblies consisting of flexible, twisted pair stranded wire with eight-position plugs at each end.
   b. Cable shall be label-verified.
   c. Cable jacket shall be factory marked at regular intervals indicating verifying organization and performance level.
   d. Patch cords shall be wired straight through; pin numbers shall be identical at each end and shall be paired to match T568B patch panel jack wiring.
   e. Patch cords shall be unkeyed.
   f. Patch cords shall be factory assembled.
5. Terminal blocks:
   a. Wall mounted or rack mounted wire termination units consisting of insulation displacement connectors mounted in plastic blocks, frames or housings.
      1) Blocks shall be type 110 or 66 which meet the requirements for Category 6 or as shown.
   b. Blocks shall be mounted on standoffs and shall include cable management hardware.
   c. Insulation displacement connectors shall terminate 22 or 24 GA solid copper wire as a minimum, and shall be connected in pairs so that horizontal cable and connected jumper wires are on separate connected terminals.
6. Standards: TIA/EIA/ANSI 568B Series.

2.3 FIBER OPTIC CABLE SYSTEM

2.4 EQUIPMENT RACKS

A. Floor mounted equipment racks shall be welded steel or aluminum relay racks with uprights to mount equipment 19 IN.
   1. Uprights shall be 3 IN deep channel, 1-1/4 IN wide, drilled and tapped 12-24 in a 1/2 IN pattern.
   2. Racks shall be provided with a standard top crossmember, and predrilled base plate to allow floor fastening.
   3. Open frame equipment racks shall be 7 FT in height and clear coated.

B. Cable Guides.
   1. Cable guides shall be specifically manufactured for the purpose of routing cables, wires and patch cords horizontally and vertically 19 IN equipment racks.
   2. Cable guides shall consist of ring or bracket-like devices mounted on rack panels for horizontal use or individually mounted for vertical use.
   3. Cable guides shall mount to racks by screws and/or nuts and lockwashers.

2.5 LABELING AND COLOR CODING

A. Labels shall be developed by the Design-Builder and approved by the Owner.
   1. Labels shall be machine printed on opaque or clear tape, stenciled onto adhesive labels.

B. Cable and Jacks:
   1. Voice: White.
   2. Data: Blue.

2.6 TELEPHONE TERMINAL CABINETS

A. Factory painted or galvanized steel NEMA 1 enclosure with hinged door.
   1. Used to house building entrance protector and terminal blocks.

2.7 EQUIPMENT MOUNTING BACKBOARD

A. Plywood backboards shall be provided, sized as shown, painted with white or light colored paint.

2.8 TELECOMMUNICATIONS OUTLET BOXES

A. Electrical boxes for telecommunication outlets shall be 4-11/16 IN square by 2-1/8 IN deep with minimum 3/8 IN deep single or two gang plaster ring as required.
   1. Provide a minimum 1 IN conduit.

PART 3 - EXECUTION

3.1 INSTALLATION

A. System components and appurtenances shall be installed in accordance with NFPA 70, manufacturer's instructions and as shown.

B. Necessary interconnections, services, and adjustments required for a complete and operable signal distribution system shall be coordinated with the local telephone company.

C. Components shall be labeled in accordance with TIA/EIA/ANSI 606.

D. Penetrations in fire-rated construction shall be firestopped.

E. Wiring shall be installed in accordance with TIA/EIA/ANSI Standards.
   1. Wiring, and terminal blocks and outlets shall be marked in accordance with TIA/EIA/ANSI 606.

F. Cables shall not be installed in the same cable tray, utility pole compartment, or floor trench compartment with ac power cables.
   1. Cables not installed in conduit or wireways shall be properly secured and neat in appearance and, if installed in plenums or other spaces used for environmental air, shall comply with NFPA 70 requirements for this type of installation.

G. Horizontal Distribution Cable:
   1. The rated cable pulling tension shall not be exceeded.
   2. Cable shall not be stressed such that twisting, stretching or kinking occurs.
   3. Cable shall not be spliced.
   4. Copper cable not in a wireway shall be suspended a minimum of 8 IN above ceilings by cable supports no greater than 60 IN apart.
   5. Cable shall not be run through structural members or in contact with pipes, ducts, or other potentially damaging items.
   6. Placement of cable parallel to power conductors shall be avoided, if possible; a minimum separation of 12 IN shall be maintained when such placement cannot be avoided.
   7. Cables shall be terminated; no cable shall contain unterminated elements.

8. Minimum bending radius shall not be exceeded during installation or once installed.
9. Cable ties shall not be excessively tightened such that the transmission characteristics of the cable are altered.

H. Telecommunications Outlets:
1. Faceplates: As a minimum each jack shall be labeled as to its function and a unique number to identify cable link.
2. Cables:
    a. Unshielded twisted pair cables shall have a minimum of 6 IN of slack cable loosely coiled into the telecommunications outlet boxes.
    b. Minimum manufacturers bend radius for each type of cable shall not be exceeded.

I. Terminal Blocks:
1. Terminal blocks shall be mounted in orderly rows and columns.
2. Adequate vertical and horizontal wire routing areas shall be provided between groups of blocks.
3. Industry standard wire routing guides shall be utilized.

J. Unshielded Twisted Pair Patch Panels:
1. Patch panels shall be mounted in equipment racks with sufficient modular jacks to accommodate the installed cable plant plus 10 percent spares.
2. Cable guides shall be provided above, below and between each panel.

K. Equipment Racks:
1. Open frame equipment racks shall be bolted to the floor.
2. Cable guides shall be bolted or screwed to racks.
3. Racks shall be installed level.
4. Ganged racks shall be bolted together.
5. Wall mounted racks shall be secured to the mounting surface to prevent fully loaded racks from separating from the mounting surface.

L. Rack Mounted Equipment: Equipment to be rack mounted shall be securely fastened to racks by means of the manufacturer's recommended fasteners.

3.2 TERMINATION

A. Cables and conductors shall sweep into termination areas; cables and conductors shall not bend at right angles.
1. Manufacturer's minimum bending radius shall not be exceeded.
2. When there are multiple system type drops to individual workstations, relative position for each system shall be maintained on each system termination block or patch panel.
3. Unshielded Twisted Pair Cable:
    a. Each pair shall be terminated on appropriate outlets, terminal blocks or patch panels.
    b. No cable shall be unterminated or contain unterminated elements.
    c. Pairs shall remain twisted together to within the proper distance from the termination as specified in the TIA/EIA/ANSI 568B Series.
    d. Conductors shall not be damaged when removing insulation.
    e. Wire insulation shall not be damaged when removing outer jacket.

3.3 GROUNDING

A. Signal distribution system ground shall be installed in the telecommunications entrance facility and in each telecommunications closet in accordance with TIA/EIA/ANSI J-STD-607.
1. Equipment racks shall be connected to the electrical safety ground.

3.4 LABELING

A. All cables will be labeled using color labels on both ends per TIA/EIA/ANSI 606.

B. All workstation and patch panel connections will be labeled using color coded labels per TIA/EIA/ANSI 606.

3.5 TESTING

A. Testing shall conform to the TIA/EIA/ANSI Standards.
   1. All test data sheets shall be downloaded from the tester, printed out and provided to the Owner.
   2. A CD ROM shall be provided to the Owner with all test results.
   3. Tester shall be capable of testing parameters for the warranted system.

END OF SECTION

SECTION 28 23 00
VIDEO SURVEILLANCE SYSTEM

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Video surveillance equipment.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. American National Standards Institute (ANSI):
      a. B40.100, Pressure Gauges and Gauge Attachments.
   2. Building code:
      a. International Code Council (ICC):
         1) International Building Code and associated standards, {2003}{2006}{2009} Edition including all amendments, referred to herein as Building Code.

1.3 SUBMITTALS

A. Shop Drawings:
   1. See Specification Section 26 05 00 for requirements for the mechanics and administration of the submittal process.
   2. Video surveillance system:
      a. Wiring diagrams and riser diagram.
      b. Equipment design considerations for future expansion, when indicated.
      c. Description of system operation.

B. Product data:
   1. Technical data on each component.
   2. Materials list and backbox schedule (including unique backboxes).

C. Project information:
   1. Name and address of video surveillance system local service organization who also stocks spare parts.

D. Contract closeout information:
   1. Operating and maintenance data.
   2. Owner instruction report.
   3. Complete servicing data.

PART 2 - PRODUCTS

2.1 VIDEO SURVEILLANCE SYSTEM OPERATION

A. Provide remote viewing of a given scene.

B. Transmit visual information to a remote location as it is occurring.

C. Record visual information for later review

2.2 MATERIALS

A. Acceptable manufacturers:
   1. Video surveillance system components:
      a. Base:
         1) Pelco.
         2) Panasonic.
   2. All basic electronic equipment by same manufacturer.
   3. Manufacturer must have established reputation and experience in production of similar apparatus for at least five years, with similar installations rendering satisfactory service.
   4. Manufacturer must have local service organization.

B. Provide video cables in conduit between all system components.

C. Provide 24 V power cable in conduit separate from system video cables.

D. Provide enclosures suitable for camera, and accessories, and environment as required.

E. Provide mounting equipment as indicated on contract drawings.

2.3 VIDEO SURVEILLANCE

A. Cameras for exterior use
   1. Image sensor: 1/4 IN EXview HAD.
   2. Horizontal resolution: 540 TV lines minimum.
   3. Signal format: NTSC.
   4. Zoom: 35X optical, 12X digital.
   5. On screen camera identification. Numbers switch selectable for each camera.
   6. Enclosure to be as specified herein.
   7. Mount as indicated.
   8. Coaxitron receiver capable.

2.4 LENS

1. Lens Type: Motorized zoom lens for 1/4” camera with auto iris and filter.
2. Aperture: f/1.4 to f/22.

2.5 CAMERA MOTION CONTROL DRIVE UNITS

A. The camera motion control drive units shall be fully compatible with the controllers specified in other sections of these specifications.

2.6 ELECTRONIC CAMERA CONTROL SYSTEM

A. All cameras with accessories that require remote control shall be controlled by an electronic control system through digital signals over the coaxial video cable. The system shall consist of control transmitters with function modules specified, receivers with matching function modules, interconnecting cables and cable extensions from receiver to camera and camera motion controller.

B. Transmitters shall be multiple camera control type for the control of cameras indicated on the drawings. Transmitters shall be for use on nominal 120 V AC system. Output signals shall be compatible with receiver and functions specified. Transmitter shall be provided with internal fused protection. Transmitters shall be desktop mounted and shall provide not less than the following functions:
   1. Transmitter On-Off.
   2. Power on illuminated signal.
   3. Pan and tilt control pushbuttons; "UP", "DOWN", "LEFT", "RIGHT".
   4. Zoom lens control; "TELE" and "WIDE".

5. Camera focus control; "NEAR" and "FAR".
6. Iris control; "OPEN" and "CLOSE".
7. Window wiper pushbutton.
8. Heater pushbutton.
9. Blower pushbutton.
10. Defroster pushbutton.
11. Camera "ON" pushbutton.
12. Receivers shall be provided inherent in each camera.

2.7 CAMERA HOUSINGS

A. Camera housings shall be compatible with camera to be installed within housing. Cable entrances shall be provided for video, power and control cables. Camera housings shall be compatible for mounting on brackets and motion controllers specified.

B. Weatherproof-tamperproof housing shall be constructed of aluminum and finished with a weatherproof, heat reflecting paint. Housing shall be internally insulated. Hinged cover shall be secured in place by tamperproof bolts. Housing shall be provided with the following features:
   1. Bottom air intake and filter.
   2. Automatically operated defroster / heater

2.8 MOUNTING BRACKETS

Camera mounting apparatus shall secure the camera and associated components to prevent damage from weather, vandals, vibrations and other detrimental forces.

2.9 VIDEO MONITORS

A. Video monitors shall be solid state type with exception of picture tube, mounted as indicated on the Drawings and as specified herein. Monitor controls shall be on-off, brightness, contrast, vertical hold and horizontal hold. Controls shall be mounted behind spring held cover on front of unit. Monitors shall contain differential input amplifier, voltage regulation and shall be rated for continuous duty. All monitors shall be UL listed.

B. 19 IN monitors shall be mounted on the dock attendant desk top and shall conform to not less than the following:
   1. Number of Pixels: 1280(H) x 1024 (V).
   2. Input impedance: Switchable.
   3. Video input: 0.5 to 2.5 V composite P/P.
   4. Sweep linearity: Less than 5 percent.
   5. Sweep geometry: Less than 2 percent.
   6. Video response: Minimum 10 MHz.
   7. Maximum video gain: 39 Db.
   8. Operating temperature: 32 degF to 113 degF.

2.10 VIDEO WIRING SYSTEMS

A. Video signal cables shall be coaxial cable, RG11U with PVC outer jacket cable installed below grade. Cables shall be installed in concealed conduit system within buildings. Cable shall conform to the following:
   1. Temperature range: Minus 30 degC to plus 75 degC.
   2. Outside diameter: 0.346 IN.
   3. Nominal impedance: 75 Ohms.
   4. Nominal capacitance: 16.2 picofarads per FT.
   5. Maximum attenuation: 3.3 db/100 FT at 400 MHz.

2.11 DIGITAL VIDEO RECORDER

A. Digital video recorder shall be PELCO DX4104 Series and shall conform to the following:
   1. Electrical: 120VAC.
   2. Signal system: NTSC/PAL, switchable.
   3. Storage capacity: 500GB.
   4. Operating Temperature: 32 degF to 95 degF.

PART 3 - EXECUTION

3.1 EQUIPMENT

A. All camera housings and support brackets shall be securely attached to mounting surfaces. Use lead shields on solid masonry, wood screws on wood, and machine bolts on structural steel. All anchoring devices shall be rated to support not less than five times the total equipment weight.

3.2 WIRING

A. All system wiring shall be installed as in conduit. Use separate raceways for video and control circuit.

3.3 TESTING

A. Provide representative of manufacturer to supervise installation and final testing of system. System subject to approval and acceptance of Engineer. On completion of acceptance tests, instruct Owner or designated representative in operation and testing of system.

END OF SECTION

SECTION 28 31 00

FIRE ALARM SYSTEM

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Material and installation requirements for:
      a. Fire Alarm Control Panel.
      b. Signal Initiating Devices.
      c. Notification Appliances.
      d. Miscellaneous Devices.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.
   2. Division 21 - Fire Suppression.
   3. Section 23 09 00 - Instrumentation and Control for HVAC Systems.
   4. Section 26 05 33 - Raceways and Boxes.
   5. Section 40 05 05 - Equipment: Basic Requirements.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. Americans with Disabilities Act (ADA):
      a. Accessibility Guidelines for Buildings and Facilities (ADAAG).
   2. FM Global (FM):
      a. All applicable standards.
      b. All components FM approved.
   3. National Electrical Manufacturers Association (NEMA).
   4. National Fire Protection Association (NFPA):
      a. 70, National Electrical Code (NEC):
         1) Article 760, Fire Alarm Systems.
      b. 72, National Fire Alarm Code.
   5. National Institute for Certification in Engineering Technologies (NICET).
   6. Underwriters Laboratories, Inc. (UL):
      a. 38, Standard for Manual Signaling Boxes for Fire Alarm Systems.
      b. 268, Smoke Detectors for Fire Alarm Systems.
      c. 268A, Standard for Smoke Detectors for Duct Applications.
      d. 464, Standard for Audible Signaling Appliances.
      e. 497B, Standard for Protectors for Data Communication and Fire Alarm Circuits.
      f. 521, Standard for Heat Detectors for Fire Protective Signaling Systems.
      g. 864, Standard for Control Units and Accessories for Fire Alarm Systems.
      h. 1971, Standard for Signaling Devices for the Hearing Impaired.
   7. Building code:
      a. International Code Council (ICC):
         1) International Building Code and associated standards, {2003}{2006}{2009} Edition including all amendments, referred to herein as Building Code.

B. Design Criteria:

1. Provide a complete fire alarm system as described in the Contract Documents and according to criteria of the Authority(ies) Having Jurisdiction (AHJ), NFPA and ADAAG.
   a. Where system requirements described in the Contract Documents exceed those of the AHJ and/or NFPA, meet the requirements of both.
2. The Contract Drawings indicate a preliminary layout of the type, location and quantity of devices based on NFPA.
   a. At a minimum, make the following adjustments to the Contract Drawing as required by the AHJ and/or NFPA and/or ADAAG and the manufacturer:
      1) Location and spacing of notification appliances.
         a) Candela of strobes associated with the spacing.
      2) Location and spacing of initiating devices.
3. Complete fire detection and alarm system design wiring diagrams, interface wiring diagrams, and operational details by system manufacturer or authorized technical representative.
4. Submit documents after design has been approved by Authority Having Jurisdiction (AHJ).

C. Design Criteria:
1. The fire alarm system shall be designed by a NICET Level 3 or 4 fire alarm technician.
   a. If required by state regulations, a professional engineer shall seal drawings submitted to the AHJ.
   b. The designer is responsible for understanding the construction of the building to take in consideration ceiling heights, ceiling construction (flat or not flat), and other features of the building that will effect the layout of devices.
2. Provide a complete fire alarm system according to criteria of the Authority(ies) Having Jurisdiction (AHJ), NFPA, ADAAG and Building Code.
3. Complete fire detection and alarm system design wiring diagrams, interface wiring diagrams, and operational details by system manufacturer or authorized technical representative.
4. Submit documents after design has been approved by Authority Having Jurisdiction (AHJ).

D. Service Organization Qualifications:
1. Offer an annual maintenance contract including complete service and equipment costs for maintenance of complete system.
2. Ten (10) years experience minimum serving fire alarm systems.
3. Provide for 24 HR emergency service.

1.3 DEFINITIONS

A. For the purposes of providing materials and installing electrical work the following definitions shall be used.
1. Outdoor Area: Exterior locations where the equipment is normally exposed to the weather and including below grade structures, such as vaults, manholes, handholes and in-ground pump stations.
2. Architecturally Finished Area: Offices, laboratories, conference rooms, restrooms, corridors and other similar occupied spaces.
3. Non-architecturally Finished Area: Pump, chemical, mechanical, electrical rooms and other similar process type rooms.
4. Hazardous areas: Class I, II or III areas as defined in NFPA 70.
5. Shop Fabricated: Manufactured or assembled equipment for which a UL test procedure has not been established.

1.4 SYSTEM DESCRIPTION

A. Automatic and manual, analog addressable, general alarm and non-coded evacuation alarm, supervised, closed-circuit, 24 Vdc microprocessor based fire detection and alarm system.

B. Provide components including but not limited to following:
   1. Main fire alarm control panel (FACP).
   2. Remote fire alarm annunciator (FAA).
   3. Analog addressable heat sensors.
   4. Analog addressable smoke sensors.
   5. Analog addressable duct smoke sensors.
   6. Sprinkler system waterflow sensor circuits.
   7. Sprinkler system pressure sensor circuits.
   8. Main, post indicator valve and OS&Y sprinkler valve tamper switch circuits.
   9. Fan control relays associated with the HVAC control system.
   10. Combination fire alarm horns with strobe.
   11. General alarm strobes.
   12. Addressable manual pull station.
   13. Fire alarm system wire, with all wiring in conduit.

C. Basic Performance:
   1. Each SLC shall be limited to only 80 percent of its total capacity at the time of initial installation.

1.5 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
   2. See Specification Section 40 05 05.
   3. Product technical data:
      a. Provide Submittal data for all products specified in PART 2 of this Specification Section.
      b. Battery calculations.
      c. Voltage drop calculations.
      d. Description of system operation.
      e. Name of local service organization.
      f. Entire system approved by AHJ.
   4. Fabrication and/or layout drawings:
      a. Plan drawing(s) showing type and locations of all fire alarm devices.
         1) Indicate salient features of each device (e.g., weatherproof, strobe candela rating).
      b. Wiring diagrams and riser diagrams.

B. Operation and Maintenance Manuals:
   1. See Specification Section 26 05 00 for requirements for:
      a. The mechanics and administration of submittal process.
      b. The content of Operation and Maintenance Manuals.

C. Miscellaneous Submittals:
   1. Field test reports.

1.6 AREA DESIGNATIONS

A. Designation of an area will determine the NEMA rating of the electrical equipment enclosures, types of conduits and installation methods to be used in that area.
   1. Outdoor areas:

a. Wet.
b. Also, corrosive and/or hazardous when specifically designated on the Drawings or in the Specification Sections.

2. Indoor areas:
   a. Dry.
   b. Also, wet, corrosive and/or hazardous when specifically designated on the Drawings or in the Specification Sections.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following manufacturers are acceptable.
   1. Fire alarm system:
      a. Edwards Systems Technology.
      b. Gamewell.
      c. Notifier.
      d. Pyrotronics.
      e. Siemens Cerberus Division.
      f. Silent Knight.
      g. SimplexGrinnell.
      h. Wheelock.
   2. Manufacturer must have local service organization.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

C. All Equipment:
   1. UL listed as a product of a single manufacturer under appropriate category.
   2. Equipment shall not be modified or installed to alter or void UL label or listing.
   3. FM approved.
   4. Approved by Fire Marshal, when required by state or local codes.

2.2 FIRE ALARM CONTROL PANEL (FACP)

A. FACP shall perform operations as described in Fire Alarm System Operation:

B. The FA system shall have 100 point minimum initiating device capacity with the capability to add additional 100 point minimum initiating device control modules.

C. Construction shall be modular with solid-state, microprocessor-based electronics.
   1. An 80-character LCD display shall indicate alarms, supervisory service conditions and any troubles.

D. Keyboards or keypads shall not be required to operate system during fire alarm conditions.

E. Provide necessary switches, relays, indicator lamps, wiring terminals, etc., to provide complete operation supervising, control, and testing facilities for entire system.

F. FACP shall allow for loading or editing special instructions and operating sequences as required.
   1. System shall be capable of on-site programming to accommodate and facilitate expansion, building parameter changes or changes as required by local codes.
   2. All software operations shall be stored in a non-volatile programmable memory within FACP.

G. System shall have provisions for disabling and enabling all circuits individually for maintenance and testing purposes.

H. System shall be capable of logging and storing 300 events in an alarm log and 300 events in a trouble log.
   1. These events shall be stored in a battery protected random access memory.
   2. Each recorded event shall include time and date of that event's occurrence.
   3. System shall have capability of recalling alarms, trouble conditions, acknowledgments, silencing and reset activities in chronological order for purpose of recreating an event history.

I. FACP shall be listed under UL 864.

J. FACP shall be in an enclosed metal cabinet with glass door specifically designed for public areas.
   1. Mounting: Surface.
   2. Finish: Beige baked enamel.

K. Each addressable device shall be represented individually in FACP.
   1. Indicate TROUBLE by a discreet LCD readout for each supervised circuit.
   2. Indicate ALARM by a discreet LCD readout for each alarm initiating addressable device.
   3. Include individual supervisory and alarm relays in each circuit arranged so that ground or open condition in any circuit or group of circuits, will not affect proper operation of any other device.

L. FACP shall include the capability to report alarm and trouble conditions via a telephone line to a third party alarm reporting services.

M. FACP shall include a system testing capability to help ensure that zoning and supervision have been maintained throughout system.
   1. Actuation of the enable walk test program at FACP shall activate "Walk-Test" mode of system which shall cause the following to occur:
      a. City connection circuit shall be disconnected.
      b. Control relay functions shall be bypassed.
      c. FACP shall indicate a trouble condition.
      d. Alarm activation of any initiation device shall cause audible signals to activate for 2 seconds.
      e. FACP shall automatically reset itself after code is complete.
      f. Any momentary opening of alarm initiating or alarm indicating circuit wiring shall cause audible signals to sound continuously for 4 seconds to indicate trouble condition.
      g. System shall have 7 distinctive walk test groups such that only a portion of system need be disabled during testing and an alarm in any other area will be processed normally.

N. General Alarm Circuits: Positive non-interfering type so that a second device can be annunciated simultaneously, or closely following first zone.

O. Power Supply:
   1. 120 Vac dedicated circuit from panelboard to integral 24 Vdc regulated power supply in FACP and battery charger.
      a. The power supply shall provide all panel and peripheral device power needs.
   2. If the FACP cannot provide power for the required number of notification appliances a power extender shall be used.
      a. An additional 120 Vac dedicated circuit from a panelboard shall be used to power the power extenders power supply and battery charger.

P. Battery:

1. Low maintenance sealed type, for fire alarm use with automatic battery charger.
2. Batteries shall be capable of operating maximum normal load of system for 24 HRS and then capable of operating system for 5 minutes in alarm condition.
3. Size batteries for the total maximum number of devices that can be connected to the FACP not the install number of devices.
4. The notification appliance power extender shall have the same battery requirements as the FACP.

Q. Location of devices shall be as shown in the drawings.

2.3 FIRE ALARM ANNUNCIATOR PANEL (FAA)

A. Located inside the control house.

B. Annunciator provides remote annunciation using a two-line 40 character, back-lit, alphanumeric, LCD readout.
   1. The readout shall display, in descriptive English language; system status, alarm type, supervisory conditions, troubles, and location.

C. LED's and a tone-alert audible indication is provided for alarm, supervisory on trouble conditions.
   1. Each condition has an acknowledge push-button switch that silences the tone-alert but leaves the LED on until all conditions are returned to normal.

D. FAA shall be an enclosed metal cabinet designed for public areas:
   1. Mounting: Flush.
   2. Finish: Beige baked enamel.

2.4 SIGNAL INITIATING DEVICES

A. Addressable Manual Pull Stations:
   1. Pull-type with handle which shall lock in a protruding manner to facilitate quick visual identification of activated station.
      a. Key reset after operation.
      b. Non-coded.
      c. Single action.
   2. High impact red Lexan with operating directions in white letters.
      a. Semi-flush mounted in architecturally finished areas.
      b. Surface mounted in non-architecturally finished areas.
      c. Surface mounted with clear Lexan weatherproof protective shield in areas designated as wet or in areas indicated in the schedules herein.
      d. Explosion proof enclosure or intrinsically safe circuit in hazardous rated areas.
   3. Stations shall be keyed alike with FACP.
   4. Standards: UL 38.

B. Addressable Sensor Base:
   1. Plug-in arrangement:
      a. Sensor and associated encapsulated electronic components are mounted in a module that connects to a fixed base with a twist-locking plug connection.
      b. The plug connection requires no springs for secure mounting and contact maintenance.
      c. Terminals in the fixed base accept building wiring.
      d. Sensor construction shall have a mounting base with a twist-lock detecting head that is lockable.
      e. The locking feature must be field removable when not required.
      f. Removal of the sensor head shall interrupt the supervisory circuit of the fire alarm detection loop and cause a trouble signal at the Control Unit.

2. LED that will flash each time it is scanned by the Control Unit.
   a. When the Control Unit determines that a sensor is in an alarm or a trouble condition, the Control Unit shall command the LED on that sensor's base to turn on steady indicating that abnormal condition exists.
   b. Sensors which do not provide a visible indication of an abnormal condition at the sensor location shall not be acceptable.
3. Magnetically actuated test switch to provide for easy alarm testing at the sensor location.
4. Each sensor shall be scanned by the Control Unit for its type identification to prevent inadvertent substitution of another sensor type.
   a. The Control Unit shall operate with the installed device but shall initiate a "Wrong Device" trouble condition until the proper type is installed or the programmed sensor type is changed.
5. Addressability: Sensors include a communication transmitter and receiver in the mounting base having a unique identification and capability for status reporting to the FACP.
6. Provide auxiliary relays in base to provide local control of equipment as described under system operation.
   a. Provide separate 24 volt supply to sensors with auxiliary relays to guarantee that sufficient power will be available to operate relays.

C. Analog Addressable Heat Sensors:
1. Fixed temperature type or combination rate-of-rise and fixed temperature type.
2. Rated at 135 DegF for ordinary areas where normal ceiling temperatures do not exceed 100 DegF, or rated 190 DegF for up to 150 DegF ceiling temperatures.
3. Self-restoring: Sensors do not require resetting or readjustment after actuation to restore them to normal operation.
4. The sensor's electronics shall be immune from false alarms caused by EMI and RFI.
5. Quantity and spacing:
   a. Smooth ceilings: In accordance with UL rating.
   b. Non-smooth ceilings: In accordance with State Fire marshal's requirements.
   c. High hazard areas: As indicated.
6. Layout is based on 30 FT spacing for fixed-type and 50 FT spacing for combination type for smooth ceiling.
7. Standards: UL 521.

D. Analog Addressable Smoke Sensors:
1. Photoelectric type, dual chamber products of combustion sensors.
2. An infrared sensor light with matching silicon cell receiver and actuated by the presence of visible products of combustion.
3. Self-restoring: Sensors do not require resetting or readjustment after actuation to restore them to normal operation.
4. The sensor's electronics shall be immune from false alarms caused by EMI and RFI.
5. Standards: UL 268.

E. Air Duct Smoke Sensor:
1. Duct smoke sensors shall utilize analog addressable photoelectric type sensor as specified herein.
2. Duct housing mounted directly to outside of duct with a sampling tube extended across duct to sample air movement.
3. Duct housing couplings slotted to insure proper alignment of sampling and exhaust tubes.
   a. Tube lengths as required per duct width.
4. Sensor housing shall have an alarm LED visible through front cover.
5. Remote red LED alarm indicator on ceiling adjacent to sensors above ceilings.
6. Standards: UL 268A.

F. Addressable Monitor Modules:
  1. Provides addressability and supervision to a conventional initiating device (e.g., tamper switches, pressure switches, flow switches).
     a. The conventional initiating device shall be wired Class B, Style B.
  2. Integral or remote LED shall be provide that will flash each time it is scanned by the Control Unit.
     a. When the Control Unit determines that a monitor module is in an alarm or a trouble condition, the Control Unit shall command the LED on that sensor's base to turn on steady indicating that abnormal condition exists.
  3. Explosion proof enclosure or intrinsically safe circuit in hazardous rated areas.

G. Sprinkler System Sensors:
  1. Provide monitor module as specified herein for waterflow sensor(s).
     a. Waterflow sensor(s) provided by Division 21.
  2. Provide monitor module as specified herein for pressure sensor(s).
     a. Pressure sensor(s) provided by Division 21.
  3. Provide monitor module as specified herein, for tamper switches associated with main water valve, post indicator valve (PIV) or OS&Y valves.
     a. Tamper switches provided by Division 21.

2.5 AUTOMATIC CONTROL DEVICES

A. Addressable Relay/Control Modules:
  1. Allows FACP to control a remotely located Form "C" contact (e.g., HVAC fans, dampers, fire shutters, elevator capture).

2.6 NOTIFICATION APPLIANCES

A. Alarm Horns:
  1. Electric-vibrating polarized type, operating on 24 Vdc, with provision for housing the operating mechanism behind a grille.
  2. Horns produce a sound pressure level of 85 dB, measured at 10 FT.
  3. Housing: Red with white "FIRE" lettering.
     a. Semi-flush or flush mounted in architecturally finished areas.
     b. Surface-mounted in non-architecturally finished areas.
  4. Horns shall be weatherproof in areas designated as wet.
  5. Horns shall be explosion proof in areas designated as hazardous.

B. Alarm Strobes:
  1. White tamper resistant lexan lens with 24 Vdc xenon strobe.
  2. Provide Candela rating as required per ADAAG and synchronize of multiple strobes when required.
  3. Housing: Red with white "FIRE" lettering.
     a. Semi-flush or flush mounted in architecturally finished areas.
     b. Surface-mounted in non-architecturally finished areas.
  4. Strobes shall be weatherproof in areas designated as wet or in areas indicated in the schedules herein.
  5. Strobes shall be explosion proof in areas designated as hazardous.

C. Combination Audio/Visual Devices:
  1. Shall be mounted in an integral unit and shall have the same features as the individual units specified herein.

D. Alarm Bells:
  1. Heavy-duty vibrating type, operating on 24 Vdc.

2. Gong: 6 IN producing a sound pressure level of 85 dB, measured at 10 FT.
3. Housing:
    a. Red.
    b. Semi-flush or flush mounted in architecturally finished areas.
    c. Surface mounted in non-architecturally finished areas.
    d. Weatherproof in areas designated as wet.

E. Standards: UL 464, UL 1971.

2.7 MISCELLANEOUS DEVICES

A. Isolated Loop Circuit Protector (Transient Suppression):
1. Hybrid solid state high performance suppression system.
    a. Do not use gas tubes, spark gaps or other suppression system components which might short or crowbar the line resulting in interruption of normal power flow to connected loads.
2. Line-to-line response time of less than one (1) nanosecond capable of accepting a 2000 amps (8 x 20 usec pulse) at 28 V.
3. Line-to-ground response time of less than 1 nanosecond capable of accepting a 2000 amps (8 x 20 usec pulse) to earth.
4. Shield-to-ground shall be capable of accepting a 5000 amps (10 x 50 usec pulse) to earth.
5. Standard: UL 497B.

2.8 WIRING

A. Conduit:
1. 1/2 IN minimum.
2. See Specification Section 26 05 33.

B. Conductors:
1. Insulation type per NFPA 70, Article 760.
2. 120 Vac and power supply connections: 12 GA, minimum.
3. Low-voltage general alarm circuits: 14 GA, minimum.
4. Low-voltage signal initiating circuits: 18 GA, minimum.
5. Annunciator and data communication circuits: As required by manufacturer, UL listed.
6. Use larger wire sizes when recommended by equipment manufacturer and per voltage drop calculations.

C. Outlet Boxes: See Specification Section 26 05 33.

2.9 SYSTEM OPERATION

A. Activation of any signal initiating device, except tamper switches, shall cause the following:
1. General audible horns and/or bells to sound, visual strobes to strobe and automatic control devices to operate.
2. Alarm information shall be displayed at the FACP LCD displays.

B. All fire alarm signals are automatically locked in at FACP and remote LCD displayed annunciators until originating device is returned to normal and FACP is manually reset.
1. Audible alarm signals shall be silence-able from FACP allowing for re-initiation following a subsequent alarm.
    a. Silencing of alarm signals shall not impair ability of system to continue to perform as specified.

C. Air Handling Equipment Fan Control:

1. De-energize indicated air-handling equipment and interlocked exhaust fans, upon operation of any alarm initiating device via relay/control module {and all smoke dampers shall close}.
2. See Specification Section 23 09 00 for mechanical equipment sequence of operation and coordinate all fan controls.
3. Fans shall not restart until FACP is manually reset.

D. Activation of any system trouble shall initiate the following:
   1. Common audible trouble signal shall sound and common trouble light shall illuminate at FACP and any remote annunciators.
   2. FACP shall indicate specific device.

E. Audible trouble signal shall be silenceable by FACP.
   1. Visual trouble indication remains until trouble condition is corrected.
      a. A subsequent trouble condition received after manually silencing shall cause audible trouble signal to resound.
      b. Restoration of system to normal causes audible trouble signal until silencing switch is returned to normal position.
   2. Trouble signal will be initiated under following conditions:
      a. Open on an initiation or alarm indicating circuit.
      b. Open in wiring to remote LCD annunciator(s).
      c. Ground fault condition.
      d. Auxiliary manual control switch out of normal position.
      e. Loss of 120 volt operating power to FACP, transponders, or remote LCD annunciators.
      f. Low or no battery voltage condition.
      g. Main sprinkler valve is closed.
      h. Post indicator valve is closed.
      i. Any sprinkler or standpipe OS&Y valve is closed.

F. Install isolated loop circuit protectors on all fire alarm data communication circuits, SLC and NAC wiring, including shields, which extends beyond the a building by either aerial or underground methods.
   1. The isolated loop circuit protector shall be located as close as practicable to the point at which the circuits leave or enter a building.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install all fire alarm equipment and wiring in accordance with local and national codes and NFPA 72.

B. Install all wiring in raceways:
   1. Install raceways and boxes in accordance with Specification Section 26 05 33.
   2. The inside of all boxes are to be painted red.

C. Install all components as indicated and in accordance with manufacturer's wiring diagrams, instructions and recommendations.

D. Make all fire alarm wiring continuous from terminal to terminal or from terminal to device pigtail lead.
   1. Circuit splices not permitted.
   2. Wiring joints, only when required at device pigtail leads shall utilize Scotchlok insulate conical spring connector.

E. Color code all wiring by type of device.

1. Coordinate colors with Owner.

F. Installation of equipment and devices that pertain to other work in contract shall be closely coordinated with appropriate subcontractors.
   1. Coordinate 8 IN minimum square access door with rubber gasket in duct approximately 2 FT upstream from smoke sensor for testing and servicing with Division 21.

G. Cover all smoke detectors with plastic bags immediately after installation to maintain cleanliness.

H. Device Mounting Schedule:
   1. Dimensions are to center of item unless otherwise indicated.
   2. Mounting heights as indicated below unless otherwise indicated on the Drawings.
      a. Manual pull stations: 48 IN.
      b. Notification appliances: 80 IN.
      c. Control panels and remote annunciators: 72 IN to top.

3.2 TESTING

A. Obtain services of a factory trained representative of system manufacturer to supervise installation and its progress, supervise final connections to equipment and provide testing to assure that system is in proper operating condition, and is in compliance with all applicable regulations.

B. Test system to satisfaction of Engineer and state and local fire authorities in accordance with NFPA 72, state and local codes and manufacturer's requirements.

3.3 INSTRUCTION

A. Manufacturer shall provide an authorized representative to instruct and train Fire Department personnel and Owner's personnel in operation of system.

3.4 SCHEDULES

END OF SECTION

SECTION 34 41 16
TRAFFIC CONTROL EQUIPMENT

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Basic requirements for warning gates.
   2. Basic requirements for barrier gates.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Section 105 - Control of the Work.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. American National Standards Institute (ANSI):
      a. B40.100, Pressure Gauges and Gauge Attachments.
   2. American Association of State Highway and Transportation Officials (AASHTO):
      a. Standard Specifications for Movable Highway Bridges.
   3. American Society for Testing and Materials (ASTM).
   4. Building code:
      a. International Code Council (ICC):
         1) International Building Code and associated standards, latest revision. Including all amendments, referred to herein as Building Code.

1.3 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
   2. Product technical data including:
      a. Technical data including assembly and component ratings.
      b. Nameplate drawing.
      c. Mounting and loading information.
      d. Installation instructions and procedures.
      e. See Specification Section 26 05 00 for additional requirements.
   3. Fabrication and/or layout drawings:
      a. General arrangement.
      b. Elevation.
      c. Wiring diagrams for all accessories.
   4. Test reports:
      a. Factory tests.

B. Operation and Maintenance Manuals:
   1. See Specification Section 26 05 00 for requirements for the mechanics and administration of submittal process.
   2. The Design-Builder shall furnish complete instructions containing the technical information required for proper installation, operation and maintenance of each assembly of equipment supplied.

1.4 DELIVERY, STORAGE AND HANDLING

A. See Specification Section 26 05 00.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following manufacturers are acceptable:
   1. Warning Gates
      a. B&B Electromatic.
      b. Roadway Manufacturing.
      c. Federal Signal Corporation.
   2. Warning Gate Flasher Light
      a. B&B Roadway.
   3. Warning Gate Motor and Brake Disconnect Switch
      a. Pass & Seymour.
      b. O-Z/Gedney.
      c. Crouse Hinds.
   4. Gong
      a. B&B Roadway.
      b. Federal Signal Corporation.
      c. Western-Cullen.
   5. Barrier Gates
      a. B&B Roadway.
      b. Federal Signal Corporation.
   6. Barrier Gate Motor and Brake
      a. Pass & Seymour.
      b. O-Z/Gedney.
      c. Crouse Hinds.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 GENERAL MATERIALS

A. Metal
   1. All metal parts of the installation, except structural steel, shall be of corrosion-resisting material such as aluminum, bronze, or stainless steel.
   2. Cast-iron, malleable iron, or steel with a hot-dip galvanized finish shall be used where specified herein or permitted by the Engineer.

B. Welding
   1. Shall meet the requirements of the American Welding Society's Structural Welding Code – Aluminum D1.2.

C. Paint
   1. Warning and barrier gate housings and arm supports and the cable anchorages shall be painted. See New Hampshire Department of Transportation Specification Section 708.

D. Nameplate
   1. Each piece of electrical equipment and apparatus shall have a corrosion-resisting metal nameplate, on which is stamped the name of the manufacturer and the rating or capacity of the equipment or apparatus.

2.3 WARNING GATE ARM

A. General:
   1. Designed, constructed and tested in accordance with applicable ANSI, NEMA and IEEE Standards.

2. Shall be adequately braced transverse to its motion to resist wind loads, designed to withstand 161 kilometer-per-hour wind load, and to reduce whipping and shall be guyed to prevent sagging.
   a. Guy wires shall be configured in such a way that they do not project beyond the warning gate housing into the sidewalk when the warning gate is in the vertical position.
3. Bumper rod with compression spring shall be provided near the end of each warning gate arm to stop the travel at the closed position without undue shock.
4. Operation:
   a. Shall open through an angle of 90 degrees from the horizontal to the vertical.
   b. The warning gate arm shall begin with zero velocity and accelerate smoothly reaching maximum velocity at mid stroke (45 degrees). The arm shall then decelerate smoothly to zero velocity at full stroke (0 and 90 degrees) preventing bounce or whip of the arm.
   c. Operating time to open or close the gate: 13 seconds.
   d. Location
      1) Shall be able to be operated from multiple locations: control desk or auxiliary location
      2) Control desk shall have provisions which enable the operator to select the location of operation, either the control desk or an auxiliary location
      3) Individual controls at all the locations which enable the gate to be raised or lowered while the corresponding pushbutton is depressed. The raise and lower circuitry shall be a momentary action. In addition, the group of two barrier gates, east and west, shall be provided with a group raise momentary control on the main desk such that all gates shall travel to their fully raised limits. The group shall stop immediately upon momentary contact of the group stop.

B. Material:
1. Warning gate arm
   a. Pair of high strength 6061- T6 aluminum tubes, spaced 279 mm apart in a vertical plane
   b. Length of arm: Shown on the Plans
   c. Warning gate arm shall be striped with alternate red and white reflectorized stripes 406 mm wide measured parallel to the edge of the warning gate arm. The stripes shall slope downward at an angle of 45 degrees away from the gate housing.
2. Fastenings used in warning gate arm assembly and for connection to warning gate stand
   a. Corrosion-resisting metal or hot-dip galvanized
3. Warning arm channels and supports
   a. Galvanized or painted in accordance with requirements for painting structural steel. See New Hampshire Department of Transportation Specification Section 708.

2.4 WARNING GATE HOUSING

A. Warning Gate Stand
1. Welded steel, hot-dip galvanized after fabrication
2. Watertight
3. Bolted to concrete or steel base as indicated on the Plans
4. Encloses:
   a. Motor
   b. Disconnect switch
   c. Gear train
   d. Limit switch
   e. Fuses for warning lights
5. Equipped with:
   a. Thermostatically controlled heater

   b. Switched service light
   c. Duplex, Specification Grade GFI receptacle sized as required

B. Gear Reducers for Driving the Warning Gate Arms
   1. Totally enclosed in oil-tight steel housings
   2. Automatically lubricated
   3. Oil sight gages shall be provided

C. Doors
   1. Watertight
   2. Removable
   3. Provide access to operating equipment
   4. Shall be large enough for convenient removal of the largest component of the operating mechanism
   5. Equipped with:
      a. Neoprene gaskets
      b. Two safety interlock switches
      c. Silicon bronze hinges with stainless steel pins
      d. Stainless steel catches and bolts
      e. Hockey puck type padlocks with common keys to the barrier gate locks

D. Internal Wiring
   1. Brought to numbered terminal block inside housing for connection of external circuits

E. Circuit Breaker
   1. Rating: As shown on the plans.
   2. Shall protect equipment within warning gate housing
   3. Shall be mounted in warning gate housing

F. All drive equipment and limit switches shall be mounted on a common base independent from the gate housing.

G. Painting
   1. New Hampshire Department of Transportation Specification Section 708.

2.5 WARNING GATE HAND CRANK

A. Operation
   1. Provides for manual operation of each warning gate
   2. Insertion of the crank or operation of a manual operation button shall release the brake and make the electrical controls inoperative

B. Stored inside the warning gate housing

C. Limit Switch
   1. Contacts
      a. 1 NO and 1 NC
      b. Prevent electrical operation of warning gates while hand cranking

2.6 WARNING GATE ARM LIGHTS

A. Number of lights - Shown on wiring diagrams

B. Unit
   1. Weatherproof
   2. Two-way
   3. Cast-aluminum
   4. Red Fresnel lenses, front and back

C. Connection
   1. Lights shall be interconnected and grounded with four-conductor portable cord
   2. Watertight connectors at the fixtures
   3. Adjacent units will flash alternately

D. Lamp to be installed in each fixture
   1. Voltage: as required
   2. Wattage: as required
   3. Red
   4. LED

E. Fuses
   1. Installed in molded rubber connection kits

F. Flasher
   1. Solid state
   2. Two alternately flashing circuits and one steady burn circuit
      a. Flash rate for the two alternately flashing circuits shall be 0.50 seconds on, 0.50 seconds off
      b. An additional steady burn circuit shall be provided for the lamp farthest from the gate stand
   3. Designed for heavy duty applications
   4. Assembly
      a. Industrial quality Components
         1) Mounting hardware as required
         2) Solid-state flasher circuitry
         3) Terminal block
            a) Clearly marked for field connections
         4) Silicon heat sink compound
         5) Transformer
      b. Wiring
         1) Fully wired at the factory
   5. Base plate compound
      a. Anodized for corrosion protection

2.7 WARNING GATE TRANSMISSION

A. Unit
   1. Fully enclosed
   2. All gear
   3. Direct drive
   4. Running in an oil bath

B. Drive train
   1. Shall not use belts or chains
   2. Shall be connected to the arm shaft with an adjustable connecting rod having self-aligning ball ends

C. Connecting rod material
   1. ASTM A311Class B high strength, fatigue resistant steel

2.8 WARNING GATE LIMIT SWITCH

A. 8-circuit rotary cam-type switch
   1. Cams shall be secured with set screws

B. Provided in each warning gate

C. Operated by the warning gate mechanism

D. Gear driven from the transmission

E. Contacts
   1. Quick-break
   2. Silvery alloy buttons

F. Limit switch shaft
   1. Stainless steel

2.9 WARNING GATE MOTOR AND BRAKE

A. Motor and gear train shall be capable of opening and closing the warning gate in about 13 seconds

B. Motor
   1. Shall be furnished as part of the warning gate by the warning gate manufacturer
   2. Totally-enclosed
   3. Voltage: as requied
   4. Phase: as required
   5. Cycles: 60
   6. Ball-bearing induction motor
   7. Not less than 560 watts (3/4 HP)
   8. Capable of withstanding instant reversal when running at full speed
   9. Controlled by a magnetic reversing contactor mounted in the motor control center
   10. Electrically and mechanically interlocked (shall be mounted in the motor control center)
   11. Protected by a three-element, thermal overload relay, with automatic reset mounted in the motor control center

C. Brake
   1. Motor-mounted
   2. Spring-set
   3. Rated as required
   4. Solenoid-release
   5. Disc brake
   6. Provided for stopping and holding the mechanism

D. Drive mechanism and motor brake shall be capable of holding the gate vertical against a wind load of 146 kilograms-per-meter

E. Disconnect switch
   1. Watertight
   2. Permit disconnecting the motor and brake from the incoming power

2.10 WARNING GONG

A. One mounted on the top of each warning gate housing

B. Mounted in a heavy-duty, cast-aluminum housing with hinged back door

C. Weatherproof

D. Motor-operated

E. Mounted with hardware in such a way to prevent theft

F. Cast-bronze, fire alarm metal

G. Shall be painted. See New Hampshire Department of Transportation Specification Section 708.

2.11 BARRIER GATE ARM

A. General:
1. Designed, constructed and tested in accordance with applicable ANSI, NEMA and IEEE Standards.
2. Barrier gate arm
   a. Barrier gate delineators
      1) Shall be mounted on brackets on the barrier gate arms
      2) Two delineator signs shall have a pedestrian arm attached as shown on the Contract Plans
         a) Pedestrian arm shall be adequately braced transverse to its motion to resist wind loads and designed to withstand 161 kilometer-per-hour wind load.
   b. Cable net
      1) Equipped with a system of three cables, laced together into a net-like structure
      2) Cable shall run inside each tube and the third cable shall along the center of the arm
      3) If a vehicle collides with a gate, the aluminum arm structure shall break away, and the cable net shall contain the vehicle
      4) Energy absorption cables shall be anchored at both ends of the barrier in the closed to traffic position
      5) Cable anchorage system shall be used at the housing or base end of the arm to absorb loads during impact
      6) Dnergy absorption cables shall be anchored at the tip end of the arm in the closed to traffic position
      7) Shall typically be capable of absorbing the energy of a 2268 kilogram vehicle traveling up to 80 kph
         a) Design-Builder shall submit calculations for the design of the energy absorption cables using this criteria
   c. Passive end latch
      1) Mounted on the arm tip
      2) Engage a rigidly mounted and anchored socket on or in a wall or sidewalk for the independent barriers
         a) This stainless steel arm socket shall be capable of supporting the barrier gate under maximum load
         b) Shall be installed as shown on the Contract Plans
         c) Shall be manufactured by the barrier gate supplier
3. Counterweight:
   a. Sectional
   b. Balanced at factory
4. Operation:
   a. Shall open through an angle of 90 degrees from the horizontal to the vertical.
   b. The warning gate arm shall begin with zero velocity and accelerate smoothly reaching maximum velocity at mid stroke (45 degrees). The arm shall then decelerate smoothly to zero velocity at full stroke (0 and 90 degrees) preventing bounce or whip of the arm.
   c. Operating time to open or close the gate: 16 seconds.
   d. Location
      1) Shall be able to be operated from multiple locations: control desk or auxiliary location
      2) Control desk shall have provisions which enable the operator to select the location of operation, either the control desk or an auxiliary location

3) Individual controls at all the locations which enable the gate to be raised or lowered while the corresponding pushbutton is depressed. The raise and lower circuitry shall be a momentary action. In addition, the group of two barrier gates, east and west, shall be provided with a group raise momentary control on the main desk such that all gates shall travel to their fully raised limits. The group shall stop immediately upon momentary contact of the group stop.

B. Material:
1. Barrier gate arm
   a. Pair of high strength 6061- T6 aluminum tubes, spaced 355 mm (14 in) apart in a vertical plane.
   b. Length of arm - Shown on the Plans.
   c. Barrier gate arm shall be striped with alternate red and white reflectorized stripes 406 mm wide measured parallel to the edge of the warning gate arm. The stripes shall slope downward at an angle of 45 degrees away from the gate housing.
   d. Cable net
      1) Three (3) annealed stainless steel cables
2. Pedestrian arm
   a. Constructed of a similar material as gate arm
   b. Manufactured by the barrier gate supplier
3. Counterweights
   a. Hot-dipped galvanized

2.12 BARRIER GATE HOUSING

A. Warning Gate Stand
1. Welded steel, hot-dip galvanized inside and out after fabrication
   a. Minimum plate thickness: 9.5 mm
2. Equipped with:
   a. Thermostatically controlled heater
   b. Switched service light
   c. Duplex, Specification Grade GFI receptacle rated as required

B. Doors
1. Watertight
2. Removable
3. Provide access to operating equipment
4. Shall be large enough for convenient removal of the largest component of the operating mechanism
5. Stop shall be mounted inside the door to secure the door from being raised off the hinges in the closed position
6. Equipped with:
   a. Neoprene gaskets
   b. Two safety interlock switches
      1) Installed and set at the factory to break the control circuit when either access door is opened
      2) Shall have a pull-to-override feature for test operation and shall automatically reset when doors are closed
   c. Silicon bronze slip-off hinges with stainless steel pins
   d. Stainless steel catches and bolts
   e. Hockey puck type padlocks with common keys to the warning gate locks

C. Circuit Breaker
1. Rating: as shown on the plans

2. Shall protect equipment within warning gate housing
3. Shall be mounted in warning gate housing

D. All drive equipment and limit switches shall be mounted on a common base independent from the gate housing.

2.13 BARRIER GATE HAND CRANK

A. Operation
1. Provides for manual operation of each warning gate
2. Insertion of the crank or operation of a manual operation button shall release the brake and make the electrical controls inoperative

B. Stored inside the warning gate housing

C. Limit Switch
1. Contacts
a. 1 NO and 1 NC
b. Prevent electrical operation of warning gates while hand cranking

2.14 BARRIER GATE ARM LIGHTS

A. Shall be same type as specified for warning gates

B. Unit
1. Two-way
2. Cast-aluminum
3. Red Fresnel lenses, front and back

C. Connection
1. Lights shall be interconnected and grounded with four-conductor flexible cables
2. Watertight connectors at the fixtures
3. Adjacent units will flash alternately

D. Lamp to be installed in each fixture
1. 120-volt
2. 8-watt
3. Red
4. LED

2.15 BARRIER GATE TRANSMISSION

A. Speed Reducer
1. Fully enclosed
2. Double-reduction
3. Worm gear
4. Totally enclosed in oil-tight steel housing
5. Shall be automatically lubricated
a. Oil sight gages or inspection plugs shall be provided

B. Barrier gate arm shall pivot in the vertical plane via a mechanical 4-bar linkage
1. Linkage driven by speed reducer

C. All driving components shall be proportioned so that the maximum stress in any part does not exceed 50 percent of the yield point of the material at the stalled torque of the motor

D. Drive train
1. Shall not use belts or chains

2. Shall be connected to the arm shaft with an adjustable connecting rod having self-aligning ball ends

E. Unit
1. Fully enclosed
2. All gear
3. Direct drive
4. Running in an oil bath

F. Connecting rod material
1. ASTM A311Class B high strength, fatigue resistant steel

2.16 BARRIER GATE LIMIT SWITCH

A. 8-circuit rotary cam-type switch
1. Adjustable cams
2. Cams shall be secured thereto with set screws

B. Driven by gear train

C. A magnetic proximity switch
1. Attached to each arm tip where shown on the Plans to detect locking of the barrier gates
2. Flexible cable shall be run between the proximity switch and the terminal blocks in the barrier gate housing

D. Shall be provided for control of the barrier gate and for interlocking

E. Conductors shall be brought to numbered terminal blocks for connection of incoming wiring

F. Adjusted so that each arm is stopped within 54 mm (2 in) of the fully open or fully closed position
1. When the barrier gates are electrically operable, they shall be operated as in normal use

2.17 BARRIER GATE MOTOR AND BRAKE

A. Motor
1. Shall be furnished as part of the barrier gate by the barrier gate manufacturer
2. Totally-enclosed
3. Voltage: as required
4. Phases: 3
5. Cycles: 60
6. Ball-bearing induction motor
7. Not less than 1.5 KW (2 HP)
8. Capable of withstanding instant reversal when running at full speed
9. Controlled by a magnetic reversing contactor mounted in the motor control center
10. Electrically and mechanically interlocked (shall be mounted in the motor control center)
11. Protected by a three-element, thermal overload relay, with automatic reset mounted in the motor control center

B. Motor and gear train shall be capable of opening and closing the warning gate in about 16 seconds

C. Brake
1. Motor-mounted
2. Spring-set
3. Rated as required
4. Solenoid-release
5. Disc brake

6. Provided for stopping and holding the mechanism

D. Drive mechanism and motor brake shall be capable of holding the gate vertical against a wind load of 146 kilograms-per-meter

E. Disconnect switch
1. Watertight
2. Permit disconnecting the motor and brake from the incoming power

2.18 SPARE PARTS

A. Shall be supplied in accordance with AASHTO Article 2.10.58 requirements and the Contract Plans.

B. Furnished and packed in suitable cartons for storage at the bridge
1. Arrange the spare parts in uniform size cartons of substantial construction
2. Typed and clearly varnished labels to indicate their contents

C. Include, but are not limited to:
1. For warning gates:
    a. One (1) motor, compete with motor pinion
    b. One (1) rotary cam limit switch with operating mechanism
    c. One (1) access door limit switch
    d. Six (6) warning light fixtures complete with lamps
    e. Six (6) lamps for warning lights
    f. Two (2) gate arms (one of each specified length)
    g. One (1) flasher unit
2. For barrier gates:
    a. One (1) motor, compete with motor pinion
    b. One (1) rotary cam limit switch with operating mechanism
    c. One (1) access door limit switch
    d. Six (6) warning light fixtures complete with lamps
    e. Six (6) lamps for warning lights
    f. Two (2) gate arms complete with cables, guys, and end toggles (one of each specified length)
    g. One (1) flasher unit
3. For traffic lights:
    a. Two (2) of each color traffic light lens installed
    b. Six (6) lens and door gaskets
    c. Twelve (12) traffic signal lamps
4. For drawbridge warning lights:
    a. Two (2) drawbridge warning light lens installed
    b. Two (2) lens and door gaskets
    c. Four (4) drawbridge warning lamps

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install in accordance with manufacturer's instructions.

B. Arrange as shown on the Drawings.

C. Warning Gates
1. The double rail aluminum arms shall be carefully attached to the supporting members so as to make a rigid connection.

2. Arms shall be counterbalanced and the limit switches and crank arms adjusted so that the arms are stopped in a truly vertical or horizontal position within 1 degree.

3.2 FIELD QUALITY CONTROL

A. Employ and pay for services of equipment manufacturer's field service representative(s) to:
   1. Inspect equipment covered by these Specifications.
   2. Supervise adjustments and installation checks.
   3. Provide test equipment, tools, and instruments necessary to accomplish equipment testing.
   4. Conduct start-up of equipment and perform operational checks.
   5. Provide Owner with a written statement that manufacturer's equipment has been installed properly, has been started up, and is ready for operation by Owner's personnel.

3.3 CLEANING

A. See Specification Section 26 05 00.

3.4 DEMONSTRATION

A. See Specification Section 26 05 00.

END OF SECTION

SECTION 40 41 13
HEAT TRACING CABLE

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Heat tracing cable as required for heat tracing of pipes as indicated on the Drawings.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Specification Section 105 - Control of the Work.
   2. Section 26 05 00 - Electrical: Basic Requirements.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. National Electrical Manufacturers Association (NEMA):
      a. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).

1.3 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of the submittal process.
   2. Product technical data:
      a. Power requirements for each circuit based upon actual length of heat trace and maintained temperature.
      b. Circuit breaker rating based upon inrush current at minimum expected start-up temperature.
      c. Length of heat tape for each pipe size and run.
      d. Coordinate and verify length and Watts/FT of heat tape required based upon pipe size and insulation thickness.
         1) Include the calculations to support the heat tape output.
      e. See Specification Section 26 05 00 for additional requirements.
   3. Fabrication and/or layout drawings:
      a. Wiring diagrams showing physical locations of thermostats and heat trace power supply.

B. Operation and Maintenance Manual:
   1. See Specification Section 26 05 00 for requirements for:
      a. The mechanics and administration of the submittal process.
      b. The content of Operation and Maintenance Manuals.

C. Miscellaneous:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of the submittal process.
   2. Test reports: Megger test results.

1.4 DELIVERY, STORAGE, AND HANDLING

A. Shall be stored such that they are not exposed to sunlight or other UV rays.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following Manufacturers are acceptable:
   1. Thermon.
   2. Chemelex Division; Raychem Corp.
   3. Chromalox.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 HEAT TRACING

A. Design Parameters:
   1. Pipe diameter, length and material: See Drawings and Division 40 Specifications.
   2. Flange, valve, pipe support size: See Drawings and Division 40 Specifications.
   3. Pipe insulation type and thickness: See Drawings and Division 40 Specifications.
   4. Safety factor: 10 percent.

B. Self-regulating or power-limiting parallel circuit construction consisting of an inner core of conductive material between parallel copper bus wires, with inverse temperature - conductivity characteristics with metal overbraid.

C. Thermostats adjustable between 35 and 200 DegF minimum with maximum differential range of 9 DegF, furnished complete with NEMA 4 enclosures in all areas, stainless steel temperature bulb and capillary.

D. All necessary or required components and accessories, such as power connection boxes, end seals, straps, tape and fitting brackets.

E. In non-corrosive and non-hazardous locations, insulation shall be Polyolefin.

F. In corrosive, hazardous and hydrocarbon locations insulation shall be Fluoropolymer (Teflon).

PART 3 - EXECUTION

3.1 PREPARATION

A. Install materials after piping has been tested and approved.

3.2 INSTALLATION

A. Insulate and heat trace wet pipe systems as indicated on Drawings.

B. Install materials in accordance with manufacturer's instructions.
   1. Each circuit shall not exceed the manufacturer's recommended maximum length.

C. For metallic piping:
   1. Heat tracing shall be installed completely wired.
   2. Cut heat trace to lengths as required and secure to pipe with glass or polyester fiber tape.

D. For non-metallic piping:
   1. Allow for extra heat trace output because non-metallic pipe has a lower heat transfer.
      a. Heat tracing shall be installed completely wired.
   2. Cut heat trace to lengths as required and secure to pipe with aluminum tape through out the length of the trace.

E. Protection and Control Requirements:
   1. Protection by a GFEPCI circuit breaker.

a. Breaker amperage rating shall be coordinated with Design-Builder when different than the Contract Drawings.

2. {Provide two (2) line sensing thermostats, one (1) for power and one (1) for alarm.} {Provide an ambient sensing thermostat for power and line sensing thermostat for alarm.}
3. The alarm thermostat shall be placed on the opposite end of the circuit from the power thermostat or power connection to allow for annunciation of partial failure of a circuit or the loss of power from a tripped GFEPCI circuit breaker.
4. Provide a monitoring module that monitors the voltage (circuit breaker status) to each circuit.
5. The alarm from the alarm thermostat and monitor module shall be annunciated on the indicated control system.

3.3 TESTING

A. Megger the cables at the manufacturers recommended voltage level three (3) times.
   1. Before installation.
   2. After attachment to pipe but before insulation is installed.
   3. After pipe insulation is installed but before energization.

END OF SECTION

SECTION 40 94 43

PROGRAMMABLE LOGIC CONTROLLER (PLC) CONTROL SYSTEM

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Programmable logic controller (PLC) control system(s), including software, programming, and training.

B. Related Specification Sections include but are not necessarily limited to:
   1. New Hampshire Department of Transportation Specification Section 105 - Control of the Work.
   2. Section 10 14 00 - Identification Devices.
   3. Section 26 05 19 - Wire and Cable - 600 Volt and Below.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
      a. C37.90.2, Trial-Use Standard Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers.
      b. C62.41, Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits.
   2. National Electrical Manufacturers Association (NEMA):
      a. ICS 1, General Standards for Industrial Control and Systems.

B. Qualifications:
   1. Installation supervisor shall have had experience in overseeing installation and startup of at least three (3) similar installations.
   2. Programmer(s) shall have had experience in programming PLCs for at least two (2) projects of similar size and complexity.

1.3 SUBMITTALS

A. Shop Drawings:
   1. See New Hampshire Department of Transportation Specification Section 105 for requirements for the mechanics and administration of submittal process.
   2. Submittals shall be original printed material or clear unblemished photocopies of original printed material. Facsimile information is not acceptable.
   3. Product technical data including:
      a. Annotated hard copies of PLC software programs.
         1) Submit program for logic in ladder diagram format as used for the specific PLC system.
         2) Annotate program listing to include the following:
            a) Written description of each rung's function.
            b) Reference to control loop number for each rung where applicable.
            c) Reference to instrumentation tag number of I/O devices for each rung where applicable.
         3) Provide written descriptions completely defining all function blocks used in program.

        4) Provide list of all addresses referenced in logic diagram with description of data associated with each address.
    b. Results of factory testing procedures.
    c. Drawings containing the following information to be submitted:
        1) Arrangement drawings for PLC system components.
        2) Panel and enclosure plans, sections and details.
        3) Access opening locations and required clearances for each panel and enclosure.
        4) Enclosure internal wiring and terminal blocks.
    d. Catalog cut sheets containing information on PLC components to be submitted as part of this Specification Section submittals.
    e. Equipment catalog cut sheets.
    f. Instrument data sheets:
        1) ISA S20 or approved equal.
        2) Separate data sheet for each instrument.
    g. Materials of construction.
    h. Minimum and maximum flow ranges.
    i. Pressure loss curves.
    j. Physical limits of components including temperature and pressure limits.
    k. Size and weight.
    l. Electrical power requirements and wiring diagrams.
    m. NEMA rating of housings.
    n. Submittals shall be marked with arrows to show exact features to be provided.
4. Certifications:
    a. Qualifications of installation supervisor.
    b. Qualifications of programmer(s).
    c. Documentation verifying that calibration equipment is certified with NIST traceability.
    d. Approvals from independent testing laboratories or approval agencies, such as UL, FM or CSA.
        1) Certification documentation is required for all equipment for which the specifications require independent agency approval.
5. Wiring diagrams shall consist of the following:
    a. Panel power distribution diagrams.
    b. Control and instrumentation wiring diagrams.
    c. PLC/RTU I/O information:
        1) Model number of I/O module.
        2) Description of I/O module type and function.
        3) Rack and slot number.
        4) Terminal number on module.
        5) Point or channel number.
        6) Programmed point addresses.
        7) Signal function and type.
    d. Wiring diagrams shall identify each wire as it is to be labeled.
6. Panel exterior layout drawings to scale and shall indicate the following:
    a. Panel materials of construction, dimensions, and total assembled weight.
    b. Panel access openings.
    c. Conduit access locations.
    d. Front panel device layout.
    e. Nameplate schedule:
        1) Nameplate location.
        2) Legend which indicates text, letter height and color, and background color.
    f. Alarm annunciator window engraving schedule.
    g. Layouts of graphic panels or mosaic displays.

7. Panel interior layout drawings shall be drawn to scale and shall indicate the following:
   a. Sub-panel or mounting pan dimensions.
   b. Interior device layouts.
   c. PLC/RTU general arrangement layouts.
   d. Wire-way locations, purpose, and dimensions.
   e. Terminal strip designations.
   f. Location of external wiring and/or piping connections.
   g. Location of lighting fixtures, switches and receptacles.
8. PLC/DCS equipment drawings.
9. HMI graphics.
10. Nameplate layout drawings.
11. Drawings, systems, and other elements are represented schematically in accordance with ISA S5.1 and ISA S5.3.
    a. The nomenclature, tag numbers, equipment numbers, panel numbers, and related series identification contained in the Contract Documents shall be employed exclusively throughout submittals.
12. All Shop Drawings shall be modified with as-built information/corrections.
13. All panel and wiring drawings shall be provided in both hardcopy and softcopy.
    a. Furnish electronic files on CD-ROM or DVD-ROM media.
    b. Drawings in MicroStation format.
14. Provide a parameter setting summary sheet for each field configurable device.
15. Certifications:
    a. Documentation verifying that calibration equipment is certified with NIST traceability.
    b. Approvals from independent testing laboratories or approval agencies, such as UL, FM or CSA.
       1) Certification documentation is required for all equipment for which the specifications require independent agency approval.
16. Testing reports: Source quality control reports.

B. Operation and Maintenance Manuals:
   1. See Specification Section 26 05 00 for requirements for:
      a. The mechanics and administration of the submittal process.
      b. The content of Operation and Maintenance Manuals.
   2. Submit maintenance procedures available to Owner.
      a. Include the location and phone numbers of service centers (including 24 HR "hot lines").
      b. Provide specific information including operation and maintenance requirements, programming assistance, troubleshooting guide, parts ordering, field service personnel requests, and service contracts.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following manufacturers are acceptable:
   1. Rockwell Automation, Allen-Bradley.
   2. Group Schneider: Modicon.
   3. General Electric Company.

B. Submit request for substitution in accordance with Specification Section 01 25 13.

2.2 PERFORMANCE AND DESIGN REQUIREMENTS

A. System Operating Criteria:
   1. Stability: After controls have taken corrective action, as result of a change in the controlled variable or a change in setpoint, oscillation of final control element shall not exceed two (2) cycles per minute or a magnitude of movement of 0.5 percent full travel.
   2. Response: Any change in setpoint or change in controlled variable shall produce a corresponding corrective change in position of final control element and become stabilized within 30 seconds.
   3. Agreement: Setpoint indication of controlled variable and measured indication of controlled variable shall agree within 3 percent of full scale over a 6:1 operating range.
   4. Repeatability: For any repeated magnitude of control signal, from either an increasing or decreasing direction, the final control element shall take a repeated position within 0.5 percent of full travel regardless of force required to position final element.
   5. Sensitivity: Controls shall respond to setpoint deviations and measured variable deviations within 1.0 percent of full scale.
   6. Performance: All instruments and control devices shall perform in accordance with manufacturer's specifications.

B. The PLC system shall accomplish the control requirements of the loop descriptions, Drawings, and Specifications.

C. PLC programming shall be documented and factory tested.

D. The PLC system shall operate in ambient conditions of 32 to 140 DegF temperature and 5 to 95 percent relative humidity without the need for purging or air conditioning.

E. Environmental Controls:
   1. Furnish circulation fans in solid state control system enclosures.
   2. Over-temperature switches shall be utilized to provide special cooling if required to maintain operating temperatures within the manufacturer's specified range.
   3. Air conditioning applications shall include means of preventing moisture condensation.

F. Where the PLC is utilized to control multiple trains of equipment and where the equipment in each train operates as a unit relatively independent of other equipment trains (e.g., facility with multiple boiler units or filter trains), the PLC components (I/O modules, power supplies, etc.) shall be assigned so that the failure of any one (1) component does not affect equipment on all trains.
   1. I/O modules shall be segregated on a train basis unless required otherwise for safety reasons.
   2. Where several equipment units operate in parallel, but are not considered assigned to a particular equipment train (e.g., multiple raw water pumps or chemical feed pumps all discharging into a common system), the PLC I/O modules associated with each equipment unit shall be assigned so that the failure of any one (1) I/O module does not affect all of the parallel operating equipment units.

G. All PLC control system components shall be capable of meeting or exceeding electromagnetic interference tests per IEEE C37.90.2.

H. Incorporate the following minimum safety measures:
   1. Watchdog function to monitor:
      a. Internal processor clock failure.
      b. Processor memory failure.
      c. Loss of communication between processor and I/O modules.
      d. Processor ceases to execute logic program.

2. Safety function wiring: Emergency shutdown switches shall not be wired into the controller.
3. Safe wiring:
   a. Unless otherwise specified, activation of alarms and stopping of equipment shall result from the de-energization of control circuits, rather than the energization of control circuits.
   b. Low voltage control signal wires:
      1) Place in conduit segregated for that purpose only.
      2) Twisted shielded wire pair.
      3) Not located in the same conduit or bundle with power wiring.
4. Initial safety conditions:
   a. Utilize program module to dictate output states in a known and safe manner prior to running of control program.
   b. Utilize program each time PLC is re-initiated and the control program activated.
5. Monitoring of internal faults and display:
   a. Internal PLC system status and faults shall be monitored and displayed.
      1) Monitored items shall include:
         a) Memory ok/loss of memory.
         b) Processor ok/processor fault.
         c) Scan time overrun.
6. Control of programs: Protect access to PLC program loading with password protection or with locked, key operated selector switches.
7. Design PLC system with high noise immunity to prevent occurrence of false logic signals resulting from switching transients, relay and circuit breaker noise or conducted and radiated radio frequency interference.
8. Operator intervention:
   a. Logic system failure shall not preclude proper operator intervention.
   b. Safety shutdown of equipment or a system shall require manual operator intervention before the equipment or system operation may be reestablished.

2.3 COMPONENTS

A. PLC System Central Processor Unit (CPU):
1. CPU shall provide communications with other control systems and man-machine interfaces as specified.
2. Memory:
   a. Battery-backed RAM.
   b. EEPROM program back-up:
      1) Automatically download to RAM in the event RAM is corrupted.
3. Memory battery backup shall be capable of 60 days memory retention with fresh battery.
   a. Provide visual indication of battery status and alarm low battery voltage.
   b. Memory battery backup shall be capable of 14 days memory retention after the "Battery Low" indicating LED is on.
4. Plug-in card design to allow quick field replacement of faulty devices.
   a. Provide unit designed for field replacement and expansion of memory without requiring rewiring or use of special tools.
5. 20 percent minimum spare useable memory capacity after all required programming is in place and operating.
6. Capable of executing all control functions required by the Specifications and Drawings.
7. Built-in three-mode (proportional-integral-derivative) control capabilities.
   a. As directly selectable algorithms requiring no user knowledge of programming languages.
8. On-line reconfigurable.

9. Lighted status indicators for "RUN" and "FAILURE."
10. Capable of manual or automatic control mode transfer from the operating console stations or from within the control strategy.
    a. Transfer shall be bumpless and balanceless.

B. Input/output (I/O) Modules:
1. Provide plug-in modular-type I/O racks with cables to connect to all other required PLC system components.
2. Provide I/O system with:
    a. I/O solid state boards with status lights indicating I/O status.
    b. Electric isolation between logic and field device.
    c. Capability of withstanding low energy common mode transient to 1000 V without failure.
    d. Incorporate noise suppression design.
    e. Capable of meeting or exceeding electrical noise tests, NEMA ICS 1-109.60-109.66.
    f. Capable of being removed and inserted into the I/O rack under power, without affecting any other I/O modules in the rack.
    g. Install 20 percent spare I/O modules.
3. Input/output connection requirements:
    a. Make connections to I/O subsystem by terminating all field wiring on terminal blocks within the I/O enclosure.
    b. Prewire I/O modules to terminal blocks.
    c. Provide terminal blocks with continuous marking strip.
    d. Size terminals to accommodate all active data base points and spares.
    e. Provide terminals for individual termination of each signal shield.
    f. Field wiring shall not be disturbed when removing or replacing an I/O module.
4. Discrete I/O modules:
    a. Interface to ON/OFF devices.
    b. I/O status indicator on module front.
    c. Voltage rating to match circuit voltage.
    d. Output module current rating:
        1) Match maximum circuit current draw.
        2) Minimum 1.0 continuous A/point for 120 Vac applications.
    e. Isolated modules for applications where one (1) module interfaces with devices utilizing different sources of power.
5. Discrete outputs shall be fused:
    a. Provide one (1) fuse per common or per isolated output.
    b. Provide blown fuse indication.
    c. External fusing shall be provided if output module does not possess internal fusing.
    d. Fuses provided external to output model shall:
        1) Be in accordance with module manufacturer's specifications.
        2) Be installed at terminal block.
6. Analog I/O modules:
    a. Input modules to accept signals indicated on Drawings or Specifications.
    b. Minimum 12 bit resolution.
    c. I/O chassis supplied power for powering connected field devices.
    d. Differential inputs and outputs.
    e. User configurable for desired fault-response state.
    f. Provide output signals as indicated on Drawings and Specifications.
    g. Individual D/A converter for each output module.
    h. Individual A/D converter for each input module.

C. Power Supply Units:

1. Provide regulated power units:
    a. Designed to operate with PLC system and shall provide power to:
        1) All components of PLC system.
        2) All two-wire field instruments.
        3) Other devices as indicated on Drawings or Specifications.
    b. Capable of supplying PLC system when all of the specified spare capacity is utilized.
    c. Each power supply shall be sized such that it will carry no more than 75 percent of capacity under normal loads.
2. Electrical service to PLC system is 105 to 125 V, 60 Hz, +1 percent, 1 PH power.
3. Separate AC circuit breakers shall be provided for each power supply.
4. If the PLC system is field expandable beyond the specified spare capacity, and if such expansion requires power supply modification, note such requirements in the submittals and allow room for power supply modification in the PLC system enclosure.
5. Capable of meeting or exceeding electrical noise tests, NEMA ICS 1-109.60-109.66.
6. Power distribution:
    a. Immune to transients and surges resultant from noisy environment.
    b. Shall provide constant voltage level DC distribution to all devices.
7. Provide uninterruptible power supply (UPS) to sustain full power to UPS powered loads listed below for a minimum of 60 minutes following loss of primary power and to ensure that the transient power surges and dips do not affect the operation of the PLC system.
    a. UPS powered loads:
        1) All rack mounted PLC components.
        2) Local operator consoles.
        3) All power supplies furnished with the PLC and associated loads.
    b. Input:
        1) 120 Vac +10 percent.
        2) 60 Hz.
        3) Line fuse protection.
    c. Output:
        1) 120 Vac (5 percent.
        2) 60 Hz.
        3) Short circuit protected.
        4) Instantaneous transfer time.
    d. IEEE C62.41 Class A voltage surges of 6000 V attenuated to less than 50 V on the output.
    e. Battery: Maintenance free lead acid.

D. PLC System Enclosure:
1. Provide panel(s) with the required enclosure rating per NEMA 250 to meet classifications identified in the Contract Documents.
2. Devices installed in panel openings shall have a NEMA enclosure rating at least equal to the panel enclosure rating.
    a. Devices that cannot be obtained with an adequate NEMA rating shall be installed behind a transparent viewing window.
    b. The window shall maintain the required NEMA rating of the enclosure.
3. Free-Standing Panels:
    a. Welded construction.
    b. Completely enclosed, self-supporting, and gasketed dusttight.
    c. Rolled lip around all sides of enclosure door opening.
    d. Seams and corners welded and ground smooth to touch and smooth in visual appearance.
    e. Full height, fully gasketed flush pan doors.
    f. Full length piano hinges rated for 1.5 times door plus instrument weight.

   g. Doors with keyed alike locking handles and three-point catch.
   h. Appropriate conduit, wiring, and instrument openings shall be provided.
   i. Lifting eyebolts to allow simple, safe rigging and lifting of panel during installation.
4. Wall Mounted Panels:
   a. Seams continuously welded and ground smooth.
   b. Rolled lip around all sides of enclosure door opening.
   c. Gasketed dust tight.
   d. Three-point latching mechanism operated by oil tight key-locking handle.
   e. Key doors alike.
   f. Continuous heavy GA hinge pin on doors.
      1) Hinges rated for 1.5 times door plus instrument weight.
   g. Front full opening door.
   h. Brackets for wall mounting.
5. Component placement:
   a. Mount all controller components vertically within the enclosure to allow maximum convection cooling.
   b. Either install power supplies above all other equipment with at least 10 IN of clearance between the power supply and the enclosure top, or adjacent to other components, but with sufficient spacing for circulation of cooling air.
   c. Do not place I/O racks directly above the CPU or power supply.
   d. Locate incoming line devices (isolation or constant voltage transformers, local power disconnects, surge suppressors, etc.) so as to keep power wire runs within an enclosure as short as possible.
   e. If items such as magnetic starters, contactors, relays, and other electromagnetic devices must be located within the same enclosure as the PLC system components, place a barrier with at least 6 IN of separation between the magnetic area and the control area.
   f. Place circulating fans close to major heat generating devices.
   g. Segregate input/output modules into groups of identical type.
6. Internal Panel Wiring:
   a. Panel wire duct shall be installed between each row of components, and adjacent to each terminal strip.
      1) Route wiring within the panel in wire-duct neatly tied and bundled with tie wraps.
      2) Follow wire-duct manufacturer's recommended fill limits.
      3) Wire-duct shall have removable snap-on covers and perforated walls for easy wire entrance.
      4) Wire-duct shall be constructed of nonmetallic materials with rating in excess of the maximum voltage carried therein.
   b. Wiring shall be installed such that if wires are removed from one (1) device, source of power will not be disrupted to other devices.
   c. Splicing and tapping of wires permitted only at terminal blocks.
   d. Wire bunches to doors shall be secured at each end so that bending or twisting will be around longitudinal axis of wire.
      1) Protect bend area with sleeve.
   e. Arrange wiring neatly, cut to proper length, with surplus wire removed.
      1) Arrange wiring with sufficient clearance.
      2) Provide abrasion protection for wire bundles that pass through openings or across edges of sheet metal.
   f. AC circuits shall be routed separate from analog signal cables and digital signal cables.
      1) Separate by at least 6 IN, except at unavoidable crossover points and at device terminations.
   g. Provide at least 6 IN of separation between intrinsically safe devices and circuits and non-intrinsically safe devices and circuits.

h. Wiring to pilot devices or rotary switches shall be individually bundled and installed with a "flexible loop" of sufficient length to permit the component to be removed from panel for maintenance without removing terminations.
i. Conductors for AC and DC circuits shall be type MTW stranded copper listed for operation with 600 V at 90 DegC.
    1) Conductor size shall be as required for load and 16 AWG minimum.
    2) Internal panel wiring color code:
        a) AC circuits:
            (1) Power wiring: Black.
            (2) Control interconnections: Yellow.
            (3) Neutral: White.
            (4) Ground: Green.
        b) Low voltage DC circuits:
            (1) Power wiring: Blue.
            (2) Control interconnections: Violet.
        c) Foreign voltage circuits: Pink.
        d) Annunciator circuits: Red.
        e) Intrinsically safe circuits: Orange.
j. Analog signal cables shall be of 600 V insulation, stranded copper, twisted-shielded pairs.
    1) Conductor size: 18 AWG minimum.
    2) Terminate shield drain conductors to ground only at one (1) end of the cable.
k. High precision 250 ohm resistors with 0.25 percent accuracy shall be used where 4-20 mA DC analog signals are converted to 1-5 Vdc signals.
    1) Resistors located at terminal strips.
    2) Resistors terminated using individual terminal blocks and with no other conductors.
    3) Resistor leads shall be un-insulated and of sufficient length to allow test or calibration equipment (e.g., HART communicator, loop calibrator) to be properly attached to the circuit with clamped test leads.
l. Analog signals for devices in separate enclosures shall not be wired in series.
    1) Loop isolators shall be used where analog signals are transmitted between control enclosures.
m. Wire and cable identification:
    1) Wire and cables numbered and tagged at each termination.
    2) Wire tags:
        a) Slip-on, PVC wire sleeves with legible, machine-printed markings.
        b) Adhesive, snap-on, or adhesive type labels are not acceptable.
    3) Markings as identified in the Shop Drawings.

7. Grounding Requirements:
    a. Equipment grounding conductors shall be separated from incoming power conductors at the point of entry.
    b. Minimize grounding conductor length within the enclosure by locating the ground reference point as close as practical to the incoming power point of entry.
    c. Bond electrical racks, chassis and machine elements to a central ground bus.
        1) Nonconductive materials, such as paint, shall be removed from the area where the equipment contacts the enclosure.
    d. Bond the enclosure to the ground bus.
        1) It is imperative that good electrical connections are made at the point of contact between the ground bus and enclosure.
    e. Panel-mounted devices shall be bonded to the panel enclosure or the panel grounding system by means of locknuts or pressure mounting methods.

f. Sub-panels and doors shall be bonded to ground.

8. Termination requirements:
   a. Wiring to circuits external to the panel connected to interposing terminal blocks.
   b. Terminal blocks rigidly mounted on DIN rail mounting channels.
   c. Terminal strips located to provide adequate space for entrance and termination of the field conductors.
   d. One (1) side of each strip of terminal blocks reserved exclusively for the termination of field conductors.
   e. Terminal block markings:
      1) Marking shall be the same as associated wire marking.
      2) Legible, machine-printed markings.
      3) Markings as identified in the shop drawings.
   f. Terminal block mechanical characteristics, and electrical characteristics shall be in accordance with NEMA ICS 4.
   g. Terminal blocks with continuous marking strips.
      1) Each terminal block shall be identified with machine printed labels.
   h. Terminals shall facilitate wire sizes as follows:
      1) 120 Vac applications: Conductor size 12 AWG minimum.
      2) Other: Conductor size 14 AWG minimum..
   i. Analog signal cable shield drain conductors shall be individually terminated.
   j. Install minimum of 20 percent spare terminals.
   k. Bladed, knife switch, isolating type terminal blocks where control voltages enter or leave the panel.
   l. Fused terminal blocks shall be used in the following circuits:
      1) Control voltage is used to energize a solenoid valve.
      2) DC power is connected to 2-wire, loop-powered instruments.
   m. Fused terminal blocks shall be provided with blown fuse indicators.
   n. When control circuits require more than one (1) field conductor connected to a single wiring point, a sufficient number of terminal points shall be connected internally to allow termination of only one (1) field conductor per terminal block.
   o. DIN rail mounting channels shall be installed along full length of the terminal strip areas to facilitate future expansion.
   p. Connections to devices with screw type terminals shall be made using spade-tongue, insulated, compression terminators.
   q. Make connections to I/O subsystem by terminating all field wiring on terminal blocks within the enclosure.
   r. Prewire I/O modules to terminal blocks.
   s. Size terminals to accommodate all active database points and spares.
   t. Provide terminals for individual termination of each signal shield.
   u. Field wiring shall not be disturbed when removing or replacing an I/O module.

E. PLC System Software and Programming:
   1. Provide all hardware and programming required to provide communication between the PLC and the man-machine interface.
   2. Provide programming to accomplish all control and monitoring requirements of the Drawings and Specifications.
   3. Provide two (2) copies of control logic program on 3-1/2 IN disks or on CD.
   4. IBM compatible software.
   5. Full documentation capability.
      a. Provide description for each rung.
   6. On/off line programming.
   7. Offline simulation prior to download.
   8. Two-step commands requiring operator verification prior to deletion of any programming.

2.4 ACCESSORIES

A. Provide all accessories required to furnish a complete PLC control system to accomplish the requirements of the Drawings and Specifications.

2.5 SOURCE QUALITY CONTROL

A. Provide a performance test after factory completion and prior to shipment.
   1. Conduct a test where the system is operated continuously and checked for correct operation including loop controls, displays, printing, keyboard functions, alarm responses, and on/off sequencing control.
   2. Conduct testing with dummy I/Os to verify each control loop operation.
   3. Allow for Owner and Engineer representatives to witness testing program.
      a. Provide minimum of 15 days notice prior to testing.
   4. Do not ship prior to successful completion of this testing program.

2.6 MAINTENANCE MATERIALS

A. Furnish Owner with the following extra materials:
   1. One (1) spare I/O card of each card type for every 10 cards or fraction thereof installed.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install PLC control system in accordance with manufacturer's written instructions.

3.2 FIELD QUALITY CONTROL

A. Employ and pay for services of equipment manufacturer's field service representative(s) to:
   1. Inspect equipment covered by these Specifications.
   2. Supervise adjustments and installation checks.
   3. Maintain and submit an accurate daily or weekly log of all commissioning functions.
      a. All commissioning functions may be witnessed by the Engineer.
      b. All reports shall be cosigned by the Design-Builder and the Engineer if witnessed.
   4. Conduct startup of equipment and perform operational checks.
   5. Provide Owner with a written statement that manufacturer's equipment has been installed properly, started up, and is ready for operation by Owner's personnel.

3.3 DEMONSTRATION

A. Demonstrate system in accordance with Specification Section 26 05 00.

B. On-Site Training:
   1. Provide employee of the manufacturer or certified representative to provide one (1) week of operating and maintenance training at the Project site after the system has successfully undergone all field testing and acceptance procedures.
      a. As a minimum, training shall cover:
         1) Hardware overview.
         2) Software overview.
         3) Maintenance.
         4) Trouble shooting.
         5) Operation, e.g., changing set points, passwords, etc.

END OF SECTION