



City of Seattle

**FIRST HILL STREETCAR
TRACTION POWER SUBSTATIONS**

Invitation to Bid # SDOT-300
October 10, 2011

SPECIFICATIONS & DRAWINGS

**FIRST HILL STREETCAR
TRACTION POWER SUBSTATIONS
Invitation to Bid # SDOT-300**

**SPECIFICATIONS AND DRAWINGS
TABLE OF CONTENTS**

Division 01 General Requirements

01 11 00	Summary of Work
01 23 00	Alternates
01 25 00	Substitution Procedures
01 31 19	Project Meetings
01 32 13	Scheduling of Work
01 33 00	Submittal Procedures
01 41 00	Regulatory Requirements
01 42 00	References
01 43 00	Quality Assurance
01 46 00	System Assurance
01 60 00	Product Requirements
01 65 00	Product Delivery Requirements
01 78 23	Operation and Maintenance Data
01 78 36	Warranties
01 78 39	Project Record Documents
01 79 00	Demonstration and Training

Division 05 Metals

05 05 00	Common Work Results for Metals
----------	--------------------------------

Division 09 Finishes

09 67 25	Dielectric Epoxy Flooring
----------	---------------------------

Division 22 Plumbing

22 45 19	Self Contained Eyewash Equipment
----------	----------------------------------

Division 26 Electrical

26 05 00	Common Work Results for Electrical
26 05 19	Low-Voltage Conductors and Cable
26 05 26	Grounding and Bonding
26 05 29	Hangers and Supports for Electrical Systems
26 05 33	Raceway and Boxes
26 12 16	Dry-Type Transformers
26 24 13	Switchboards
26 24 16	Low-Voltage Panelboards
26 50 00	Lighting

Division 34 Transportation

34 21 05	Common Work Results for TPSS
34 21 12	TPSS Installation
34 21 16	TPSS Enclosures
34 21 19	Dc Switchgear
34 21 23	Transformer-Rectifier Unit
34 21 25	TPSS Dc Control Power
34 21 31	TPSS Alarm Panel
34 21 33	Rail Voltage Monitoring and Grounding System
34 21 46	Traction Power Dc Contactor Panel
34 21 50	Dc Surge Arrestors
34 21 73	TE System Studies

34 21 80 TES Spare Parts and Special Tools
34 21 90 TPSS Testing

Drawings

JP01 Cover Sheet
JP03 Traction Electrification System Abbreviations
JP04 Traction Electrification System Symbols
JP06 Sectionalizing Diagram Mainline
JP10 TPSS Key Map
JP11 King St Station TPSS Site Plan
JP12 S Main St TPSS Site Plan
JP13 E James St TPSS Site Plan
JP14 E Howell St TPSS Site Plan
JP15 OMF TPSS Site Plan
JP20 Typical Mainline TPSS One-Line Diagram
JP21 Typical Mainline TPSS Ac Elementary Diagram
JP22 Typical Substation Ac/Dc Panel Schedule and Schematic
JP23 Typical Prefabricated TPSS Equipment Layout
JP24 Typical Prefabricated TPSS Exterior Elevations
JP25 Typical Prefabricated TPSS Interior Elevations
JP29 Typical Surge Arrester Installation Details
JP30 King St TPSS Equipment Layout
JP31 King St TPSS Interior Elevations
JP32 King St Building One-Line Diagram
JP35 OMF TPSS One-Line Diagram
JP36 OMF TPSS Equipment Layout Plan
JP37 OMF TPSS Interior Elevation
JP38 OMF TPSS Dc Contactor Panel Detail
JP40 Typical Substation Local Area Network Diagram
JP41 Typical TPSS Alarm Panel HMI One-Line Screen Layout
JP42 Typical TPSS Alarm Panel HMI Screen Layout
JP43 Typical TPSS Alarm Panel HMI Event Log Screen Layout

Richard M. Eacker
Engineer

LTK Engineering Services
Firm



SECTION 01 11 00
SUMMARY OF WORK

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. A description of Work provided complete in this Contract.
- B. A list of equipment designed, furnished, commissioned, and tested but not installed under this Contract.
- C. A description of work by others related to the Work of this Contract.

1.02 WORK INCLUDED

- A. Prepackaged traction power substations:
 - 1. Design, furnish, commission, and test three new, self-contained, 350 kW, 750 Vdc prepackaged traction power substations, complete.
 - 2. Perform the following in cooperation with an installation contractor and the Engineer:
 - a. Energize traction power substations.
 - b. Conduct short circuit testing of the traction power substations.
 - c. Conduct train start testing of the traction power substations.
 - 3. Make final relay settings in each traction power substation after completion of testing.
 - 4. Perform traction electrification system studies: Short-circuit study, ac coordination study, dc coordination study, and arc-flash hazard analysis study.
 - 5. See Section 01 23 00, Alternates for the addition of a fourth prepackaged traction power substation.
- B. Built-in-place traction power substations:
 - 1. Design, furnish equipment for, commission, energize, and test two built-in-place traction power substations, installed by others: King Street TPSS and Operations and Maintenance Facility (OMF) TPSS.
 - 2. Furnish the following equipment, as shown on Contract Drawings:
 - a. Ac switchboard, including breaker.
 - b. Dc switchgear, including positive disconnect switch (89P), negative disconnect switch (89N), and feeder breaker.

- c. Transformer-rectifier unit.
 - d. Battery charger eliminator, batteries, enclosed low voltage switch, and fuses.
 - e. Dc panelboard with circuit breakers.
 - f. TPSS alarm panel.
 - g. Traction power dc contactor panel (for Operation and Maintenance Facility (OMF) only).
 - h. Dc breaker test station.
 - i. Dc surge arresters, enclosure, and grounds.
 - j. Mobile work station.
 - k. Eyewash station.
- 3. During installation, advise installation contractor, verify that equipment and wiring are installed correctly, and document changes made for as-built drawings
 - 4. See Section 01 23 00, Alternates for the deletion of the King Street traction power substation.

1.03 WORK OF OTHER CONTRACTS

- A. A civil contractor will provide a foundation, ground mat, and stairs, where needed, for each substation.
- B. An installation contractor will
 - 1. Connect the ground mat to the four corners of each substation.
 - 2. Provide utility power to each substation
 - 3. Provide OCS, dc positive feeders, and dc negative returns, including connection to each substation.
 - 4. Install equipment for the OMF and King Street traction power substations.

PART 2 PRODUCTS

Not Used.

PART 3 EXECUTION

Not Used.

END OF SECTION 01 11 00

SECTION 01 23 00

ALTERNATES

PART 1 GENERAL

- A. Section Includes:
 - 1. Alternates related to King Street Substation.
- B. Related Sections:
 - 1. Section 22 45 19 – Self Contained Eyewash Equipment
 - 2. Section 34 21 05 – Common Work Results for TPSS
 - 3. Section 34 21 19 – Dc Switchgear,
 - 4. Section 34 21 23 – Transformer Rectifier Unit
 - 5. Section 34 21 25 – TPSS Dc Control Power
 - 6. 34 21 31 – TPSS Alarm Panel

1.02 ALTERNATE NO. 1 – DELETE KING STREET STATION TPSS

- A. Deduct the cost of furnishing equipment and oversight for construction of the built-in-place traction power substation at King Street.
- B. See Section 01 11 00 Summary of Work, Section 22 45 19, Self Contained Eyewash Equipment, Section 34 21 05, Common Work Results for TPSS, Section 34 21 19, Dc Switchgear, Section 34 21 23, Transformer Rectifier Unit, Section 34 21 25, TPSS Dc Control Power, and 34 21 31, TPSS Alarm Panel

1.03 ALTERNATE NO. 2 – DELETE KING STREET TPSS AND ADD PREFABRICATED TPSS

- A. Deduct the cost of furnishing equipment and oversight for construction of the built-in-place traction power substation at King Street.
- B. Add the cost of providing one additional prepackaged traction power substation to be located inside an existing parking structure.
- C. Additional substation is identical to the three prepackaged substations in the base contract.

PART 2 PRODUCTS

Not Used.

PART 3 EXECUTION

Not Used.

END OF SECTION 01 23 00

SECTION 01 25 00
SUBSTITUTION PROCEDURES

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. Administrative and procedural requirements for substitutions.
- B. Refer to Request for Substitution Form, attached to this Section.
- C. Applies to substitutions after Notice of Award.

1.02 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Substitution Requests: Submit each request for consideration on separate request form.
- C. Submit Request for Substitution Form provided in Attachment A. Supplement form with following documentation in addition to requirements stated on form.
 - 1. Statement indicating why specified product or fabrication or installation cannot be provided, if applicable.
 - 2. Detailed comparison of significant qualities of proposed substitution with those of product specified.
 - a. Include annotated copy of applicable Contract Specifications Section.
 - b. Significant qualities may include attributes such as performance, weight, size, durability, visual effect, sustainable design characteristics, warranties, and specific features and requirements indicated.
 - c. Indicate deviations from product specified.
 - 3. Product Data, including drawings and descriptions of product and fabrication and installation procedures.
 - 4. Samples, where applicable or requested.
 - 5. Certificates and qualification data, where applicable or requested.
 - 6. List of similar installations for completed projects with project names and addresses and names and addresses of engineers, and owners.
 - 7. Material test reports from a qualified testing agency indicating and interpreting test results for compliance with requirements indicated.

8. Detailed Contractor's manufacturing schedule using original product, and a detailed comparison of Contractor's manufacturing schedule using proposed substitution with product specified for Work, including effect on overall Contract Time.
9. If specified product or material cannot be provided within Contract Time, include letter from manufacturer, on manufacturer's letterhead, stating date of receipt of purchase order, reasons for lack of availability or delays in delivery, and normal lead time between receipt of purchase order and delivery.
10. Contractor's certification that proposed substitution complies with requirements in Contract Documents except as indicated in substitution request, is compatible with related materials, and is appropriate for applications indicated.
11. Contractor's certification that it issued the purchase order in sufficient time to return original products.

1.03 QUALITY ASSURANCE

- A. Compatibility of Substitutions: Investigate and document compatibility of proposed substitution with related products and materials. Engage approved qualified testing agency to perform compatibility tests recommended by manufacturers.

1.04 PROCEDURES

- A. Coordination: Modify or adjust affected work as necessary to integrate work of approved substitution.

PART 2 PRODUCTS

Not Used.

PART 3 EXECUTION

Not Used.

ATTACHMENT

- A. Request for Substitution Form

END OF SECTION 01 25 00

SECTION 01 25 00 - ATTACHMENT A

REQUEST FOR SUBSTITUTION FORM

TO: _____

We submit for your consideration the following item instead of the specified item as indicated below:

SPECIFICATION

SECTION	ARTICLE	SPECIFIED ITEM
_____	_____	_____

Proposed Product Option/Substitution: _____

Attach complete technical data and other information as required in Section 01 25 00, Substitution Procedures, to verify statements below.

Include complete information on changes to Contract Drawings and Contract Specifications that proposed product option/substitution will require for its proper installation.

Fill in Blanks Below:

- A. Does the product option/substitution affect dimensions shown on Contract Drawings?

- B. The Contractor agrees to pay for changes to the design, including engineering and detailing costs caused by the requested product option/substitution.
 Yes No
- C. What effect does product option/substitution have on other work? _____
- D. Differences between proposed product option/substitution and specified item?

- E. Manufacturer's guarantees of the proposed and specified items are:
 Same Different (explain on attachment)

The undersigned states that the function, appearance, and quality of the proposed items are equivalent or superior to the specified item.

Submitted By:

For Use by the Owner:

Signature

Accepted Accepted As Noted

Firm

Not Accepted

Address

By _____

Date

Date _____

Telephone

Remarks _____

END OF FORM

SECTION 01 31 19
PROJECT MEETINGS

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. Project meetings throughout the project.
- B. Design conference.
- C. Other special meetings

1.02 SUBMITTALS

- A. Submit initial meeting minutes format to the Engineer for approval.

1.03 PROJECT MEETINGS

- A. Kick-off meeting: Will be scheduled and conducted in Seattle by the Engineer not more than 21 working days after the effective date of the Notice of Contract Award.
 - 1. Attendance is required by the Contractor project manager and other necessary personnel.
 - 2. The Engineer will provide written notice of this meeting not less than four working days before the date of the meeting.
- B. Submit questions to the Engineer a minimum of three days before the meeting so Engineer has adequate time to prepare answers.
- C. At this meeting, the Engineer will:
 - 1. Introduce representatives of the Owner, governmental agencies, and public and private utilities.
 - 2. Explain and discuss the responsibilities and authorities of the Engineer and the Owner.
 - 3. Discuss Safety Certification process requirements.
 - 4. Discuss procedures for processing Change Notices (CNs), Change Orders (COs), correspondence, Requests for Information (RFIs), shop drawings, submittals, product data, and samples.
 - 5. Discuss monthly progress payments.
 - 6. Discuss Progress Meetings.

7. Discuss final payments.
 8. Discuss project schedule
- D. Plan to discuss the following at this meeting:
1. Introduce project representatives and briefly describe each person's responsibilities.
 2. Discuss deliveries of substations and other equipment.
 3. Discuss construction progress schedule, including critical path activities.
 4. Discuss public safety measures.

1.04 PROGRESS MEETINGS

- A. Progress meetings will be scheduled by the Engineer no more than once each week during the period of performance of the Contract.
- B. Meetings may be conducted by telephone conference. Contractor shall provide a conference call in number.
- C. Include representatives of Subcontractors who are or will be performing work during the current and following month in the progress meetings.
- D. Distribute notices of these meetings before such meetings to Subcontractors.
- E. Prepare agenda for construction progress meetings a minimum of 24 hours before the meeting and e-mail to the Engineer for review. It will generally include the following:
 1. Discussion of the status of the Critical Path activities, including submittals. Discussion of methods intended to bring late activities back on schedule.
 2. Discussion of design issues.
 3. Discussion of status of RFIs.
- F. Prepare meeting minutes within three days following the meeting and e-mail draft to meeting attendees for review. Make corrections and transmit final minutes before the next meeting. Submit initial meeting minutes format to the Engineer for approval.

1.05 DESIGN CONFERENCE

- A. Traction power substation design conference will be held at manufacturer's facility within 45 days of NTP. Contractor and subcontractor design personnel are required to attend. The following will be discussed:
 1. Basic TPSS layouts.
 2. One-line diagram.

3. Proposed basic TPSS parts.
4. Proposed sequence of TPSS work.
5. Design, production and field testing procedures.
6. Submittal list.

1.06 SPECIAL MEETINGS

- A. Special meetings will be scheduled and conducted by the Engineer throughout the project as the Engineer deems necessary.
- B. Meetings may be called by the Engineer or Contractor to discuss submittals.

PART 2 PRODUCTS

Not Used.

PART 3 EXECUTION

Not Used.

END OF SECTION 01 31 19

SECTION 01 32 13

SCHEDULING OF WORK

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. Requirements for the preparation, revision, and submittal of Contract Critical Path Method (CPM) Schedule.

1.02 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. General Requirements:
 - 1. Schedule and execute manufacturing, delivery, commissioning, and testing in accordance with the Contract Documents.
 - 2. Schedules shall represent a practical and logical plan to complete the work within the Contract time.
 - 3. The submittal of schedules shall be understood to be the Contractor's representation that the schedule meets the requirements of the Contract Documents and that the work will be executed in the sequence and duration indicated in the schedule.
 - 4. Submittals required by the Contract Documents shall be included in the schedule.
 - 5. Failure to include an element of work required for performance of the Contract or failure to properly sequence the work shall not excuse the Contractor from completing Work within the Contract Time.
 - 6. Schedule submittals are subject to the Engineer's approval. The Owner retains the right to withhold appropriate monies (up to the full value of the progress payment) from progress payments until the Contractor submits a schedule in accordance with these provisions.
 - 7. Use Microsoft Project, Primavera Project Planner (P6), Version 6.2, or later, or approved equal software to prepare required schedules.
 - 8. Schedules shall be developed using industry standard "best practices" including, but not limited to:
 - a. No open-ended activities.
 - b. No use of constraints other than those defined in the Contract Documents without the prior approval of the Engineer.
 - c. No negative leads or lags.

- d. No excess leads or lags without prior justification and approval from the Engineer.

C. Baseline CPM Schedule:

1. If in the opinion of the Engineer the schedule is determined to be impractical or not in compliance with the Contract Documents, the Contractor shall revise the schedule and resubmit within 14 Days.
 - a. Show clearly on the Contract Schedule the sequence and interdependence of activities.
 - b. Indicate on the schedule diagram a clearly defined critical path.
 - c. Include with the schedule submittal a detailed written narrative describing the approach and methods for completion of the work. Include assumptions and specific schedule risks identified in development of the schedule.

D. Monthly CPM Schedule Update:

1. The Monthly CPM Schedule Update shall have a data date (stated) as of the last day of the corresponding month (for example; for schedules submitted at the beginning of February 2011 the data date shall be 31 January 2011).
2. The Monthly CPM Schedule Update shall incorporate all progress to-date.
3. Provide with the monthly CPM schedule update submittal a written narrative. Include the following:
 - a. Changes, additions or deletions that have been made to the schedule since the prior month and a reason for each of the changes.
 - b. Assumptions made in developing and updating the schedule.
 - c. Major risk items that could potentially have an adverse impact to the schedule and how these risks are being addressed.
4. If in the opinion of the Engineer the schedule is impractical or not in compliance with the Contract Documents, the Contractor shall revise the schedule and resubmit within seven calendar days.

1.03 REQUESTS FOR TIME EXTENSIONS

- A. Submit a written request for extension of Contract Time in accordance with General Provisions and Special Provisions of the Contract. Include the following:
 1. Justification for the extension of time, supporting evidence, and specific references to the current approved schedule at the time the qualifying event occurred.
 2. Analysis of a calendar time-scaled CPM network schedule (FRAGNET) and reports depicting the time impact basis of the request with the affected areas prominently

highlighted. Use only the current and accepted schedule at the time the qualifying event occurred when determining time extension request.

- B. If the Owner finds that the Contractor is entitled to an extension of time under the General Provisions and Special Provisions of the Contract, the Owner will decide the length of extension based upon analysis of the current schedule and data relevant to the extension.
- C. Extensions of time for performance under the General Provisions and Special Provisions of the Contract will be granted only to the extent that equitable time adjustments for the affected activity exceed the total float along the relevant path of the accepted current schedule.

PART 2 PRODUCTS

Not Used.

PART 3 EXECUTION

Not Used.

END OF SECTION 01 32 13

SECTION 01 33 00
SUBMITTAL PROCEDURES

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. General requirements and procedures for preparing and submitting product data, shop drawings, samples, and other submittals for review and approval.

1.02 DEFINITIONS

- A. Product Data: Includes illustrations, standard schedules, diagrams, performance charts, instructions, and brochures that illustrate physical appearance, size, and other characteristics of materials and equipment for some portion of the work.
- B. Shop Drawings: Drawings, diagrams, schedules and other data specially prepared for the Work by the Contractor or a subcontractor, sub-subcontractor, manufacturer, supplier, or distributor to illustrate some portion of the Work.
- C. Samples: Physical examples of materials, equipment, or workmanship that illustrate functional and aesthetic characteristics of a material or product and establish standard by which the work will be judged.
- D. Day: Calendar day.

1.03 SUBMITTALS

- A. Schedule of Submittals: Within 45 Days after the effective date of Notice to Proceed, submit a complete submittal list.
 - 1. Add submittals to CPM schedule, as required by Section 01 32 13, Scheduling of Work.
 - 2. Include for each planned submittal:
 - a. Date on which each submittal will be submitted.
 - b. Product data, shop drawings, and samples: Include description of the item and name of manufacturer, trade name, and model number.
 - c. Contract Specifications reference, by Section and Article.
 - d. Intended submission/resubmission date(s).
 - e. Lead time to delivery/anticipated delivery date(s).
 - 3. Highlight submittals that will require expedited review to meet the Contract schedule.
 - 4. Highlight submittals that are on the critical path.

5. Update and resubmit on a monthly basis.

1.04 CONTRACTOR'S RESPONSIBILITIES

- A. Submit in a timely manner:
 1. Submit product data and samples not less than 30 days before scheduled procurement. Contractor shall be responsible for scheduling submittals such that the project schedule is not delayed.
 2. Submit shop drawings not less than 30 days before work involving such drawings is to be performed as indicated on the Contractor's CPM Schedule.
 3. Contractor shall bear the risk when products, equipment, or materials are procured before approval of submittals or work is started before approval of shop drawings.
- B. Contractor's Review:
 1. Stamp and sign as reviewed and approved by the Contractor before submission, including subcontractor submittals.
 2. If the submittal is designated to be sent to the Engineer for information, obtain approval by the designated approval authority before submission to the Engineer.
 3. Coordinate each submittal with the requirements of the Work.
 - a. Place particular emphasis upon ensuring that each submittal of one trade is compatible with other submittals of that trade and with the submittals of other trades.
 - b. Submit complete with all relevant data required for review.
 4. Contractor shall be responsible for the correctness of the drawings, for shop fits and field connections, and for the results obtained by the use of such drawings.
- C. Attend meetings as requested by the Engineer to address issues related to the review of submittals.

1.05 THE ENGINEER'S REVIEW

- A. Each submittal listed in the Specifications shall be submitted for review and approval by the Engineer. The Engineer will indicate the submittal disposition as follows:
 1. NO EXCEPTIONS TAKEN means
 - a. Submittal appears to conform to requirements of Contract Documents.
 - b. Manufacture, fabrication, assembly, and installation of described product may proceed.
 - c. Submittal need not be resubmitted.

2. EXCEPTIONS AS NOTED - RESUBMISSION NOT REQUIRED means
 - a. Submittal appears to conform to requirements of Contract Documents upon Contractor incorporating reviewer's corrections.
 - b. Manufacture, fabrication, assembly, and installation of described product may proceed.
 - c. Submittals need not be resubmitted unless Contractor challenges reviewer's exception.
 3. EXCEPTIONS AS NOTED - RESUBMISSION REQUIRED means
 - a. Submittal appears to conform to requirements of Contract Documents upon Contractor incorporating reviewer's corrections.
 - b. Manufacture, fabrication, assembly, and installation of the described product may proceed after Contractor incorporates reviewer's corrections and Engineer verifies that reviewer's corrections have been made.
 - c. Resubmission is required.
 - d. Resubmit within 30 days of date of reviewer's transmittal.
 4. REJECTED means
 - a. Submittal is deficient to the degree that the reviewer cannot correct the submittal with a reasonable degree of effort.
 - b. Reviewer has not made a thorough review of the submittal;
 - c. Submittal needs revision.
 - d. Submittal is to be corrected and resubmitted.
- B. The Engineer will transmit the disposition of the Contractor's submittal within 30 days after submittals have been received.
 - C. Incomplete submittal packages will be returned without review.
 - D. Include at least 30 days in the Contractor's CPM schedule for the Owner and other parties to review submittals, unless otherwise specified.
 - E. Allow 30 days for review by the Owner of each re-submittal.

1.06 SUBMITTAL PROCEDURES

- A. Identify submittals with the Contract Specification number, followed by the Specification Article number, paragraph number and subparagraph number, followed by the review cycle number of the submittal.
 - 1. Example: 34 21 19 - 1.03 B 2.001
- B. Submittal Medium:
 - 1. Provide electronic copy in pdf format with bookmarks to separate sections.
 - 2. For schedule submittals and final as-built submittals, provide electronic copies in PDF format and native format.
- C. Include the following information:
 - 1. Contract title and number.
 - 2. Applicable standards that the product meets, such as ASTM or IEEE.
 - 3. Identification of deviations from the Contract Drawings and Contract Specifications.
 - 4. Contractor's stamp, initialed or signed, certifying:
 - a. Dimensional compatibility of the product with the space in which it is intended to be used.
 - b. Review of submittals for compliance with the specified requirements.
 - c. Compatibility of the product with other products with which it is to perform or with which it will be contiguous.
- D. Attach a transmittal form to each submittal.

1.07 CHANGES

- A. Changes in Reviewed Submittals: Changes in reviewed submittals will not be permitted unless those approved submittals with changes have been resubmitted and reviewed, in the same manner as the original submittal.
- B. Changes in products for which shop drawings, product data, or samples have been submitted will not be permitted unless those changes have been accepted and approved, in writing, by the Engineer.
- C. Supplemental Submittals: Initiated by the Contractor for consideration of corrective procedures.
 - 1. Shall contain sufficient data for review.
 - 2. Make supplemental submittals in the same manner as initial submittals.

1.08 PRODUCT DATA

- A. Clearly indicate on product selection tables which product and which options are being provided.
- B. Line through or delete information that is not applicable to the Contract.

1.09 SHOP DRAWINGS

- A. General:
 - 1. Submit only the following standard sizes (in inches), except as otherwise permitted by the Owner:
 - a. 8.5 by 11
 - b. 11 by 17
 - c. 17 by 22
 - d. 22 by 34
 - 2. Drawings shall be fully legible. Text on 22 by 34 drawings shall not be smaller than 1/8 inch and on 11 by 17 drawings shall not be smaller than 1/16 inch.
 - 3. Include a title block in the lower right hand corner that identifies the Contractor, Subcontractor, Contract by number and title, subject matter of the drawing, sheet number, date of the original issue of the drawing, and the serial number and date of each revision.
 - 4. Submittal Stamp and Action Block Space: Include a 5-inch square blank space, in the lower right corner, just above the title block, in which the Engineer may indicate the action taken.
- B. Provide sufficient dimensions on drawings so that size and location may be determined without calculation.
- C. Sample Drawings: The first drawings submitted by Contractor, subcontractor, or vendor will be reviewed for conformance. Once approval is given, use this approved drawing format as the standard and prepare subsequent drawings to a quality equal to the approved standard.

1.10 SAMPLES

- A. Furnish to the Engineer samples indicated in the Contract Documents. Submit samples without charge, with shipping charges prepaid. Materials for which samples are required shall not be used in the Work until samples are reviewed.
- B. Label each sample with the following data:
 - 1. Name, number, and location of project.
 - 2. Name of Contractor.

3. Material or equipment represented, and location in the project.
 4. Name of producer, brand, trade name if applicable, and place of origin.
 5. Date of submittal.
- C. Approval of a sample will be only for characteristics and use named in submittal and approval, and shall not be construed to change or modify Contract requirements.
- D. Furnish test samples as required by Contract Documents.
1. Samples of material from local sources shall be taken by or in the presence of the Engineer; otherwise, samples will not be considered for testing.
 2. Failure of a material to pass specified tests will be sufficient cause for refusal to consider, under this Contract, further samples of the same brand, make, or source of that material. The Engineer reserves the right to disapprove material that has previously proven unsatisfactory in service.
 3. Samples of material delivered on site or in place may be taken by the Engineer for Quality Assurance testing and will not be returned to the Contractor. Failure of samples to meet Contract requirements will annul previous approvals of item tested.

1.11 MANUFACTURER TEST REPORTS

- A. Certain specification sections permit Manufacturer Test Reports in lieu of producing new test and supporting documentation.
- B. Test shall have been conducted in accordance with Contract Documents and standards specified.
- C. Provide legible signed copies by authorized representative of testing agency of equipment tested that is the same as specified.

PART 2 PRODUCTS

Not Used.

PART 3 EXECUTION

Not Used.

END OF SECTION 01 33 00

SECTION 01 41 00

REGULATORY REQUIREMENTS

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. Procedural and administrative requirements for compliance with governing regulations and codes and standards imposed upon the Work.
- B. These requirements include obtaining permits, licenses, inspections, releases and similar requirements associated with applicable regulations, codes and standards.

1.02 DEFINITIONS

- A. Authority Having Jurisdiction: As defined in NFPA 70, Article 100, Definitions.

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Permits obtained by Contractor: Submit a copy before performing work covered by the permit.
- C. Approvals when work is complete for permits obtained by Contractor. Include a copy of permit.

1.04 AUTHORITY AND PRECEDENCE OF CODES AND ORDINANCES

- A. Authority: Applicable codes and ordinances, whether referenced in the Contract Documents or not, shall have full force and effect as though printed in their entirety in the Specifications.
- B. Precedence: The more stringent requirement shall take precedence where specified requirements differ from the requirements of applicable codes and ordinances.
 - 1. The Contract Documents shall take precedence where the Contract Documents require or describe products or execution of better quality, higher standard, or greater size or rating than required by applicable codes and ordinances, so long as such increase is legal.
 - 2. When no requirements are identified in the Contract Documents, comply with all requirements of applicable codes, laws, ordinances, rules, regulations, and standards of authorities having jurisdiction.

1.05 APPLICABLE CODES, LAWS, AND ORDINANCES

- A. Performance of the Work shall be governed by all applicable codes, laws, ordinances, rules, and regulations of Federal, State, and local governmental agencies and jurisdictions having authority over the Work.
- B. Performance of the Work shall meet or exceed the minimum requirements of the codes as adopted and modified by the Authority Having Jurisdiction.
- C. Performance of the Work shall be accomplished in conformance with all rules and regulations of public utilities, utility districts, and other agencies with authority over the Work.
- D. Where such laws, ordinances, rules, and regulations require more care or greater time to accomplish Work, or require better quality, higher standards, greater size, or higher ratings, Work shall be accomplished in conformance to such requirements with no change to the Contract Time and Contract Sum, except where changes in the laws, ordinances, rules, and regulations occur subsequent to the execution date of the Contract.
- E. Dates of Codes, Laws, and Ordinances:
 - 1. Applicable edition of codes shall be that adopted by the City of Seattle at the time of issuance of permits by the authority having jurisdiction and shall include modifications and additions adopted by that jurisdiction.
 - 2. Applicable date of laws and ordinances shall be the date of performance of the Work.

1.06 PERMITS OBTAINED BY CONTRACTOR

- A. The Contractor shall be responsible for determining what licenses, permits, and plan review are required by the authority having jurisdiction, and complying with all requirements including but not limited to those listed below, required to perform Work.
 - 1. Building and Electrical: After NTP, coordinate with City of Seattle (City) and State of Washington (State), to determine required licenses, permits, and plan review.
- B. Obtain required licensing, permitting, plan review, and inspections. Incorporate changes required to meet the State or City's codes at no additional expense to the Owner.
 - 1. Calculate submittal dates to achieve schedule requirements. Rejection of permit application may require Contractor to adjust design or provide such additional information as required by the City or State.
 - 2. Modifications or delays necessary to receive the City or State's approval shall not result in additional costs or schedule delays to the Owner.

1.07 POSTING PERMITS

- A. Post permits at the site of Work.
- B. Post permits required by law only.

PART 2 PRODUCTS

Not Used.

PART 3 EXECUTION

Not Used.

END OF SECTION 01 41 00

SECTION 01 42 00

REFERENCES

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. Abbreviations.
- B. Definitions.
- C. Explanation of Specifications style.
- D. Reference Standards.

1.02 ABBREVIATIONS

A.	Amperes	A
B.	Alternating current	ac
C.	American Wire Gage	AWG
D.	Direct current	dc
E.	Human machine interface	HMI
F.	Kilo volts	kV
G.	Kilo volt amps	kVA
H.	Kilo volt amps reactive	kVA _r
I.	Kilo volt amps reactive hour	kVA _r h
J.	Kilowatts	kW
K.	Kilowatt hour	kWh
L.	Light emitting diode	LED
M.	Medium voltage	MV
N.	Notice to Proceed	NTP
O.	Operations and Maintenance Facility	OMF
P.	Pounds per square inch	psi

Q.	Seattle City Light	SCL
R.	Traction Power Substation	TPSS
S.	Traction power transformer	TPT

1.03 DEFINITION OF TERMS

A. Furnish, Install, and Provide:

1. Furnish means to supply and deliver to project site, ready for installation.
2. Install means to place in position for service or use.
3. Provide means to furnish and install, complete and ready for intended use.

B. Other Definitions:

1. Approved: When used to convey the Engineer's action on Contractor's applications and requests, "approved" is limited to the Engineer's duties and responsibilities as stated in the Specifications and the Contract Terms and Conditions.
2. Change Order: A written document issued by the Owner to the Contractor which alters the scope of the Work to be performed by the Contractor, changes the schedule of performance of the Work, increases or decreases the Contract Price, increases or decreases the Contract time, or makes another change to the Contract.
3. Contract Documents: Contract Drawings and Contract Specifications.
4. Engineer: Used to designate the representative of the Owner assigned to be the primary point of contact with the Contractor.
5. Indicated: Requirements expressed by graphic representations or in written form on Drawings, in Specifications, and in other Contract Documents. Other terms including "shown," "noted," "scheduled," and "specified" have the same meaning as "indicated."
6. Regulations: Laws, ordinances, statutes, regulations, rules, and lawful orders issued by authorities having jurisdiction, whether Federal, State, or local, and rules, conventions, and agreements within the construction industry that control performance of the Work.
7. The City: The City of Seattle.
8. Work: The requirements of the Contract as specified, shown, indicated, or implied in the Contract Documents, including alterations, amendments, or extensions made by Change Orders.

C. Specification Style:

1. These specifications are written in imperative mood and streamlined form. This imperative language is directed to the Contractor, unless specifically noted otherwise.

The words "shall be" are included by inference where a colon (:) is used within sentences or phrases.

2. Examples:

- a. "Prepare meeting minutes within three days following the meeting," means that the Contractor shall prepare the meeting minutes.
- b. "Adhesive: Spread with a notched trowel" means "adhesive shall be spread with a notched trowel" and the Contractor is responsible for this work.

1.04 REFERENCE STANDARDS

- A. Reference standards are referenced in other sections of the Specifications to establish requirements for the Work. These references are identified in each section by document number and title.
- B. Applicability of Standards: Unless the Contract Documents include more stringent requirements, applicable industry standards have the same force and effect as if bound or copied directly into the Contract Documents to the extent referenced. Such standards are made a part of the Contract Documents by reference.
- C. Conflicting Requirements: Where compliance with two or more standards is specified and the standards establish different or conflicting requirements for minimum quantities or quality levels, comply with most stringent requirement. Refer uncertainties and requirements that are different, but apparently equal, to Engineer for a decision before proceeding.
- D. Publication Dates: Comply with standards in effect as of date of the Contract Documents, unless otherwise indicated.
- E. Copies of Standards: Each entity engaged in Work on this Contract should be familiar with industry standards applicable to its construction activity. Copies of applicable standards are not bound with the Contract Documents.
 1. Where copies of standards are needed to perform a required construction activity, obtain copies directly from publication source.

PART 2 PRODUCTS

Not Used.

PART 3 EXECUTION

Not Used.

END OF SECTION 01 42 00

SECTION 01 43 00
QUALITY ASSURANCE

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. Requirements for Contractor to establish, implement and maintain an effective Quality Program to manage, control, document and assure work complies with requirements specified in the Contract Documents.
- B. Systemic Failures.

1.02 REFERENCE STANDARDS

- A. This Section incorporates by reference the latest revisions of the following documents:
 - 1. Federal Transit Administration (FTA)
 - a. FTA-IT-90-5001-02.1, Quality Assurance and Quality Control Guidelines
 - 2. International Organization for Standardization (ISO)
 - a. ISO 9000, Quality Management Systems – Fundamentals and Vocabulary
 - b. ISO 9001, Quality Management Systems – Requirements

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Qualifications:
 - 1. Quality Assurance Manager, within 30 days after Notice to Proceed (NTP).
 - 2. Independent Testing Laboratories, minimum of 30 days before scheduled use.
 - 3. Quality Control Inspectors.
- C. Quality Program Plan, within 60 Days after NTP.
- D. Testing Laboratory Inspection and Test Reports, within 30 days after completion of the inspection or test.
- E. List of Subcontractors and subconsultants within 45 Days after NTP. Provide updates at least 30 days before each new subcontractor or subconsultant beginning work on Contract.
- F. Document Control Procedure, within 15 Days after effective date of Notice to Proceed.

- G. Proposed repair or replacement for systemic failure.

1.04 CONTRACTOR QUALITY ASSURANCE REQUIREMENTS

- A. Quality Assurance (QA) Manager: Assign a QA Manager responsible for managing and acting on quality matters and who has authority to act on all quality matters as a representative of Contractor.
 - 1. Quality Assurance Manager cannot have responsibilities for this Contract that conflict or appear to conflict with his or her responsibility for quality matters.
 - 2. Qualification of Contractor QA Manager:
 - a. Minimum five years overall quality experience:
 - 1) Minimum two years prior experience as a QA Manager, on transit project(s) of comparable complexity to this Contract.
 - 2) Minimum two years as a Quality Control (QC) Manager or Supervisor, Quality Engineer, Quality Auditor or QC Inspector.
 - 3. Proposed QA Manager shall be approved by the Engineer before assignment to the project. At the sole discretion of the Engineer, Contractor may be required to replace QA Manager.
 - 4. QA Manager's responsibilities include development and implementation of Quality Program Plan.
- B. Quality Program Plan (QPP):
 - 1. Submit ISO 9001 certification or submit a Quality Program Plan, as described:
 - 2. Describe plans, procedures, and organization necessary to design, procure, install, inspect, and test to achieve compliance with the requirements of Contract Documents.
 - 3. Include operations, both on-site and off-site including fabrication, manufacturing and suppliers.
 - 4. Address the 15 quality elements identified in FTA-IT-90-5001-02.1.
 - 5. Provide descriptions of, and references to Quality procedures and work instructions, including specified requirements unique to this Contract, that relate to quality system elements defined in ISO 9000 and ISO 9001.
 - 6. Include the following elements in Contractor QPP:
 - a. QA/QC Organization and staff, including job description and an organizational chart showing relationship between Contractor's General Manager, Project Manager, Quality Manager, Subcontractors, and consultants.
 - b. Documented quality system.

- c. Design control.
- d. Document control and submittal management.
- e. Subcontractor, consultant and supplier Control.
- f. Identification, traceability and receiving, handling, storage and control of products, materials and equipment.
- g. Process control and control of special fabrication processes, i.e. welding, plating, and soldering.
- h. Inspection and testing.
- i. Control of measuring and test equipment.
- j. Inspection and test reporting.
- k. Identification, control, and correction of non-conforming conditions.
- l. Corrective actions.
- m. Quality records.
- n. Training.
- o. Configuration control for software.
- p. Change control for factory drawings, fabrications, assembly, wiring, testing, and as-built drawings.

C. Independent Testing Laboratories:

- 1. Employ services of Independent Testing Laboratories if required by Contract Documents, to confirm acceptable quality of materials, parts, and equipment not currently certified by test laboratories.
- 2. Employ only independent testing laboratories that are currently certified by a nationally or state recognized regulatory agency or an industry-sponsored organization.
- 3. Obtain approval to use independent testing laboratories from Engineer before starting Work for which testing is required by Contract Documents. Independent testing laboratories shall have special inspection capability and certification.

D. Quality Control Inspectors:

- 1. Employ qualified and/or certified quality control inspectors and test technicians with a minimum of two years quality control experience or testing experience in the type of work for which they are responsible for inspecting and testing.

2. Upon request from the Engineer, provide qualifications and certifications of the quality control inspectors.
3. Quality control inspectors shall report directly to the Contractor's QA Manager and cannot have responsibilities for this Contract that conflict or appear to conflict with his primary responsibility for quality matters.
4. Mobilize the number of experienced quality control inspectors necessary to perform the Quality Control requirements.

PART 2 PRODUCTS

Not Used.

PART 3 EXECUTION

3.01 SYSTEMIC FAILURES

- A. Time Period: Monitor component failures during the commissioning, testing, and warranty phase.
- B. Systemic Failure: Failure of ten percent or more of the same components used for the same function during a 12-month window within this time period. The 12-month window applies individually for each component systemic failure.
- C. Within 30 days of receiving notification of systemic failure, begin a program to repair or replace all components of the type involved in the systemic failure, including those that have passed beyond the warranty period.
- D. Develop the repair or replacement for the components to remedy the nature and probable cause of the component failure.
- E. The proposed repair or replacement shall be submitted to the Engineer for approval.
- F. Components shall be replaced at no cost to the Owner.
- G. The correction of defects in design, material, or workmanship shall not result in an increase in required maintenance.

END OF SECTION 01 43 00

SECTION 01 46 00
SYSTEM ASSURANCE

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. Develop and implement a Systems Assurance Program for this Contract, encompassing system safety, reliability and maintainability engineering to accomplish the following.
 - 1. Avoid, eliminate or reduce potential identified hazards at the early stage of the project life.
 - 2. Control and minimize hazards to passengers, personnel, and public.
 - 3. Incorporate fail-safe design principle if possible.
 - 4. Use high reliability and predictable failure modes components.
 - 5. Minimize maintenance costs throughout useful life.
- B. Support for the Owner's Safety Certification Program.

1.02 REFERENCE STANDARDS

- A. This Section incorporates by reference the latest revisions of the following documents:
- B. U.S. Department of Transportation, Federal Transit Administration
 - 1. DOT-FTA-MA-26-5005-00-01, Hazard Analysis Guidelines for Transit Projects
 - 2. DOT-FTA-MA-90-5006-02-01, Handbook for Transit Safety and Security Certification, Volpe National Transportation Systems Center

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Qualifications:
 - 1. Résumé for each proposed person preparing required submittals.
 - 2. Samples of similar documents prepared by each proposed person for previous projects.
- C. Proposed Software: Product data, list of projects where used, sample output.

- D. System Safety Program Plan (SSPP):
 - 1. Submit a schedule for submittal of the required hazard analyses that conforms to the schedule in DOT-FTA-MA-26-5005-00-01.
 - 2. Submit the following hazard analyses included in the SSPP in compliance with DOT-FTA-MA-26-5005-00-01:
 - a. Preliminary Hazard Analysis (PHA).
 - b. Failure Modes and Effects Analysis (FMEA).
 - c. Fault Tree Analysis (FTA).
 - d. Operating Hazard Analysis (OHA)

1.04 QUALITY ASSURANCE

- A. Qualifications:
 - 1. Documents required in this Section shall be prepared by persons with a minimum of five years experience preparing comparable documents for the transit industry.
 - 2. Provide samples of documents from previous projects that demonstrate familiarity with the process and subject matter.
- B. Software: Prepare required documents using recognized industry analysis software.

PART 2 PRODUCTS

2.01 SYSTEM SAFETY PROGRAM PLAN (SSPP)

- A. The SSPP is designed to eliminate and/or control identified hazards.
- B. Conduct safety analyses in accordance with the guidelines in DOT-FTA-MA-26-5005-00-01 and conform to the schedule in this FTA document.
- C. Prepare the following documents in accordance with the guidelines in DOT-FTA-MA-26-5005-00-01:
 - 1. Preliminary Hazard Analysis (PHA): Perform analysis and submit document during the concept-planning phase.
 - 2. Failure Modes and Effects Analysis (FMEA):
 - a. Perform analysis and submit document during preliminary design so that identified changes can be incorporated into the final design.
 - b. Update during the commissioning and integrated testing phase if additional hazards are identified.

3. Fault Tree Analysis (FTA): Perform analysis and submit document at the beginning of final design.
 4. Operating Hazard Analysis (OHA):
 - a. Perform analysis and submit document during the latter portion of final design.
 - b. Update during the commissioning and integrated testing phase if additional hazards are identified.
- D. Implementation:
1. Change design if necessary to eliminate identified hazards.
 2. Where hazards cannot be eliminated, include safety devices and warning devices in design to mitigate hazards.
 3. If an identified hazard can be mitigated only by procedures and training, identify specifically where the hazard has been addressed in training program and Operation and Maintenance Manuals.

PART 3 EXECUTION

3.01 SAFETY CERTIFICATION PROGRAM

- A. The Owner is implementing an FTA Safety Certification Program (reference DOT-FTA-MA-90-5006-02-01).
- B. Support the Owner's implementation of the program as directed by Engineer.
- C. Participation includes activities such as assisting the Owner with development of checklists and documentation, identifying submittals that satisfy requirements of the Certifiable Item List, providing standards to which components are designed and tested, and identifying safety-related instructions in training and maintenance documents.

END OF SECTION 01 46 00

SECTION 01 60 00
PRODUCT REQUIREMENTS

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. General product requirements.

PART 2 PRODUCTS

2.01 GENERAL REQUIREMENTS

- A. Products shall be new.
- B. Products shall not be used that have been or are planned to be discontinued by the manufacturer, even if new.
- C. Products of the same generic type shall be by the same manufacturer.

2.02 BUILT-IN-PLACE TRACTION POWER SUBSTATIONS

- A. Equipment and materials furnished for installation by others shall be identical to equipment and materials provided for prefabricated substations.

PART 3 EXECUTION

3.01 MANUFACTURER'S INSTRUCTIONS

- A. When Contract Documents require that installation of Work comply with manufacturer's recommendations or instructions, submit copies of such recommendations or instructions to Engineer and distribute to installers. Maintain one set at site until installation is complete.
- B. Handle, install, connect, clean, condition, and adjust products in strict compliance with manufacturer's recommendations, instructions, and requirements of these Specifications.
- C. Do not omit steps in manufacturer's instructions unless specifically modified or exempted by Contract Documents.
- D. Should job conditions or specified requirements conflict with manufacturer's recommendations or instructions, notify Engineer.

END OF SECTION 01 60 00

SECTION 01 65 00

PRODUCT DELIVERY REQUIREMENTS

PART 1 GENERAL

1.01 SUMMARY

- A. Section Includes: Requirements for packing, shipping, and delivery at the site.
- B. Related Sections:
 - 1. Section 34 21 90 – TPSS Testing

1.02 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Product data: Shrink wrap installer, material, and system.
- C. TPSS slab inspection report.
- D. Shipping release.
- E. Equipment inspection report for equipment shipped separately for built-in-place substations.
- F. Delivery plan, including schedule, a sketch showing location of crane and truck for picking, and a traffic control plan, if required.
- G. Impactographic record.

1.03 STORAGE AND HANDLING REQUIREMENTS

- A. Before and after TPSS is shipped to site, provide temporary heat inside building after installation of electrical equipment if building is stored outside of a climate controlled building.
- B. Before and after TPSS is shipped to site, provide sufficient heat at all times to prevent the condensation of moisture inside the building.

1.04 SHIPMENT AND DELIVERY REQUIREMENTS

- A. Substation shall not be shipped to the site until specified factory tests are complete, all punchlist items have been corrected, and substation is ready for Field Acceptance Testing (see Section 34 21 90, TPSS Testing).

- B. Before scheduling shipping, submit a shipping release to the Engineer for signature.
 - 1. The shipping release shall certify that the substation is complete, has passed all specified factory tests, complies with approved Contractor's drawings and samples, and complies with other agreed upon conditions for shipping.
 - 2. Submit a list of all known defects with the request for shipping release.
 - 3. The Engineer, at his or her sole discretion, may permit shipment of a substation with minor defects that will not affect testing and can easily be corrected after shipment.

- C. Before Delivery:
 - 1. Coordinate TPSS shipment schedule with the Engineer.
 - 2. Inspect each TPSS slab, installed by others, and report to Engineer immediately if there are defects that would prevent setting the TPSS.

- D. Packaging:
 - 1. Shrink wrap each TPSS enclosure with 12 mil shrink wrap before shipping.
 - 2. Ship each section of equipment not inside the TPSS enclosure securely wrapped, crated or packaged, and label for safe handling in shipment to avoid damage or distortion.
 - 3. Switchgear assemblies:
 - a. Split into shipping groups for handling as indicated on drawings or per the manufacturer's recommendations.
 - b. Design shipping groups to be shipped by truck or rail.
 - c. Bolt to skids.
 - d. Package and ship accessories separately.
 - e. Provide each switchgear shipping group with lifting eyes for handling solely by crane.
 - 4. Include one copy of handling instructions with the equipment at time of shipment.

- E. Impactograph:
 - 1. Provide each TPSS enclosure, and each section of electrical and electronic equipment shipped separately from TPSS enclosure with a continuous recording impactograph mounted on the interior of the enclosure or equipment.
 - 2. Set the unit to record impacts in the 2 g to 5 g range.

3. Remove impactographic record after building is set on site or for separate equipment, after it is unloaded.
4. Submit impactographic record as part of the substation history book.

F. Delivery:

1. Contact Seattle Department of Transportation: Commercial Vehicle Enforcement, Traffic Management Division, (206) 684-5086.
 - a. Obtain necessary permit for oversize load before entering the City of Seattle.
 - b. Observe restricted hours for oversize loads within the City of Seattle.
2. Deliver each prepackaged TPSS to a location adjacent to its concrete slab, provided by others.
3. Pick prepackaged TPSS from delivery truck and set on concrete slab in correct position and orientation, ready to be secured. TPSS will be secured to slab by others.
4. Unload individual pieces of equipment for built-in-place substations. Move into final locations in the substation room unless directed by the Engineer to another location on the site. Remove shipping materials and inspect equipment for damage.

PART 2 PRODUCTS

Not Used.

PART 3 EXECUTION

Not Used.

END OF SECTION 01 65 00

SECTION 01 78 23

OPERATION AND MAINTENANCE DATA

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. Operation and Maintenance (O&M) Manual for prefabricated traction power substations and built-in-place traction power substations.
- B. Renewal Parts Catalog.
- C. Posted Operating Instructions.

1.02 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. O&M Manual:
 - 1. Submit for prefabricated traction power substations and built-in-place traction power substations.
 - 2. Submit minimum of 90 days before scheduled energization of first substation.
 - 3. For initial review, prepare one complete hard copy set and one electronic version.
 - 4. After final approval of submitted O&M manual submit 10 hard copy sets and five electronic copies.
- C. Renewal Parts Catalog. Submit at the same time as O&M manual.
- D. Posted Operating Instructions:
 - 1. Submit wording for each printed instruction.
 - 2. Submit shop drawing of mounting.
 - 3. Submit location for prefabricated substations and for built-in-place traction power substations.

PART 2 PRODUCTS

2.01 OPERATION AND MAINTENANCE MANUALS

A. Format:

1. Include the following in each volume, specific to that volume of the manual:
 - a. Frontispiece: Preceding and facing the title page, showing a recognizable illustration of the equipment described.
 - b. Title Page: Include the name and function of the equipment, manufacturer's identification number(s), and the Contract Specifications number(s) and title(s).
 - c. Table of Contents: List the sections and subsection titles with the page on which each starts and a list of included drawings for each section or subsection.
2. Format of content:
 - a. Information shall cover the exact equipment provided and shall not consist of marked up general catalog data.
 - b. Delete information on material or equipment not used.
 - c. Include drawings and diagrams for major assemblies and subassemblies.
 - d. Include descriptive brochures providing physical and functional description of the equipment.
 - 1) Brochures shall be original, printed materials or high quality color prints from electronic media.
 - 2) Brochures shall not be photocopies.
3. Dividers: Insert dividers with identifying tabs to separate sections of the manual.
4. Pages: 8-1/2 inches by 11 inches in size or folded to that size.
5. Binders: Heavy duty, D-ring, locking, three-ring binders not filled to more than 2/3 of their capacity.
6. Paper: 47 pound bond.

B. Content:

1. Furnish maintenance and operating instructions for all equipment and systems installed, including the following:
2. Installation:
 - a. Pre-installation inspection.

- b. Installation verification checklist.
 - c. Torque: Include manufacturer's recommended torque information for each type of bolted connection used.
 - d. Calibration.
 - e. Preparation for operation for initial installation.
3. Operation:
- a. Performance specifications.
 - b. Operating limitations.
 - c. Include step-by-step procedures for
 - 1) Starting: Furnish start-up checklist.
 - 2) Restarting.
 - 3) Operating.
 - 4) Shutdown.
 - 5) Emergency requirements.
4. Preventative Maintenance:
- a. Include step-by-step procedures for
 - 1) Inspection.
 - 2) Operation checks.
 - 3) Cleaning.
 - 4) Lubrication.
 - 5) Adjustments.
5. Corrective Maintenance:
- a. Include step-by-step procedures for
 - 1) Repair.
 - 2) Disassembly.
 - 3) Reassembly of the equipment for proper operation.

6. Overhaul:
 - a. Parameters that indicate an overhaul is required.
 - b. Disassembly.
 - c. Parts to replace.
 - d. Adjustment, cleaning, etc. for parts not replaced.
 - e. Reassembly of the equipment for proper operation.
 - f. Preparation for operation after overhaul.

C. Appendices:

1. Glossary.
2. Bill of Materials:
 - a. Furnish complete with all necessary information, including part numbers and catalog item numbers if applicable, for identifying parts.
 - b. Identify parts or assemblies obtained from another manufacturer by the name of that manufacturer and its identifying part number.
 - c. Supply the size, capacity, or other characteristics of the part if required for identification.
3. Torque table for all types of bolts used in bolted connections.
4. Spare Parts and Special Tools:
 - a. Furnish a list of contractual and recommended spare parts
 - b. Furnish a list of special tools required for maintenance.
5. Safety: Safety precautions.
6. Testing: Copies of Field Acceptance Testing procedures and test reports.
7. Warranty information.
8. Others appendices as needed.

D. Special Submittal Procedures:

1. Work with Engineer to review O&M Manuals together in a meeting environment, if requested

2. Revise manuals in accordance with directions and comments from both meeting inputs and formal mark-ups by reviewers.
 3. Resubmit as required in accordance with Section 01 33 00, Submittal Procedures.
- E. Revisions: If subsequent modifications are made to equipment, revise operation and maintenance procedures.
1. Revise the O&M Manuals to show the equipment as installed.
 2. Revise by issue of replacement pages to the final O&M Manuals, or by reissue of the O&M Manuals, at the Engineer's option.
 3. Submit the revisions to the O&M Manuals not later than 30 Days following revision of the equipment.

2.02 RENEWAL PARTS CATALOG

- A. Enumerate and describe every component with its related parts, including supplier's number, Contractor's number, Drawings Apparatus Reference number, and provision for entry of the Owner's part number.
- B. Use cut-away and exploded drawings to aid identification of parts not readily identified by description.
- C. Parts common to different components, such as bolts and nuts, shall bear the same Contractor's number with a reference to other components in which they are found.
- D. For each part or component, list all the assemblies of which it is a component.
- E. Standard parts:
 1. Identify commercially available items such as common standard fastenings, fuses, lamps, fittings, etc., by standard hardware nomenclature besides Contractor's number.
 2. Furnish a separate list of these items in the catalog with adequate information to order these items through commercial channels.
- F. Furnish a complete itemization of servicing materials (oils, paints, special compounds, greases, etc.) required and component requiring its use.
- G. Furnish ordering and procurement information required for components and subassemblies to the lowest level replaceable component. Ensure that the Owner will not need to request information from Contractor at a future date.
- H. Submit lists in the form of reproducible Bills of Materials suitable for loose-leaf binding adequately cross-referenced to related drawings and Bills of Material.

2.03 POSTED OPERATING INSTRUCTIONS

- A. Provide a printed sheet under clear acrylic plastic, giving brief, concise operating instructions for equipment listed below. List below is a minimum. Provide additional operating instructions where directed by Engineer.
 - 1. Ac switchgear.
 - 2. Dc switchgear.
 - 3. Positive and negative switches.
 - 4. Substation alarm panel.
 - 5. Air conditioners.
 - 6. Rail voltage monitoring and grounding system.
- B. Submit wording, shop drawing of mounting, and locations for approval.

PART 3 EXECUTION

3.01 POSTED OPERATING INSTRUCTIONS

- A. Install posted operating instructions in prefabricated substations in approved locations before delivery to site.
- B. Install posted operating instructions in built-in-place substations in approved locations during commissioning.
- C. Mount to wall with sheet metal screws, square with lines of building.

END OF SECTION 01 78 23

SECTION 01 78 36

WARRANTIES

PART 1 GENERAL

1.01 SUMMARY

- A. Section Includes: Warranty periods for substation enclosure and equipment.
- B. Related Sections:
 - 1. Section 05 05 00 – Common Work Results for Metals
 - 2. Section 26 50 00 – Lighting Section
 - 3. Section 34 21 05 – Common Work Results for TPSS
 - 4. Section 34 21 23 – Transformer-Rectifier Unit

1.02 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Warranties.

1.03 MANUFACTURER WARRANTY

- A. Provide the following extended manufacturer's warranties:
 - 1. Unproven equipment: Five years. See Section 34 21 05, Common Work Results for TPSS for specific requirements.
 - 2. Substation enclosure powder coat finish: Five years. See Section 05 05 00, Common Work Results for Metals for specific requirements.
 - 3. Traction power transformers: Five years. See Section 34 21 23, Transformer-Rectifier Unit.
 - 4. Emergency light batteries: Ten years. See Section 26 50 00, Lighting, for specific requirements.
- B. Provide a one-year warranty for all other components.

PART 2 PRODUCTS

Not Used.

PART 3 EXECUTION

Not Used.

END OF SECTION 01 78 36

SECTION 01 78 39
PROJECT RECORD DOCUMENTS

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. Requirements for as-built drawings.

1.02 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.

- B. Incremental Submission of As-Built Drawings:

1. Upon request from the Engineer, make available copies of selected as-built drawings in color.
2. Incremental as-built drawings requested by the Engineer shall be stamped "As-Built", signed, and dated by Contractor.
3. Include a transmittal letter containing the following information:
 - a. Date of submission.
 - b. Project title and number.
 - c. List of items covered in the incremental as-built submission
 - d. Contractor's name and address.
 - e. Certification that each document as submitted is complete and accurate.
 - f. Signature of Contractor or its authorized representative.

- C. Final Submission of As-Built Drawings:

1. At completion of Work, and before requesting Final Acceptance of Work, draft red-line revisions in AutoCAD and deliver as-built drawings to the Engineer.
2. Stamp final as-built drawings "As-Built," sign, and date.
3. Submit five hard copies and three electronic copies on CDs in AutoCAD (latest version) and in PDF formats.
4. Submit as-built drawings with a transmittal letter containing the following information:
 - a. Date of submission.

- b. Project title and number.
- c. Contractor's name and address.
- d. Certification that as-built drawings as submitted are complete and accurate.
- e. Signature of Contractor or its authorized representative.

PART 2 PRODUCTS

Not Used.

PART 3 EXECUTION

3.01 MAINTENANCE OF AS-BUILT DRAWINGS

- A. Maintain in each substation a current version of approved shop drawings with redline revisions to drawings showing changes made after approval.
- B. Protect drawings from damage.
- C. Make drawings available for periodic review by the Engineer.

END OF SECTION 01 78 39

SECTION 01 79 00

DEMONSTRATION AND TRAINING

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. Requirements for instruction and training of Operations and Maintenance personnel in the management, operation, and maintenance of furnished equipment and systems.

1.02 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Submit drafts of the instructor guide and training manual six months before the start of training.
- C. Submit resumes of proposed instructors.
- D. Submit final versions one month before the start of training. Training shall not begin until the instructor guide and training manual are approved by the Engineer.
 - 1. Instructor guide: Provide three hard copies and one electronic copy.
 - 2. Training manual: Provide one hard copy for each participant, three additional hard copies, and one electronic copy.
- E. Submit DVD format videos if videos are used in training.
- F. Submit Training Reports not later than one week after completion of course.

PART 2 PRODUCTS

2.01 TRAINING PROGRAM

- A. Design program to train the Owner's maintenance and operations personnel in details of furnished equipment and systems and enable them to operate, service, and maintain systems such that systems will perform and continue to perform in accordance with requirements of this Contract.
- B. Provide a logically related sequence of separate courses covering system operation, overall system maintenance, and equipment operation and maintenance.
- C. Ensure operations and maintenance personnel are fully trained before start of passenger service.

- D. Operations and Maintenance Personnel Qualifications:
 - 1. Assume personnel to be trained have only basic skills pertinent to their craft.
 - 2. Assume Operations and Maintenance personnel to be trained have no knowledge of features of specific equipment or systems to be taught.
- E. Training Materials: At a minimum, provide an instructor's guide and a training manual.

2.02 TRAINING COURSES

- A. Course requirements:
 - 1. Include classroom, hands-on, and field instruction, as appropriate, and models, mockups, documentation, and aids to carry out the program.
 - 2. Class Sizes: Unless otherwise specified elsewhere in these Specifications, the Owner will be able to send up to 10 participants to each of the training courses specified.
 - 3. Duration: Maximum eight hours per day.
 - 4. Training Location and Classrooms: Conduct training courses in facilities provided by the Owner. The facilities will be equipped with tables and chairs.
 - 5. Provide video players and projectors as required.
 - 6. Provide instructors who are fluent in English.
 - 7. Provide literature and equipment necessary to train personnel.
 - 8. Training on actual system equipment and spare equipment will be permitted; however, such use shall not interfere with pre-revenue tests and system demonstrations.
- B. Equipment Operations and Maintenance Training:
 - 1. Provide training in the operation and maintenance of equipment systems furnished.
 - 2. Provide hardware training including, but not limited to:
 - a. Equipment operation.
 - b. Troubleshooting procedures, including field diagnostics and test equipment.
 - c. Interface with other equipment.
 - d. Preventative maintenance procedures.

3. Provide Operations and Maintenance personnel with a thorough knowledge of the equipment and its operation, its interface with other equipment, and the capabilities and use of test equipment.
 4. Provide participants with theoretical background and hands-on experience in troubleshooting, repair procedures, and preventive maintenance procedures.
 5. Introduce faults in an actual substation to provide hands-on experience in troubleshooting
 6. Include board level troubleshooting and repair.
 7. Include component level repair where appropriate.
 8. Course participants shall operate actual in place equipment, and learn how to use test equipment and fixtures to troubleshoot problems and repair failures.
 9. Enable Operations and Maintenance personnel to develop a self sufficient hardware maintenance team for the equipment.
 10. Include a page by page review and explanation of approved O&M Manuals.
- C. Supplemental Training:
1. Provide extended, duplicate, or additional training for the systems provided, as deemed necessary by the Engineer, due to modification of systems and equipment configuration made after completion of the scheduled training courses.

2.03 PARTICIPANT TRAINING MATERIALS

- A. Provide Owner-specific materials prepared specifically for use as training aids.
- B. Use reference manuals, operating and maintenance manuals, and user's manuals as supplementary training materials.
- C. Tailor principal documents used for training to reflect the Owner's equipment and specific user requirements.
- D. Provide each course participant a copy of training manual and other pertinent material before beginning courses.
- E. Upon completion of each course, instructor's manuals, training manuals, and training aids become the property of the Owner unless such items are specifically exempted by the Engineer.
- F. The Owner reserves the right to copy training materials and aids for use in Owner-conducted training courses.
- G. Provide special tools, equipment, training aids, and other materials required to train course participants. Provide sufficient quantity of special tools and other training equipment for the number of participants attending the course.

- H. Use actual hardware and photographs taken during the manufacturing process wherever possible. Actual hardware used for training shall pass re-inspection and acceptance testing before being placed in service.
- I. Videos:
 - 1. Use prerecorded lectures as supplementary training material.
 - 2. Do not use videos as a replacement for a classroom instructor, or as the primary training vehicle.
 - 3. The Owner shall have the right to videotape training courses presented by the Contractor use these videotapes to train personnel in the future.

2.04 INSTRUCTOR GUIDE

- A. Instructor Guide shall contain a separate section for each training session.
 - 1. Each section shall include detailed instructor actions to take during program presentation.
 - 2. If a PowerPoint presentation is used, include print out of slides in each section for the corresponding session
- B. Supply the following materials with each Instructor Guide:
 - 1. Microsoft PowerPoint presentation file on disk.
 - 2. Slides, pictures, charts used in support of the lesson.
 - 3. One complete student handout package.
 - 4. One copy of material referenced in the lesson.
- C. Each Instructor Guide shall contain the following information for each section:
 - 1. Title: Short and descriptive, including lesson name and target audience.
 - 2. Time to Teach: Estimated time to teach, an approximate period that may vary due to student number and knowledge level.
 - 3. Objective: One or more performance-based objectives each of which specifies:
 - a. End-of-course performance expected of the student.
 - b. Conditions under which behavior will occur.
 - c. Measurable minimum level of performance considered acceptable.
 - 4. References: List sources of material presented, include maintenance manuals, test equipment manuals, and other documents developed for this Contract.

5. Materials List: List materials needed to teach content, include training aids (such as charts, projectors, and size and type of facility), student handouts (such as books, drawings, and schematics), equipment (such as tools and parts for disassembly).
6. Introduction: Cover at least the following areas:
 - a. Introduction of subject covered by the lesson.
 - b. Lesson objectives.
 - c. An outline of the lesson.
 - d. A schedule of the lesson's activities.
7. Presentation: Presentation should be in outline form, narrative is acceptable but not necessary.
 - a. Suggested numbering system:

- A.
- B.
 - 1.
 2.
 - a.
 - b.
 - (1)
 - (2)
 - (a)
 - (b)

- D. Presentation portion of the Instructor Guide should be detailed enough to:
 1. Serve as a written record of the specific facts and information.
 2. Allow another instructor with knowledge of the area to teach the class.
 3. Ensure that the subject delivery is consistent each time the lesson is given.
 4. Allow replication of evaluations, tests, and quizzes given in conjunction with this lesson.

2.05 TRAINING REPORTS

- A. Grading system: Establish to report progress of each trainee during a course and identify requirements for further training for each participant.

B. Training Reports:

1. Include graded tests (without names) with raw scores.
2. Include a summary of the results of monitoring and evaluating.
3. Include records of student attendance and performance.

PART 3 EXECUTION

Not Used.

END OF SECTION 01 79 00

SECTION 05 05 00

COMMON WORK RESULTS FOR METALS

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. Galvanizing.
- B. Shop applied coatings for metal fabrications.
- C. Welding.

1.02 REFERENCES

- A. Definitions:
 - 1. Galvanneal: Hot-dip zinc coating process followed by heating steel to approximately 1000 to 1050 degrees F and holding at this temperature to allow the zinc coating to alloy with iron by diffusion between the molten zinc and iron from the steel.
 - 2. Hot-dip galvanizing: Dipping steel members and assemblies into molten zinc for lasting, or long-term corrosion protection. Resultant zinc coating fuses permanently with base steel material.
- B. Reference Standards:
 - 1. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:
 - 2. The American Society for Nondestructive Testing (ASNT)
 - a. Recommended Practice No. SNT-TC-1A: Personnel Qualification and Certification in Nondestructive Testing
 - 3. American Welding Society (AWS)
 - a. AWS A5 Series, Filler Metal Specifications
 - b. AWS B1.10M/B1.10, Guide for the Nondestructive Examination of Welds
 - c. AWS D1.1/D1.1M, Structural Welding Code – Steel
 - d. AWS D1.3/D1.3M, Structural Welding Code – Sheet Steel
 - e. AWS QC1, Standard for AWS Certification of Welding Inspectors

4. ASTM International (ASTM):
- a. ASTM A53/A53M, Pipe, Steel, Black and Hot-Dipped Zinc-Coated, Welded and Seamless
 - b. ASTM A123/A123M, Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
 - c. ASTM A143/143M, Safeguarding against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement
 - d. ASTM A153/A153M, Zinc Coating (Hot-Dip) on Iron and Steel Hardware
 - e. ASTM A384/A384M, Safeguarding against Warpage and Distortion During Hot-Dip Galvanizing of Steel Assemblies
 - f. ASTM A385/A385M, Providing High-Quality Zinc Coatings (Hot Dip)
 - g. ASTM A653/A653M, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
 - h. ASTM A780/A780M, Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings
 - i. ASTM B6, Standard Specification for Zinc
 - j. ASTM B117, Standard Practice for Operating Salt Spray (Fog) Apparatus
 - k. ASTM D522, Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings
 - l. ASTM D968, Standard Test Methods for Abrasion Resistance of Organic Coatings by Falling Abrasive
 - m. ASTM D1308, Standard Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes
 - n. ASTM D2247, Standard Practice for Testing Water Resistance of Coatings in 100% Relative Humidity
 - o. ASTM D2248, Standard Practice for Detergent Resistance of Organic Finishes
 - p. ASTM D2794, Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)
 - q. ASTM D3170, Standard Test Method for Chipping Resistance of Coatings
 - r. ASTM D3359, Standard Test Methods for Measuring Adhesion by Tape Test
 - s. ASTM D3363, Standard Test Method for Film Hardness by Pencil Test

- t. ASTM D3451, Standard Guide for Testing Coating Powders and Powder Coatings
 - u. ASTM D6132, Standard Test Method for Nondestructive Measurement of Dry Film Thickness of Applied Organic Coatings Using an Ultrasonic Gage
 - v. ASTM D6695, Standard Practice for Xenon-Arc Exposures of Paint and Related Coatings
 - w. ASTM D7091, Standard Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals
 - x. ASTM E94, Guide for Radiographic Testing
 - y. ASTM E164, Practice for Ultrasonic Contact Examination of Weldments
 - z. ASTM E165, Standard Test Method for Liquid Penetrant Examination
 - aa. ASTM E709, Guide for Magnetic Particle Examination
 - bb. ASTM E1032, Method for Radiographic Examination of Weldments
 - cc. ASTM G151, Standard Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources
 - dd. ASTM G155, Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials
5. The Society for Protective Coatings (SSPC)
- a. SSPC-SP6, Commercial Blast Cleaning
 - b. SSPC-SP8, Pickling

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Certification:
 - 1. Furnish notarized certificates of compliance with ASTM and AWS requirements specified in this Section.
 - 2. Certifications shall state that the galvanizing or finish is in conformance with this Section.
 - a. Each certificate for galvanizing shall be signed by the galvanizer and include a detailed description of all material and methods used.

- b. Each certificate for shop applied coatings shall be signed by the applier and include a detailed description of all material and methods used.

C. Shop Applied Coatings:

1. Qualifications Submittals (for each applicator) minimum 60 days before work is scheduled.
 - a. Evidence that the applicator is an approved and authorized applicator of the coating formulator's products.
 - b. Certification that the applicator has been authorized to provide the coating formulator's warranty.
 - c. Applicator's quality control procedures.
2. Literature and Instructions:
 - a. Descriptive and technical data sheets describing products proposed for use. Include, for each indicated substrate, chemical and performance characteristics of each coating system.
 - b. Documentation of application process.
3. Color Samples:
 - a. Match colors specified on 12-inch long sections of extrusions and 12-inch square heavy gage sheet metal, materials matching indicated substrates, for the Engineer's review.
 - b. Include additional samples for each indicated color demonstrating color match of recommended field touchup materials.
4. Testing:
 - a. Certified test results evidencing compliance of applied coatings with the application and testing requirements specified in this Section.
5. Repair:
 - a. Manufacturer recommended repair procedures and materials.
 - b. If repair is necessary, submit repair sample after salt spray testing.
6. Maintenance Information and Field Touchup Materials:
 - a. Manufacturer's recommended touchup and maintenance materials and procedures for field touchup of marred or damaged coatings using air-drying spray materials in matching colors.

D. Welding:

1. Welder Qualifications:

- a. Submit certified copies of qualification test records for each welder, welding operator and tack welder to be employed in the Work 150 Days after NTP.
- b. Comply with requirements of AWS D1.1/D1.1M, and AWS QC1.
- c. Submit welders' identification marks (I.D.) for each welder along with qualifications.

2. Welding Procedures:

- a. Before welding, submit the procedure that will be used for qualifying welding procedures.
- b. For procedures other than those prequalified in accordance with AWS D1.1/D1.1M, submit a copy of procedure qualification test records in accordance with the qualification requirements of AWS D1.1/D1.1M.

3. Welding Records and Data:

- a. Retain radiographs upon completion of fabrication.
- b. Retain certifications that magnetic particle and dye-penetrant inspections have been satisfactorily completed.
- c. Submit records of ultrasonic testing to the Engineer upon completion.
- d. If field welding is permitted, submit descriptive data for field welding equipment.

4. Mill Certificates:

- a. Retain mill certificates and certified copy of reports for analyses and tests required by referenced ASTM and AWS specifications.

1.04 QUALITY ASSURANCE

A. Coating Applicator Qualifications:

1. Engage an experienced coating applicator that is licensed or approved by the powder coating manufacturer.
2. Applicator shall have demonstrated the ability to properly apply the coating and have quality control procedures firmly established in its shop.
3. Engineer may, at his option, visit the applicator's facility to confirm adherence to quality control procedures.

- B. Single Source for Galvanized and Finished Metal Fabrications:
 - 1. Use products of one manufacturer on each specific item to ensure exact color match and finish appearance.
- C. Welding:
 - 1. Welder Qualifications:
 - a. Welders, Welding operators and tack welders shall be qualified in accordance with AWS D1.1/D1.1M.
 - b. For sheet steel, welders shall be qualified in accordance with AWS D1.3/D1.3M, Qualification Section.
 - c. Welding shall be done by qualified, certified welders who make only those welds for which they have been qualified in accordance with AWS, or other approved qualifying procedures.
 - d. Records of welder qualification tests shall be made available for review upon the Engineer's request.
 - 2. Welding Procedure Qualification:
 - a. Welding procedures shall be prequalified or qualified in accordance with AWS D1.1/D1.1M.
 - b. For sheet steel, proposed welding procedures shall be qualified in accordance with AWS D1.3/D1.3M. Prequalification is not applicable to sheet steel.
 - 3. Welding Inspector Qualifications: Welds to be inspected by the Contractor shall be inspected and certified by an AWS Certified Welding Inspector (CWI), certified in accordance with AWS QC1.
 - 4. Testing Personnel Qualification:
 - a. Personnel performing nondestructive testing shall be qualified and certified in accordance with the American Society for Nondestructive Testing Recommended Practice No. SNT-TC-1A.
 - b. Only persons certified for NDT Level I and working under a NDT Level II person or persons certified for NDT Level II may perform nondestructive testing.
 - 5. Weldability of Steel: For structural steel requiring impact test qualification and for corrosion resistant structural steel, establish weldability of steel and procedures for welding it by qualification in accordance with AWS D1.1/D1.1M, to match the notch toughness and weathering characteristics of the base metal.

1.05 DELIVERY, STORAGE, AND HANDLING

- A. Deliver, handle, and store metal fabrications in a manner that prevents damage to the item, its galvanizing, and its finish.

1.06 WARRANTY

- A. Provide written warranty starting on date of conditional acceptance stating that shop applied coating will not blister, peel, crack, chalk, change color or have other forms of degradation during warranty period. See Section 01 78 36, Warranties for length of warranty.
- B. Coating failure:
 - 1. In the event that coating failure occurs within warranty period, replace item indicating coating failure, including full cost of labor and materials for such replacement.
 - 2. Replacement items shall be new and finished with same type coating meeting requirements of this section.
 - 3. Replacement items shall match adjacent members.
- C. The Engineer may permit field repairs in lieu of replacement, provided coating failure is minor in scope and field repair material and method employed match its adjacent member. Repairs shall be compatible with original surface.

PART 2 PRODUCTS

2.01 GALVANIZING

- A. Hot-Dip Galvanized Coating
 - 1. Wherever materials are called out as "hot-dip galvanized" or "galvanized," provide a zinc coating after fabrication using the hot-dip galvanizing process complying with ASTM A123/A123M and A153/A153M.
 - a. Galvanizing bath shall contain 0.05 to 0.09 percent nickel by weight.
 - b. The coating is intended to be hot-dip galvanizing applied in addition to normal manufacturer's finish.
 - c. Specified materials or products which are not readily available in the specified hot-dip finish, shall be "custom" hot-dipped after manufacture by an independent galvanizer.
 - 2. Where finishes are called out as galvanized and the specified product cannot be hot-dip galvanized either before or after manufacture, provide the specified product with a finish that will perform equal to hot-dip galvanized as approved by the Engineer.
 - 3. Before galvanizing: Inspect iron and steel hardware before galvanizing and verify suitability for galvanizing. Replace items which are not suitable for galvanizing.
 - 4. Material Suitable for Galvanizing:
 - a. Geometrically suitable for galvanizing as specified in ASTM A384/A384M and ASTM A385/A385M.

- b. Steel materials suitable for galvanizing include structural shapes, pipe, sheet, fabrications, and assemblies.
 - c. Material chemically suitable for galvanizing. Verify with supplier or fabricator.
 - 5. Zinc for galvanizing: Conform to ASTM B6, as specified in ASTM A123/A123M.
 - 6. Preparation of Steel Members:
 - a. Galvanized members requiring shop fabrication shall be welded, drilled, and assembled, as applicable, before galvanizing.
 - b. Galvanized members that are to be field welded or that are to be shop welded to ungalvanized members shall be masked to a distance of 1 inch from weld line before galvanizing.
 - c. Members to be galvanized shall be abrasively cleaned, in accordance with SSPC-SP6.
 - d. Pickle steel surfaces before hot-dip galvanizing in accordance with SSPC-SP8.
 - 7. Steel members, fabrications, and assemblies to be galvanized after fabrication:
 - a. Method: Hot-dip process in accordance with ASTM A123/A123M.
 - b. Weight of zinc coating: Conform to requirements of ASTM A153/A153M.
 - c. Components: Smooth after galvanizing.
 - 8. Embrittlement: Safeguard against steel embrittlement in accordance with ASTM A143/A143M.
 - 9. Warpage:
 - a. Safeguard against warpage or distortion of steel members in accordance with ASTM A384/A384M.
 - b. Notify the Engineer of potential warpage problems that require modification in design before proceeding with steel fabrications. Costs for alternative designs shall be performed at no additional cost to the Owner.
 - 10. Finish, uniformity, and adherence of coating: ASTM A153/A153M.
- B. Galvannealed Coating:
 - 1. Wherever materials are called out as "galvannealed," provide a zinc-iron alloy coating applied by a hot-dip process complying with ASTM A653/A653M.
- C. Mechanical Galvanizing shall not be used.

2.02 SHOP APPLIED COATINGS

- A. Provide shop-applied polyester triglycidyl isocyanurate (T.G.I.C.) coatings, thermo-cured color finish systems based on dry, powdered resins, commonly known as "powder coat."
 - 1. Primer: Apply primer compatible with powder top coat, as confirmed by powder coat manufacturer.
 - 2. Top Coat:
 - a. Interior:
 - 1) Approved Manufacturer/Product: Tiger Drylac.
 - 2) Substitutions: Per 01 25 00, Substitution Procedures.
 - b. Exterior: Anti-graffiti powder coating for easy removal of typical spray paint used for graffiti.
 - 1) Approved Manufacturer/Product: Tiger Drylac Series 44.
 - 2) Substitutions: Per 01 25 00, Substitution Procedures.
- B. Dry Film Thickness:
 - 1. Primer: 3.5 mils minimum.
 - 2. Top coat: 3.5 mils minimum.
- C. Coating shall meet the testing requirements of ASTM D3451 and other standards indicated below:
 - 1. Physical Properties of Powder Coatings:
 - a. Measurement of film thickness: ASTM D6132 or D7091.
 - b. Abrasion resistance: ASTM D968.
 - c. Adhesion: ASTM D3359, Method B, 5B.
 - d. Elongation (flexibility): Mandrell Bending Test, ASTM D522, equal to or greater than 3 mm.
 - e. Household chemical resistance: ASTM D1308.
 - f. Detergent resistance: ASTM D2248.
 - g. Chip resistance: ASTM D3170.

- h. Gloss:
 - 1) Interior: 25 to 40 percent reflective gloss.
 - 2) Exterior: ASTM D523, 80 to 90 plus.
 - i. Pencil hardness:
 - 1) Interior: ASTM D3363, F minimum.
 - 2) Exterior: ASTM D3363, 4H (minimum).
 - j. Impact resistance: ASTM D2794, 80 (in/lb), no appearance of cracks.
- 2. Accelerated Artificial Weathering: ASTM D6695, ASTM G151, ASTM G155.
 - 3. Accelerated Environmental Exposure:
 - a. Salt spray:
 - 1) Interior: ASTM B117, maximum undercut failure of 1/16 inch at scribed test lines; no blistering.
 - 2) Exterior: ASTM B117, 500 hours, maximum undercut failure 1 (mm); no blistering.
 - b. Humidity Resistance: ASTM D2247, 500 hours, maximum undercutting 1 mm, no blistering.
- D. Perform mechanical processing such as sawing, drilling, milling, cutting, and bending before applying shop applied coatings.
 - E. Cleaning:
 - 1. Clean surfaces to be coated as follows:
 - a. Remove all dust, dirt, and other surface debris by vacuuming, wiping dry with clean cloths or compressed air.
 - b. Rinse scrubbed surfaces with clean water until foreign matter is flushed from surface.
 - c. Allow surfaces to drain completely and allow to thoroughly dry.
 - d. Use water blasting only when necessary for extreme cases of contamination by oily residue and where hand washing is impractical.
 - e. If the above procedures do not clean the substrate surfaces, clean the surfaces with high pressure water washing.

F. Pretreatment:

1. Wash parts in a four stage iron-phosphate washer for steel or zinc-phosphate washer for galvanized steel, or in accordance with primer manufacturer's recommendations.
2. Dry parts before application of power coating.
3. Treatment of the substrate: ASTM D3451.

G. Application:

1. Edges: Treat and finish as required to ensure specified minimum dry film coating thickness is achieved. Precoating of edges may be required.
2. Apply primer in accordance with manufacturer's written application instructions.
3. Apply top coat in accordance with manufacturer's written application instructions.
4. Allow surfaces to cure for time period in accordance with manufacturer's cure curves.
5. Inspect parts after cooling.

H. Color:

1. TPSS Enclosure Exterior: Color will be provided by the Engineer.
2. TPSS Enclosure Interior: RAL 9010, Pure White.
3. Electrical Equipment: RAL 7040, Window Grey.

2.03 WELDING

A. Rod/Electrodes:

1. Electrodes for structural plate, shapes, pipe, tubes, and bars shall conform to AWS A5 Series Standards and shall be coated rods or wire of size and classification number as recommended by their manufacturers for the conditions of actual use.
2. Electrodes for sheet steel shall conform to AWS A5 Series Standards and shall be coated rods or wire of size and classification number, as recommended by their manufacturers for the conditions of actual use.
3. Matching filler metal requirements shall conform to AWS D1.1/D1.1M, Table 3.1.

B. Stud Shear Connectors: Only products of manufacturers qualified in accordance with AWS D1.1/D1.1M will be accepted for this Work.

C. Shop Welding:

1. Perform shop welding as indicated in accordance with AWS D1.1/D1.1M, and AWS D1.3/D1.3M, as applicable to the Work.

2. Welders shall mark adjacent to completed welds their welder I.D., using metal stamp, metal engraving, keel, paint stick, or other appropriate marking material.
3. Welding of stud shear connectors shall conform to AWS D1.1/D1.1M, Section 7. "Stud Welding," and the stud manufacturer's instructions.

2.04 SOURCE QUALITY CONTROL

- A. Galvanizer Coordination Drawings: To safeguard against distortion, provide shop drawings to galvanizer of non-standard fabrications, tubular fabrications, fabrications with dimension greater than galvanizer's kettle size, and fabrications with materials of different thicknesses.
- B. Galvanizer's Stamp: Galvanized materials shall be marked with the galvanizer's stamp.
- C. Galvanizing Inspection and Repair:
 1. Inspect galvanizing for full coverage and adhesion to steel.
 - a. Grind rough areas to produce a uniform surface.
 - b. Repair field cutting of metal, welds, steel grinding, scratches and other damages, and coat masked areas, in accordance with ASTM A780/A780M, Repair of Hot-Dip Galvanizing.
 - c. Sprayed Zinc: Clean and preheat to assure freedom from loose material, moisture, oil grease, or other foreign matter before applying zinc. Apply zinc coating by metallizing spray to clean and dry surfaces.
 - d. Zinc-Based Solders and Wire:
 - 1) Clean to remove loose material and contaminants, and heat to approximately 572 degrees F.
 - 2) Apply zinc-alloy repair compound by spreading material over heated surface in accordance with compound manufacturer's instructions.
 - 3) Remove repair compound residues with damp cloth or by rinsing with water.
 - e. Organic cold galvanizing coating: Minimum 95 percent metallic zinc by weight in dried film.
 - 1) Approved Manufacturer: ZRC Products Company.
 - 2) Substitutions: Per 01 25 00, Substitution Procedures.
 2. Dry film thickness of applied repair materials: Not less than galvanized coating thickness required by ASTM A53/A53M, A123/A123M, or A153/A153M.

D. Welding Inspections and Tests by the Contractor:

1. Visual Inspection:
 - a. All welds shall be visually examined in accordance with AWS D1.1/D1.1M.
 - b. Quality of welds and standards of acceptance shall be in accordance with AWS D1.1/D1.1M.
2. Nondestructive Testing: Nondestructive testing shall conform to AWS B1.10M/B1.10.
3. Random Testing: Randomly test 10 percent of welds by either liquid penetrant inspection or magnetic particle inspection.
 - a. Liquid Penetrant Inspection: Liquid dye penetrant inspection of welds shall conform to ASTM E165.
 - b. Magnetic Particle Inspection: Magnetic particle inspection of welds shall conform to ASTM E709.
4. Additional Testing: If random testing reveals possible flaws, test the welds in question, and additional welds if directed by the Engineer, using ultrasonic or radiographic testing. Requirement for this additional testing shall be at no additional cost to the Owner and shall be at the sole discretion of the Engineer.
 - a. Ultrasonic Testing: Comply with AWS D1.1/D1.1M and ASTM E164, as applicable.
 - b. Radiographic Testing: Comply with AWS D1.1/D1.1M and ASTM E94 and ASTM E1032, as applicable.
5. Test Results:
 - a. Forward test result information to the Engineer immediately after test results are available, stating the acceptance or rejection of fabricated components, so that repairs and reinspection or testing may be performed as soon as possible.
6. Repairs:
 - a. Repair unacceptable welds in accordance with AWS D1.1/D1.1M.
 - b. Reinspect or retest repaired or corrected welds as specified for the original weld.

E. Shop Inspections and Tests by the Engineer:

1. Galvanizing, shop applied coatings, and welds are subject to inspections and tests by the Engineer.
2. The Engineer will make test results available to the Contractor.

PART 3 EXECUTION

3.01 SITE QUALITY CONTROL

- A. Galvanizing: After delivery of substation, inspect and repair damage to galvanizing.
 - 1. Repair field cutting of metal, welds, steel grinding, scratches and other damages, and coat masked areas, in accordance with ASTM A780/A780M.
 - 2. Dry film thickness of applied repair materials: Not less than galvanized coating thickness required by ASTM A53/A53M, A123/A123M, or A153/A153M.
- B. Shop Applied Coating: After delivery of substation, inspect and repair damage to shop applied coating.
 - 1. Repair minor film scratches and other blemishes in film surfaces in accordance with coating manufacturer's recommended procedures and materials.
 - a. Submit recommended procedures and materials.
 - b. Prepare a sample demonstrating the proposed repair procedures and materials, and subject to salt spray test per ASTM B117.
 - c. Submit the sample after testing.
 - 2. Finished repairs shall match original finish for color and gloss, shall adhere to original finish, and shall exhibit no removal of coating film or blistering during dry adhesion testing when tested in accordance with ASTM D3359.
 - 3. Remove coated items damaged beyond repair and replace with newly fabricated and coated items.
- C. Welding Inspections and Tests:
 - 1. Perform tests of field welds as specified for shop welds.
 - 2. Engineer will perform visual inspections of field welds as specified for shop welds.
- D. Field Welding: Shall be performed as specified for shop welding.

END OF SECTION 05 05 00

SECTION 09 67 25

DIELECTRIC EPOXY FLOORING

PART 1 GENERAL

1.01 SUMMARY

- A. Section Includes: Trowel-applied dielectric, epoxy-resin flooring for traction power substation floors.
- B. Related Sections:
 - 1. Section 34 21 90 – TPSS Testing

1.02 REFERENCE STANDARDS

- A. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:
- B. ASTM International (ASTM)
 - 1. ASTM D149, Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
 - 2. ASTM D695, Standard Test Method for Compressive Properties of Rigid Plastics
 - 3. ASTM D4541, Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Product Data: Include preparation and installation instructions.
- C. Installer Certificates: Signed by manufacturers certifying that installers comply with requirements.
- D. Operation and Maintenance Data:
 - 1. Submit data in accordance with Section 01 78 23, Operation and Maintenance Data, including the following requirements:
 - a. Manufacturer's cleaning and maintenance instructions.

1.04 QUALITY ASSURANCE

- A. Installer Qualifications: Engage an installer who is certified in writing by epoxy flooring manufacturer as qualified to install manufacturer's products.

B. Application Conditions:

1. Environmental Limitations: Comply with manufacturer's written instructions for substrate temperature, ambient temperature, moisture, ventilation, and other conditions affecting flooring installation.
2. Provide permanent lighting or, if permanent lighting is not in place, simulate permanent lighting conditions during flooring installation.
3. Close spaces to traffic during flooring application and for not less than 24 hours after application unless manufacturer recommends a longer period.

1.05 DELIVERY, STORAGE, AND HANDLING

- A. Deliver materials to assembly site in supplier's original wrappings and containers, labeled with source's or manufacturer's name, material or product brand name, and lot number.
- B. Store materials in their original, undamaged packages and containers, inside a well-ventilated area protected from weather, moisture, soiling, extreme temperatures, and humidity.

PART 2 PRODUCTS

2.01 PERFORMANCE REQUIREMENTS

- A. Provide flooring capable of the following when applied at 1/4-inch thickness:
 1. Dielectric service, in accordance with ASTM D149: 58,000 Vdc.
 2. Bond strength to concrete in accordance with ASTM D4541: 400 psi minimum.
 3. Abrasion Resistance: Not more than 0.5 grams loss when tested with Tabor abrader with 1000 gram load for 1000 cycles.
 4. Compressive strength per ASTM D695: 8500 psi.
- B. Performance of In-Place Flooring: Capable of withstanding testing conditions specified in 34 21 90, Traction Power Substation Testing without arcing or passing current beyond specified limit.

2.02 EPOXY-RESIN FLOORING

- A. Epoxy-Resin Flooring: Subject to compliance with requirements, provide Hallemite Dielectric Grey Amazite by RBC Industries, Inc.
 1. Thickness: 1/4 inch nominal.
 2. Color: Manufacturer's standard grey.
 3. Substitutions: Per 01 25 00 Substitution Procedures.

B. Materials:

1. Epoxy-Resin Matrix: Manufacturer's standard recommended for use indicated.
2. Aggregates: Silica sand in gradation recommended by resin manufacturer.

2.03 SHOP FABRICATION

A. Preparation:

1. Clean substrates of substances, including oil, grease, and curing compounds, that might impair flooring bond. Provide clean, dry, and neutral substrate for flooring application.
2. Rough sand metallic floors as recommended by manufacturer to insure adhesion.
3. Apply masking at stop points and at adjacent surfaces which are not to be coated, so that the flooring will finish at clean lines.

B. Epoxy-Resin Flooring Installation:

1. Apply the epoxy to the area shown on Contract Drawings.
2. Place and finish flooring according to manufacturer's written instructions.
3. Installation Tolerance: Limit variation in flooring surface from level to 1/4 inch in 10 feet; non-cumulative.
4. Where the edge joins the bare floor, taper the material from the full thickness to the height of the floor over a minimum of a 6-inch wide area.
5. Ensure that matrix components and fluids from grinding operations do not stain flooring by reacting with divider and control-joint strips.
6. Primer: Apply to flooring substrates according to manufacturer's written instructions.
7. Install epoxy floor coating to a minimum thickness of 1/4 inch as a one piece surface.
8. Where the epoxy floor covering meets a wall insulating panel, the floor covering shall completely fill gap to a minimum thickness of 1/4 inch.

2.04 SOURCE QUALITY CONTROL

- A. Inspect floor for cracks and joints. Repair in accordance with manufacturer's recommendations.
- B. Cut out and replace flooring areas that evidence lack of bond with substrate.
- C. Cut out flooring areas in panels defined by strips and replace to match adjacent flooring, or repair panels according to manufacturer's written recommendations, as approved by the Engineer.

- D. Testing: Test in accordance with Section 34 21 90, TPSS Testing. If flooring fails to provide specified level of electrical insulation, apply additional layers of epoxy until specified levels are achieved.

PART 3 EXECUTION

3.01 FIELD QUALITY CONTROL

- A. Inspection: After delivery to site, inspect floor for shipping damage.
- B. Testing: After delivery to site, test in accordance with Section 34 21 90, TPSS Testing, to ensure that floor has not been damaged during shipping.

END OF SECTION 09 67 25

SECTION 22 45 19

SELF CONTAINED EYEWASH EQUIPMENT

PART 1 GENERAL

1.01 SUMMARY

- A. Section Includes: Self-contained eyewash equipment for installation in substations.
- B. Products Furnished But Not Installed Under This Section:
 - 1. Two self-contained eyewash units, complete with solution, one for Operations and Maintenance Facility (OMF) traction power substation (TPSS) and one for King Street TPSS.

1.02 REFERENCE STANDARDS

- A. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:
- B. American National Standards Institute (ANSI)
 - 1. ANSI Z358.1, Standard for Emergency Eyewash and Shower Equipment

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Product Data:
 - 1. Eyewash station.
 - 2. Eyewash solution cartridge.
- C. Operation and Maintenance Data:
 - 1. Submit data in accordance with Section 01 78 23, Operation and Maintenance Data
 - 2. Submit manufacturer's operating and maintenance instructions on products identified above.

PART 2 PRODUCTS

2.01 MATERIALS

- A. Eyewash Stations:
 - 1. Self-contained eyewash station meeting the requirements of ANSI Z358.1 using factory-sealed cartridges of eyewash solution.

2. Eyewash stations shall be suitable for wall mounting at locations indicated on Contract Documents and incorporate a fluid reservoir for discharged solution.
- B. Eyewash Saline Assembly:
1. Factory-sealed cartridge assembly containing contaminant-free, pH-balanced saline solution with integral nozzle(s) for solution delivery in a gentle flow meeting ANSI Z358.1 requirements.
 2. Cartridge assemblies shall have a two-year shelf life from date of manufacture.

2.02 MANUFACTURER

- A. Provide eyewash station and cartridges that are products of a single manufacturer.
- B. Acceptable Manufacturer/Product: Sperian Protection Fend-All Pure Flow 1000.
 1. Substitutions: Per 01 25 00, Substitution Procedures.

2.03 ASSEMBLY

- A. Provide one eyewash station complete with eyewash fluid in each substation. (Eyewash station for built-in-place substations are furnished, only.)
- B. Install eyewash station in accordance with manufacturer instructions immediately adjacent to battery installation. Locations shall meet requirements of ANSI Z358.1.
- C. Install eyewash solution cartridge(s) in accordance with manufacturer instructions.
- D. Provide translucent 6-mil polyethylene sheeting as a secure and dust-proof, temporary cover over each completed eyewash station.

PART 3 EXECUTION

3.01 SITE QUALITY CONTROL

- A. Remove temporary cover after final commissioning of substation and verify that eyewash station is clean and ready to use.

END OF SECTION 22 45 19

SECTION 26 05 00

COMMON WORK RESULTS FOR ELECTRICAL

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. General electrical requirements and wiring devices, switches, and control relays.
2. Requirements for labeling and listing of electrical equipment and products, and for field evaluation for products not listed.
3. Utility metering.
4. Requirements of this section apply to all 26 xx xx sections, 34 21 xx sections, and 34 23 xx sections.

B. Related Sections:

1. Section 34 21 05 – Common Work Results for TPSS.

1.02 REFERENCES

A. Definitions:

1. Intelligent Electronic Device (IED): See definition in Section 34 21 05, Common Work Results for TES.
2. Authority Having Jurisdiction (AHJ): As defined in NFPA 70, Article 100, Definitions.

B. Reference Standards:

1. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:
2. ASTM International (ASTM)
 - a. ASTM D570, Standard Test Method for Water Absorption of Plastics
3. Institute of Electrical and Electronics Engineers (IEEE)
 - a. IEEE C2, National Electrical Safety Code
4. International Conference of Building Officials
 - a. International Building Code (IBC) (with amendments by the Authority Having Jurisdiction)

5. National Electrical Contractors Association
 - a. NECA 1, Standard Practices for Good Workmanship in Electrical Construction
6. National Electrical Manufacturers Association (NEMA)
 - a. NEMA WD 1, General Requirements for Wiring Devices
 - b. NEMA WD 5, Specific-Purpose Wiring Devices
 - c. NEMA 250, Enclosures for Electrical Equipment (1000 Volts Maximum)
7. National Fire Protection Association (NFPA)
 - a. NFPA 70, National Electrical Code (with amendments by the Authority Having Jurisdiction)
 - b. NFPA 130, Fixed Guideway Transit and Passenger Rail Systems
8. Underwriters Laboratories (UL)
 - a. UL 224, Extruded Insulating Tubing

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Product Data: Submit manufacturer's product data for products specified in this section.
 1. Submit evidence of conformance to referenced standards.
- C. List of Materials: Include materials and equipment proposed for use specified in this section.
 1. Give name of manufacturer, brand name, and catalog number of each item.
 2. Submit the list complete at one time, with items arranged and identified in numerical sequence by Article and Paragraph numbers.
- D. Factory Test and Inspection Certification:
 1. If factory tests and inspections for specified materials and equipment have been performed previously on identical materials or equipment, additional testing may be waived at the Engineer's discretion.
 - a. Submit certified copies of test reports for Engineer's approval.
 - b. Accompany test reports by signed statements from the manufacturer certifying that the previously tested material or equipment is physically, mechanically, and electrically identical to that proposed for the Project.

- c. Include wiring and control diagrams.
- E. Submit a request for permission to perform a Field Evaluation for equipment that is not labeled or listed.
- F. Shop Drawings:
 - 1. Submit shop drawings showing equipment layouts and fabricated work being provided under these Specifications.
 - 2. Submit such drawings before fabrication, and within ample time to prevent delays in the Work.
 - 3. Include electrical diagrams for equipment and equipment installation.
- G. Seismic Calculations: Submit sealed seismic design and bracing calculations that include equipment and raceways in each Section of these Specifications.
- H. Field Test Reports: Submit certified field test reports of field tests, verifying compliance of equipment and systems with Specification requirements.
- I. Operation and Maintenance Manuals:
 - 1. Submit operation and maintenance instructions and data for equipment provided under this Division, in accordance with the requirements of Section 01 78 23, Operation and Maintenance Data.
 - 2. Include recommended maintenance materials and spare parts list for installed equipment.

1.04 QUALITY ASSURANCE

- A. Compliance with Applicable Standards:
 - 1. Where equipment or materials are specified to conform to the standards of organizations such as ANSI, ASTM, IEEE, and NEMA, submit evidence of such conformance for review and record purposes.
 - 2. The label or listing of the specified agency will be acceptable evidence.
 - 3. Submit evidence of compliance to seismic safety requirements of the International Building Code and NFPA 70 with amendments to these codes by the Authority Having Jurisdiction.
- B. Listed and Labeled Equipment and Material:
 - 1. Provide wherever standards for these products have been established.
 - 2. Materials that are not listed or labeled require approval by Engineer before use.
 - 3. Products which have not been tested or certified for the use intended shall not be used when equivalent listed or labeled materials are available.

4. The label or listing will be acceptable as sufficient evidence that the materials and equipment do conform to the specified standards.
 5. Electrical equipment and material not listed or labeled shall be furnished with a Field Evaluation label provided by an approved Testing Laboratory, and certifying that the equipment conforms to the requirements of UL, ANSI, and other standards as required by the Authority Having Jurisdiction.
 - a. This product evaluation may be performed in the factory or on-site as approved by Engineer.
 - b. Submit to Engineer a request for permission to perform a Field Evaluation, whether in the factory or onsite.
- C. Qualifications: Workers shall be experienced in the type of work they are performing.
- D. Perform Work in compliance with the following industry standards and regulations:
1. NFPA 70, National Electrical Code (with amendments of the Authority Having Jurisdiction).
 2. NFPA 130, Standard for Fixed Guideway Transit and Passenger Rail Systems.
 3. NECA 1, Standard Practices for Good Workmanship in Electrical Construction.
 4. IEEE C2, National Electrical Safety Code.

PART 2 PRODUCTS

2.01 MATERIALS

- A. Provide materials and equipment of design, sizes, and ratings as indicated and suitable for the intended purpose.
- B. Methods of fabrication, assembly, and installation shall comply with specified standards.
- C. Provide only new products that are free from defects.

2.02 SOFTWARE

- A. Provide interface and configuration software for uploading settings to and downloading event history from intelligent electronic device (IED).
- B. Provide software that will work with each type of IED provided under a Division 26 specification section.
- C. Software shall work on a standard laptop with Microsoft Windows XP and 7 operating systems.

2.03 COMPONENTS

A. Switches:

1. Provide 120 - 277 Vac tumbler-type toggle switches conforming to minimum requirements of NEMA WD 1, heavy-duty general-use type.
2. Provide switches that operate in any position and are fully enclosed with entire body and cover of molded phenolic, urea, or melamine. Do not use fiber, paper, or similar flammable insulating material for body or cover.
3. Mounting yoke: Metal with plaster ears, insulated from the mechanism and fastened to the switch body by bolts, screws, rivets, or other substantial means.
 - a. Dimensions: Section of the yoke normally intended to bear on the surface outside the box shall have a minimum over-all dimension of 3/4 inch, measured at right angles to the longitudinal axis of the yoke.
4. Switch contacts: Silver or silver alloy.
5. Wiring: Back or side wired.
6. Terminals: Screw type or combination screw-clamp type.
7. Terminal screws: No. 8 or larger, captive or terminal type.
8. Switch Color: Gray, or as selected by Engineer.
9. Applications:
 - a. Incandescent or Fluorescent Lighting: Fully-rated 20 A at 120 V or 277 V.
 - b. Straight resistance loads: May be snap switches as specified in this section, of the proper rating up to 30 A at 120 - 277 V.
10. Testing: Capable of withstanding tests as outlined in NEMA WD 1. If requested by Engineer, submit evidence that the types of switches proposed have satisfactorily withstood these tests.

B. Receptacles:

1. Receptacle Standards: NEMA WD 1, heavy-duty general-use type.
2. Convenience Receptacles:
 - a. Bodies and Bases: Fire-resistant, nonabsorptive, hot-molded phenolic.
 - b. Plaster ears: Metal, integral with supporting member.
 - c. Receptacle Color: Ivory, or as selected by Engineer.

- d. Configuration: 20R, single- or duplex-type as indicated.
 - e. Wiring: Back or side wired.
 - f. Terminals: Screw type or combination screw-clamp type.
 - g. Contacts: Double-grip bronze type with spring steel backup clips so that both sides of each male prong of the plug will be in firm contact. Applies also to grounding contact.
- 3. Locking-blade Receptacles: NEMA WD 5.
 - 4. GFCI Receptacles: Duplex receptacles, 120 V, 60 Hz, 20 A with built-in test, reset buttons, and ground fault tripped indication.
 - a. Trip: Interrupt the circuit within 1/30 second on a 5 milliampere earth leakage current.
 - b. Use GFCIs designed for end of run installation or with provisions for feeding through to protect other outlets on the circuit.
- C. Cover Plates:
- 1. Provide multi-gang plates where required. Segmented cover plates are not acceptable.
 - 2. Device covers: Raised, galvanized steel.
 - 3. Weatherproof cover plates: Die-cast, copper-free aluminum listed for wet locations with self-closing spring door and rubber gasket. Provide rain cover where required or as indicated.
- D. Individual Control Relays: Provide convertible contacts rated a minimum of 10 A, 600 V unless otherwise indicated.
- 1. Verify coil voltage, and number and type of contacts.
 - 2. Provide NEMA 250 Type 1 enclosures.

2.04 IDENTIFICATION

- A. Wire and cable tags:
- 1. Sleeves: Non-fading, heat-shrink plastic, machine-printed sleeve labels.
 - a. Approved Manufacturer/Product: Brady HEATEX™ labels.
 - 1) Substitutions: Per 01 25 00, Substitution Procedures.
 - b. Material: Polyolefin heat shrinkable tubing.

- c. Standards: UL 224 and ASTM D570.
 - d. Print: Cable destination and number of conductors in cable as described in Contract Drawings.
2. Cable Tags: Non-fading, plastic, printed cable tags with holes for attachment to cable with plastic cable ties.
- a. Approved Manufacturer/Product: Almeter Industries Inc., plastic slide in cable tags. Numbers shall be 1.5 inches long.
 - 1) Substitutions: Per 01 25 00, Substitution Procedures.
 - b. Affix cable tags with plastic tie wraps.
- B. Conduit Identification Labels: Laminated, machine-printed labels with high-strength adhesive, black letters on yellow background.
- 1. 2-inch and smaller conduits: 3/4-inch wide
 - 2. 2-1/2-inch and larger conduits: 1-inch wide labels.
 - 3. Approved Manufacturer/Product: Brother TZ-series tape.
 - 1) Substitutions: Per 01 25 00, Substitution Procedures.
 - 4. Use label printer compatible with chosen tape.
- C. Nameplates: See Specification Section 34 21 05, Common Work Results for TPSS.

2.05 UTILITY METERING

- A. Provide EUSERC compliant metering meeting the requirements of Seattle City Light (SCL), where indicated on Contract Drawings.

2.06 ASSEMBLY

- A. General Requirements:
 - 1. Install products in accordance with product listings, manufacturer's recommendations, relevant codes and regulations, and standard industry practice for electrical installations.
 - 2. Install electrical materials, equipment, appurtenances, and accessories in locations as indicated and in accordance with NECA 1.
 - 3. Install supporting members, fastenings, framing, hangers, bracing, brackets, straps, bolts, and angles as required to set and connect the Work rigidly.
 - 4. Control erection tolerance requirements so as to not impair the strength, safety, serviceability, or appearance of the installations.

5. Seal equipment enclosures against dust, whenever dusty conditions are present inside the rooms or outside, during the construction period.
- B. Complete installation: Contract Drawings show electrical equipment diagrammatically and do not show all accessories or fittings that may be required. Provide complete and operable electrical systems and installations in conformance with these Specifications.
- C. Anchoring and Support:
1. Do not weld electrical materials for attachment or support.
 2. Provide anchor bolts and anchorage items as required, and field check to ensure proper alignment and location.
 3. Provide templates and layout drawings to ensure correct placing of anchorage items in concrete.
- D. Wiring:
1. Provide wiring systems complete as indicated and required for proper service.
 2. Provide ample slack wire for motor loops, service connections, and extensions.
- E. Wiring Devices and Cover Plates:
1. Install switches, receptacles, special purpose outlets, and cover plates complete in accordance with NECA 1, NFPA 70, and local electrical codes.
 2. Locate wiring devices at heights in accordance with NECA 1, except as otherwise indicated.
 3. For exterior and damp locations, mount receptacles in watertight cast metal outlet boxes with threaded hubs or bosses and provide with weatherproof cover plate.
 4. Provide GFCI duplex receptacles where indicated.
 5. Provide a cover plate for each switch, receptacle, and special purpose outlet.
- F. Installation in Vicinity of Rectifier and Dc Distribution Equipment:
1. Within 6 feet of dc rectifier, dc switchgear, and dc distribution equipment, provide non-metallic raceways, boxes, covers, equipment, and supports.
 2. Alternatively, provide substantial insulating barriers to prevent simultaneous contact with dc equipment enclosures and adjacent metal surfaces.
- G. Torquing:
1. Torque bolted connections in accordance with manufacturer's recommendations.

2. Use a torque wrench calibrated within the past 12 months and bearing a calibration sticker.
3. Torque busses and bus connections per manufacturer's recommendations or according to the following table.

Silicon Bronze Bolt Standard Dry Torque		
Bolt Size Inches	Threads/ inch	Inch Pounds
1/4	20	68.8
	28	87
5/16	18	123
	24	131
3/8	16	219
	24	240
7/16	14	349
	20	371
1/2	13	480
	20	502
9/16	12	632
	18	697
5/8	11	1030
	18	1154
3/4	10	1416
	16	1382

4. Torque cable connections per manufacturer's recommendations, or according to the following table.

Steel Bolt Standard Dry Torque in Foot Pounds							
		SAE Grade					
Bolt Size Inches	Course thread/ inch	0-1-2	3	5	6	7	8
1/4	20	6	9	10	12.5	13	14
5/16	18	12	17	19	24	25	29
3/8	16	20	30	33	43	44	47
7/16	14	32	47	54	69	71	78
1/2	13	47	69	78	106	110	119
9/16	12	69	103	114	150	154	169
5/8	11	96	145	154	209	215	230
3/4	10	155	234	257	350	360	380

5. Apply torque mark after torquing connection.

2.07 SEISMIC DESIGN AND BRACING

- A. Equipment provided under this Contract shall meet seismic requirements specified in the International Building Code (IBC) with modifications by the Authority Having Jurisdiction.
- B. Provide suitable bracing and anchorage and submit calculations performed and sealed by a structural engineer registered in the State of Washington.

PART 3 EXECUTION

3.01 INTERFACE WITH OTHER WORK

- A. Coordinate with Work by other contractors.
- B. Make indicated connections to previously completed work.

END OF SECTION 26 05 00

SECTION 26 05 19

LOW-VOLTAGE CONDUCTORS AND CABLE

PART 1 GENERAL

1.01 SUMMARY

- A. Section Includes:
 - 1. Low-voltage wire and cable.
 - 2. Dc traction power cable.
 - 3. Wiring connections, splices, and terminations.
- B. Related Sections:
 - 1. Section 26 05 00 – Common Work Results for Electrical
 - 2. Section 26 05 29 – Hangers and Supports for Electrical Systems

1.02 REFERENCES

- A. Definitions:
 - 1. Low-voltage cable: A single or multi-conductor insulated cable rated 2000 V or less.
- B. Reference Standards:
 - 1. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:
 - 2. Association of American Railroads (AAR)
 - a. AAR RP-585, Wiring and Cable Specification
 - 3. ASTM International (ASTM)
 - a. ASTM B3, Specification for Soft or Annealed Copper Wire
 - b. ASTM B8, Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft
 - c. ASTM B33, Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes
 - d. ASTM B172, Standard Specification for Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors

- e. ASTM B496, Standard Specification for Compact Round Concentric-Lay-Stranded Copper Conductors
 - f. ASTM D747, Standard Test Method for Apparent Bending Modulus of Plastics by Means of a Cantilever Beam
 - g. ASTM D1000, Test Methods for Pressure-Sensitive Adhesive-Coated Tapes Used for Electrical and Electronic Applications
 - h. ASTM D3005, Specification for Low-Temperature Resistant Vinyl Chloride Plastic Pressure-Sensitive Electrical Insulating Tape
4. Institute of Electrical and Electronics Engineers (IEEE)
 - a. IEEE 383, Standard for Qualifying Class 1E Electric Cables and Field Splices for Nuclear Power Generating Stations
 5. International Cable Engineering Association (ICEA)
 - a. ICEA S-95-658/NEMA WC 70, Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy
 6. InterNational Electrical Testing Association, (NETA)
 - a. ANSI/NETA ATS, Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems
 7. National Electrical Contractors Association
 - a. NECA 1, Standard Practices for Good Workmanship in Electrical Contracting
 8. National Fire Protection Association
 - a. NFPA 70, National Electrical Code (with amendments by the Authority Having Jurisdiction)
 9. Underwriter's Laboratories (UL)
 - a. UL 44, Thermoset-Insulated Wires and Cables
 - b. UL 1277, Electrical Power and Control Tray Cables with Optional Optical-Fiber Member
 - c. UL 1581, Reference Standard for Electrical Wires, Cables, and Flexible Cords
 - d. UL 2196, Tests for Fire Resistive Cables

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.

- B. Submit Product Data on the following items:
1. Single-conductor wire and cable of each type.
 2. Multi-conductor cable of each type.
 3. Terminating materials.
- C. Product information for each type and size of wire and cable shall include the following:
1. Manufacturer of wire and cable, and certificate of compliance.
 2. Number and size of strands composing each conductor.
 3. Conductor insulation composition and thickness.
 4. Average overall diameter of finished wire and cable.
 5. Minimum insulation resistance in megohms per 1000 feet at 30 degrees C ambient.
 6. Jacket composition and thickness in mils.
 7. Total number of conductors per cable.
 8. Shield material (if any) and thickness.
 9. Conductor resistance and reactance in ohms per 1000 feet at 25 degrees C ambient.
 10. Conductor ampacity at 30 degrees C ambient for 600 V wire and cable.
- D. Submit Test Procedures and Test Reports:
1. Certified test reports for Production Tests, Final Tests, and Flame Tests.
 2. Test procedures, including details of proposed test equipment.
 3. Field Test Report, including the following:
 - a. Continuity test.
 - b. Phase test for three-phase circuits.
 - c. Insulation resistance test.
 - d. Cable insulation test for dc feeder cables.
- E. As-built Drawings:
1. Submit as specified in Section 01 78 39, Project Record Documents.

2. Show splices in low-voltage cable, where permitted by Engineer, on as-built drawings.

1.04 QUALITY ASSURANCE

- A. Qualifications: Cable manufacturer shall have a minimum of five years experience successfully manufacturing the type of cable to be supplied by that manufacturer.

1.05 DELIVERY, STORAGE, AND HANDLING

- A. Ship each unit securely wrapped, packaged, and labeled for safe handling in shipment and to avoid damage.
- B. Deliver wire and cable to the site in unbroken standard coils or reels with attached tag bearing manufacturer's name, wire trade name, and listing information.
- C. Store wire and cable in secure and dry storage facility, in accordance with NECA 1.

PART 2 PRODUCTS

2.01 GENERAL REQUIREMENTS

- A. Wire and Cable Marking: Verify that wire and cable markings comply with applicable NEMA and NFPA 70 requirements.

2.02 600 V SINGLE CONDUCTOR CABLE

- A. Conductor Material: ICEA stranded or solid copper meeting requirements of ASTM B3, soft drawn.
- B. Conductor Type:
 1. Size 12 AWG and Smaller: Solid conductor.
 2. Size 10 AWG and Larger: Class B stranded.
- C. Insulation:
 1. Size 14 to 1/0 AWG: Type XHHW-2, cross-linked polyethylene insulated in accordance with ICEA S-95-658/NEMA WC 70.
 2. Size 2/0 AWG and Larger: Type XHHW-2, cross-linked polyethylene insulated in accordance with ICEA S-95-658/NEMA WC 70 or type RHH/RHW, ethylene-propylene-rubber-insulated in accordance with ICEA S-95-658/NEMA WC 70.
 3. Voltage Rating: 600 V.
 4. Temperature Rating: Insulation temperature rating not less than 90 degrees C in wet or dry locations.

D. Fire Ratings:

1. Fire-Retardant Properties: Ensure that power cable for emergency related equipment; and emergency lighting cables have flame propagating criteria of IEEE 383 and have a minimum circuit time of five minutes in the flame test of IEEE 383.
2. Fire-Rated Cables: Where required by NFPA 70, provide fire-rated cables meeting the requirements of UL 2196. Provide a complete conduit and cable system meeting the two-hour survivability requirement including junction boxes, conduit and splice/tap connections.
 - a. Approved Manufacturer/Product: Tyco Thermal Controls, Raychem RHW.
 - b. Substitutions: Per 01 25 00, Substitution Procedures.

2.03 600 V SWITCHBOARD WIRE

- A. Conductor: Stranded, tinned, annealed copper per ASTM B33.
- B. Insulation: Thermoset, chemically cross-linked polyethylene, UL Type SIS, 90 degrees C. Flame rated per UL 1581, Vertical Flame (VW-1).

2.04 2000 V SWITCHBOARD WIRE

- A. Conductor: Annealed, tinned flexible-stranded copper per ASTM B33, ASTM B172, and AAR RP-585.
- B. Insulation: Flame-retardant, crosslinked polyolefin, rated 2000 V, 110 C, 45 mil minimum thickness.
- C. Approved Manufacturer/Product: Rockbestos Exane-1068A.
 1. Substitutions: Per 01 25 00, Substitution Procedures.

2.05 2 KV SINGLE-CONDUCTOR DC FEEDER CABLE

- A. General:
 1. Type RHW-2, 90 degrees C, unshielded, size as indicated.
 2. Insulation and jacket system shall be rated for application up to 2000 V.
 3. Cable shall be suitable for use on service and feeders, indoors or outdoors, in wet or dry locations, or in raceway/duct. Cable shall be sunlight resistant and suitable for installation at 0 degrees C and in cable tray.
 4. Cables shall meet or exceed the requirements of ICEA S-95-658/NEMA WC 70, UL 44, and UL 1581.
- B. Conductors: Annealed, uncoated copper, round or compact, concentric-lay stranded per ASTM B496.

- C. Insulation: Ethylene-propylene rubber (EPR) meeting electrical and physical requirements of ICEA S-95-658/NEMA WC 70.
 - 1. No polyethylene shall be allowed as a component of the insulation and EPR insulation shall be compounded by the cable manufacturer.
 - 2. For flexibility, the insulation compound shall have an Apparent Bending Modulus of 2600 psi or less in accordance with Standard Test Method ASTM D747.
- D. Overall Sheath Jacket: Thermosetting chlorinated polyethylene unless noted otherwise.
- E. Approved Manufacturer/Product: The Okonite Company, Okoguard-Okolon TS-CPE.
 - 1. Substitutions: Per 01 25 00, Substitution Procedures.

2.06 MULTI-CONDUCTOR, LOW-VOLTAGE CABLE

- A. Provide multi-conductor cable conforming to ICEA S-95-658/NEMA WC 70, approved for use in cable tray, with the following additional requirements:
 - 1. Conductors: Bare, soft annealed copper per ASTM B33, Class B stranded in accordance with ASTM B8. Quantity of conductors as indicated.
 - 2. Insulation: As specified above for single conductor cable.
 - 3. Overall Covering: Cable shall be provided with sunlight-resistant jacket over the insulation meeting the flame-spread requirements of UL 1277.
 - 4. Multiple conductors for control wire shall be minimum of 14 AWG stranded copper.
 - 5. Insulation Rating: 600 V.
- B. Multi-conductor cable shall be made by assembling individual or twisted pairs of insulated conductors into a tight cylindrical form using fillers that are compatible with other materials in the cable. The jacket used shall fit tightly to form a firm assembly.
- C. Fire-Rated Multi-Conductor Cables: Comply with UL 2196. Provide a complete cable and support system meeting the two-hour survivability requirement including junction boxes, raceway, connectors and splice/tap connections.
 - 1. Approved Manufacturer/Product: Tyco Thermal Controls, Raychem MC.
 - 2. Substitutions: Per 01 25 00, Substitution Procedures.

2.07 FIXTURE WIRE

- A. Provide fixture wire conforming to the following requirements:
 - 1. Type: SF-2 silicone rubber insulated.
 - 2. Conductor: Stranded copper conductor 16 AWG or larger as indicated.

2.08 BARE CONDUCTOR

- A. ASTM B3, Class B stranded, annealed soft-drawn copper conductor unless otherwise indicated. Size as indicated. Use bare conductor for ground wire only.

2.09 COLOR CODING OF CONDUCTORS (600 V)

- A. Identify individual conductors of multi-conductor cables by means of solid colors, stripes, or printing, unless otherwise approved by Engineer.
- B. Jacket Printing: Cables shall have printing on the jacket or a printed marker tape under the jacket. Jacket printing shall appear at intervals of not more than 30 inches and shall include, but not be limited to the following:
 - 1. Number of conductors.
 - 2. Conductor size.
 - 3. Voltage rating.
 - 4. Name of manufacturer.
 - 5. Manufacturer's type.
 - 6. Date of manufacture.
- C. Footage Marker Tape: Provide cables with a footage marker tape under the jacket or hot-foil footage printing on the jacket.
- D. Ac Power Cables: Conform to the following color coding for power cables:

<u>Conductor</u>	<u>480Y/277 V</u>	<u>208Y/120 V</u>
Phase A	Brown	Black
Phase B	Orange	Red
Phase C	Yellow	Blue
Neutral	White	White
Ground	Green	Green

- E. Use solid color insulation or solid color coating for branch circuit phase conductors No. 10 AWG and smaller and neutral and equipment ground conductors.
- F. Use a background color other than white or green for phase conductors with colored tracers.

2.10 TERMINAL CONNECTORS

- A. Provide termination fittings listed for use with cable furnished, NEMA standard.
- B. No. 10 AWG and smaller conductors: Heavy duty, ring type, nylon insulated.
- C. No. 8 AWG and larger conductors: Tool-applied compression connectors of material and design compatible with conductors on which used.

- D. No. 4/0 AWG and larger conductors: Long-barrel, double-compression type, with two NEMA standard bolt holes in tongue unless otherwise indicated.
- E. Compression Tools: Shall apply a hexagonal compression using mechanical, electrical, or hydraulic power mechanism that ensures a complete compression cycle.

2.11 INSULATING MATERIAL FOR TERMINATIONS

- A. Provide insulating material for terminations of type accepted by Engineer for the particular use, location, and voltage.
- B. Electrical insulating tape for general use: Vinyl plastic with rubber based pressure sensitive adhesive, pliable from temperatures of minus 18 degrees C to 105 degrees C. Verify tape has the following minimum properties when tested in accordance with ASTM D3005:
 - 1. Thickness: 7 mils.
 - 2. Breaking Strength: 15 pounds per inch.
 - 3. Elongation: 200 percent.
 - 4. Dielectric Strength: 10 kV/mil.
 - 5. Insulation Resistance (Direct method of electrolytic corrosion): 10 megohms.
- C. Rubber electrical insulating tape for protective overwrapping: Silicone rubber with a silicone pressure-sensitive adhesive. Verify tape has the following minimum properties when tested in accordance with ASTM D1000:
 - 1. Elongation: 525 percent.
 - 2. Dielectric Strength: 13 kV.
 - 3. Insulation Resistance (Indirect Method of Electrolytic Corrosion): 10 megohms.
- D. Arc-proof tape: 3M, Type 77 Fire and Electric Arc Proofing Tape, or approved equal.
 - 1. Tape shall be self extinguishing and shall be compatible with conductor insulation and jacket.
 - 2. Tape shall not deteriorate when subjected to water, salt water, gases, or sewage.
 - 3. Substitutions: Per 01 25 00, Substitution Procedures.
- E. Mark each tape package to indicate shelf-life expiration date.

2.12 INSULATED CABLE CLAMPS

- A. Thermoplastic elastomer, high-dielectric split-sleeve cable bushing and two-piece, galvanized or stainless-steel clamp assembly for installation on hot-dip galvanized framing channel.
 - 1. Approved Manufacturer/Product: B-Line, Insulclamp.
 - 2. Substitutions: Per 01 25 00, Substitution Procedures.
- B. See Section 26 05 29, Hangers and Supports for Electrical Systems, for framing channel requirements.

2.13 CABLE TIES (TIE WRAPS)

- A. Self-extinguishing nylon with a temperature range of minus 40 degrees F to 185 degrees F.
- B. Cable ties shall have a locking hub or head with a stainless steel locking barb on one end and a taper on the other end.
- C. Width:
 - 1. Adequate to prevent damage to wire or cable insulation.
 - 2. For traction power cables, minimum 1/2 inch.
- D. Outdoor use: Ultraviolet-resistant material.

2.14 IDENTIFICATION

- A. Identify conductors and cables at all terminal points and duct entrances at junction boxes, switches, circuit breakers, and pullboxes with tags specified in Section 26 05 00, Common Work Results for Electrical.
- B. Engineer will furnish cable numbering system.

2.15 TEST INSTRUMENTS

- A. Electrical Megohmmeter for Insulation Testing.
 - 1. 1000 Vdc output voltage suitable for resistance measurement from 500 kilohm to 500,000 megohms. Use a megohmmeter with an internal bleeder resistor for discharge.
 - 2. Approved Manufacturer: Hipotronics.
 - 3. Substitutions: Per 01 25 00, Substitution Procedures.
- B. High-Potential Test Set:
 - 1. Portable high-potential dc test set, 0 to 130 kVdc, 10 mA with regulated output.

2. Internal shorting solenoid and discharge resistor.
3. Full-scale accuracy: 2 percent.
4. Capable of measuring cable insulation resistance up to 5,000,000 megohms.
5. Approved Manufacturer: Hipotronics.
6. Substitutions: Per 01 25 00, Substitution Procedures.

2.16 ASSEMBLY

A. Wire and cable type requirements

1. Substation power circuits, ac and dc: 600 V single conductor cable.
2. Within switchgear, where not exposed to medium voltage: 600 V switchboard wire.
3. Within dc switchgear and rectifier: 2000 V switchboard wire.
4. Dc feeders: Single conductor power cable, 2 kV rated.
5. Cable sizes up to 4/0 AWG in cable tray: Multi-conductor cable.
6. Where required by NFPA 70, provide fire-rated multi-conductor cables.
7. Use bare conductor for ground wire only.

B. Circuit Separation

1. Physically separate conductors and cables on circuits of different voltages or systems to reduce the possibility of unsafe conditions, interference, or equipment damage.
2. The following major circuit groups shall not be harnessed or bundled together, shall not run in the same conduit and shall be physically separated and secured in vaults, enclosures, and cable trays.
 - a. Medium-voltage ac circuits.
 - b. Low-voltage ac circuits.
 - c. Low-voltage dc circuits: 600 V rated.
 - d. Low-voltage dc circuits: 2000 V rated.
 - e. Dc control circuits.
 - f. Dc traction power positive feeders.
 - g. Dc traction power negative feeders.

- C. Install wires and cables in accordance with manufacturer's recommendations and restrictions.
- D. Do not bend cables during installation, either permanently or temporarily, to radii less than 12 times the outer diameters, except where conditions make the specified radius impractical and shorter radii are permitted by the manufacturer.
- E. Bundle cable and conductors neatly and securely with cable ties in branch circuit panelboards, cabinets and control boards. Bundle power cables separately from control cables.
- F. Motors:
 - 1. Install motor feeders, service connections, and extensions in accordance with the referenced codes.
 - 2. Install motor feeder in liquid-tight flexible conduit of 18-inches minimum length at motor conduit box.
- G. Install wire and cable in conduit as indicated and in accordance with NECA 1.
- H. Terminations:
 - 1. Use continuous lengths of wire and cable between power source and equipment. Splices are not permitted.
 - 2. Tools:
 - a. Use terminator installation tools and installation techniques recommended by the manufacturer.
 - b. Conductor sizes through No. 6 AWG: Mechanical hand tools may be used, with dies for each conductor size as recommended by the manufacturer.
 - c. Conductor sizes larger than No. 6 AWG: Use hydraulic tools with hexagonal or circumferential dies as recommended by the manufacturer.
 - d. Use compression tools which permanently imprint die information on the completed connection.
 - 3. Control and Switchboard Wires: Terminate each wire held with screw-type terminals using an insulated sleeve (nylon), ring-tongue-type or locking spade-type, crimp-on lugs.
- I. Wiring Within Enclosures:
 - 1. Requirements below apply to all electrical equipment enclosures, including junction boxes.

2. General:
 - a. Install wire as continuous lengths inside substations, without splices between terminations.
 - b. Wiring entering a removable enclosure shall be harnessed and secured to facilitate removal.
 - c. Wires from different wire runs shall not be harnessed together or with internal wiring.
3. Wire support:
 - a. Attach wiring within enclosures to conductor supports rigidly fastened to the enclosure structure.
 - b. Wiring supports shall be free from edges, bolt heads, or similar areas and shall not interfere with nor contact enclosure covers.
 - c. Secure wiring such that there is no strain on wire terminals, multi-pin connector pins, or other wire termination hardware.
 - d. Use of adhesive wire supports is not permitted.
4. Wire dress:
 - a. Allow sufficient slack at terminals to accommodate vibration, equipment shifting, cover removal, and component replacement.
 - b. Provide additional wire length for re-termination of wires without excess tension or splicing as follows:
 - 1) No. 10 and smaller: Three re-terminations.
 - 2) No. 8 and larger: Two re-terminations.
5. Terminal blocks: Provide with insulated covers.
6. Cubicle doors: Protect wires at hinges.

2.17 SOURCE QUALITY CONTROL

- A. Inspect wire and cable for physical damage and proper connections.
- B. Wire and Cable Testing:
 1. Test after terminations are complete. Do not connect equipment to wire and cable systems during tests.
 2. Perform continuity test on power and equipment branch circuit conductors.

3. Verify phasing for circuits to three-phase loads.
4. Perform wire and cable insulation resistance tests:
 - a. Measure insulation resistance with a 1000 Vdc megohmmeter.
 - b. Measure insulation resistance between conductor and ground.
 - c. Test cables after terminations are complete. Do not connect equipment to the cable system during tests.
 - d. Acceptance Criteria for 600 V wire and cable: 10 Megohms for 1,000 feet when measured at 25 C.
 - e. Test Failure: If insulation resistance values are unacceptable, correct deficiency and retest. If the test fails again, replace the entire wire or cable segment.

PART 3 EXECUTION

3.01 FIELD QUALITY CONTROL

- A. Wire and Cable Testing:
 1. Retest wire and cable after delivery of substation.
 2. Perform tests in accordance with NETA Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems.
 3. Wire and Cable Insulation Resistance Tests:
 - a. Measure insulation resistance with a 1000 Vdc megohmmeter. Insulation resistance measurement may be made with the dc high-potential test set if equipment is suitable for that purpose.
 - b. Measure insulation resistance between conductor and ground.
 - c. Disconnect equipment from the cable system during tests.

END OF SECTION 26 05 19

SECTION 26 05 26
GROUNDING AND BONDING

PART 1 GENERAL

1.01 SUMMARY

- A. Section Includes:
 - 1. Power system grounding, electrical equipment grounding, and raceway grounding.
 - 2. Requirements for substation ground bus.
- B. Related Sections:
 - 1. Section 26 05 19 – Low-Voltage Conductors and Cable
 - 2. Section 34 21 16 – TPSS Enclosures

1.02 REFERENCE STANDARDS

- A. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:
- B. ASTM International (ASTM)
 - 1. ASTM B3, Specification for Soft or Annealed Copper Wire
 - 2. ASTM B187, Specification for Copper Bar, Bus Bar, Rod and Shapes
- C. National Fire Protection Association (NFPA)
 - 1. NFPA 70, National Electrical Code (with amendments by the Authority Having Jurisdiction)

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Product Data: Specified materials.
- C. Substation interior perimeter ground bus drawings:
 - 1. Provide plan view showing perimeter ground bus, equipment, and ground connections.
 - 2. Provide elevations of each wall showing height of perimeter ground bus and connections to equipment.

1.04 QUALITY ASSURANCE

- A. Regulatory Requirements:
 - 1. Unless otherwise specified, electrical equipment and material shall be listed and labeled for the purpose for which it is used, by the Underwriters Laboratories, Inc. (UL).
 - 2. All installations shall be in accordance with NFPA 70.

1.05 DELIVERY, STORAGE, AND HANDLING

- A. Ship each item of equipment and materials securely wrapped, packaged, and labeled for safe handling in shipment and to avoid damage.
- B. Store equipment and materials in secure and dry storage facility.

PART 2 PRODUCTS

2.01 EQUIPMENT AND MATERIALS

- A. Bare Conductors: ASTM B3, Class B stranded, annealed copper conductor, unless otherwise indicated, size as indicated.
- B. Single Conductor Insulated Wire: Refer to Section 26 05 19, Low-Voltage Conductors and Cables.
- C. Bus Bar: ASTM B187, 98 percent conductivity copper, size as indicated.
 - 1. Substation Ground bus: 1/4-inch thick, silver plated. See below for width.
- D. Terminal Lugs: Exothermically-welded or compression-type approved for the application.
- E. Jumpers: Tin-plated copper, braided, flexible jumper.
- F. Compression Connections: Connectors and compression tools of a single manufacturer. Connectors shall have an inspection port for use in checking proper conductor insertion.
- G. Compression Tools: For field quality control, compression tools shall not release before completion of the compression cycle and shall emboss the die index number into the connector as the crimp is completed.
- H. Bolted connectors: Burndy, or approved equal.

2.02 ASSEMBLY

- A. Raceway Ground:
 - 1. Assemble metallic conduits to provide a continuous ground path.
 - a. Bond metallic conduits using insulated grounding bushings.

- b. Connect grounding bushings to the grounding system using conductors sized to comply with NFPA 70.
 2. Equipment Ground: In metallic and nonmetallic conduits where conductors are installed, provide a separate equipment grounding conductor, sized to comply with NFPA 70, Article 250, and installed in accordance with these Specifications.
- B. Equipment and Enclosure Grounds:
 1. Connect electrical and distribution equipment to the grounding system. Size cables or bus as specified.
 2. Connect non-electrical equipment with metallic enclosures to the grounding system.
 3. Bond boxes to the raceway or conduit system with a copper jumper solidly bolted to the box, sized to comply with NFPA 70.
- C. Equipment Grounding Requirements:
 1. Install a copper equipment grounding conductor in each raceway and bond to metallic raceways and boxes at access and pull points.
 2. Size equipment grounding conductors in accordance with NFPA 70 to provide adequate conduction path for ground faults. Increase size as required to allow for circuit voltage drop.
 3. Ground metallic raceways, boxes, cabinets, exposed expansion joints, lighting fixtures, motors, transformers and receptacles. Provide grounding bushings or compression connectors attached with machine screws for bonding.
- D. Substation Interior Perimeter Ground Bus:
 1. Provide 2-inch ground bus around entire perimeter of substation interior.
 - a. Mount on stand-off insulators.
 - b. Install at 18 inches above finished floor where there are no obstructions, and up to 8 feet above finished floor to avoid equipment or doorways.
 2. Provide 1-inch ground bus from ac switchgear, ac surge arresters, panelboards, and other electrical equipment to perimeter ground bus.
 3. Connect interior perimeter ground bus to four substation enclosure exterior grounding pads specified in Section 34 21 16, TPSS Enclosures.

PART 3 EXECUTION

Not Used.

END OF SECTION 26 05 26

SECTION 26 05 29

HANGERS AND SUPPORTS FOR ELECTRICAL SYSTEMS

PART 1 GENERAL

1.01 SUMMARY

- A. Section Includes: Raceway and equipment supports.
- B. Related Sections:
 - 1. Section 26 05 33 – Raceways and Boxes

1.02 REFERENCE STANDARDS

- A. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:
- B. ASTM International (ASTM)
 - 1. ASTM A123/A123M, Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Product Data:
 - 1. Submit for each type of material specified.
 - 2. Indicate the name of manufacturer, brand name, and catalog number for each type of material.

PART 2 PRODUCTS

2.01 RACEWAY SUPPORTS

- A. Conduit clamps for individual conduit supports shall be one hole, galvanized heavy-gage steel, or galvanized malleable iron with clamp back.
- B. Channels, fittings and conduit racks shall be as specified in this Section.
- C. Straps and clamps shall be listed for the task.

2.02 FRAMING CHANNEL AND FITTINGS

- A. Hanger rods shall be galvanized steel or electro-galvanized and zinc chromate coated steel, 3/8-inch minimum.

- B. Channels and channel fittings, clamps and accessories shall be hot-dip galvanized, or electro-galvanized and zinc chromate coated steel.
- C. Channels shall be 14-gage minimum, 13/16 inch or 1-5/8 inch-deep by 1-5/8 inch-wide minimum.
- D. Where heavy-duty racks are called out, channel shall be 12 gage single or double 1-5/8 inch deep by 1-5/8 inch wide.
- E. Prohibited: Aluminum, or light gage or strength metals or materials shall not be used.
- F. Approved Manufacturers: Unistrut, Powerstrut, Beeline, Steel City.
 - 1. Substitutions: Per 01 25 00, Substitution Procedures.

2.03 ANCHORS

- A. Anchor Rating: Sufficient strength to support four times the load.
- B. For metal, use machine screws, bolts, or welded studs with nuts and lockwashers.
- C. Prohibited: Powder driven anchors or studs shall not be used.

2.04 FASTENERS AND HARDWARE

- A. Fasteners and hardware shall be suitable for the use and environment intended.
 - 1. Fasteners shall be corrosion resistant.
 - 2. Plated steel fasteners: Use only indoors, in dry locations.
 - 3. Prohibited: Unplated steel shall not be used.
- B. Stainless steel fasteners shall be used in splice boxes where exposed to weather, or in damp or wet locations.
- C. Bolted connections shall be made using lock washers.

2.05 CORROSION CONTROL

- A. Material and equipment shall be designed to ensure satisfactory operation and life in the environmental conditions that exist where the material or equipment is installed.
- B. Wherever "galvanized" or "hot-dip galvanized" is called out in this Section of the Specification, the material shall be coated in accordance with ASTM A123/A123M.
- C. Galvanneal finish is an acceptable alternative to hot-dip galvanizing of sheet or structural steel if cut edges are protected from corrosion.

- D. Organic cold galvanizing coating: Minimum 95 percent metallic zinc by weight in dried film.
 - 1. Approved Manufacturer: ZRC Products Company.
 - 2. Substitutions: Per 01 25 00, Substitution Procedures.

2.06 ASSEMBLY

A. Conduit Supports and Racks:

- 1. Load Rating: Conduit supports shall be capable of supporting a load equal to the sum of the weights of the conduit, wire, and the hanger itself, plus 200 pounds.
- 2. Spare capacity: Minimum 25 percent.
- 3. Multiple runs of exposed conduit: Group and support on conduit racks constructed from steel channels, conduit clamps and fittings.
- 4. Vertical conduit racks: Provide supplementary bolted stop-blocks below each conduit clamp in a vertical strut to assure that clamps cannot slide down the channel.
- 5. Multiple Conduits 2-inch or Larger: Support with heavy-duty channel, clamps and accessories.
- 6. Individual Horizontal Conduits 2-inch or Larger: Support with individual hangers.
- 7. Conduits 1-1/2 inch or smaller: Support with one-hole conduit straps with back spacers or individual conduit racks.
- 8. Insulated: When conduit is within 18 inches above rectifier and dc switchgear, support with insulated materials.
- 9. Make fittings up tight to prohibit movement, unless longitudinal movement is required due to conduit expansion.

B. Cable Tray Supports:

- 1. Support in accordance with Section 26 05 33, Raceways and Boxes, using steel channels, threaded rods and hardware.
- 2. Insulate cable tray supports where cable tray runs over rectifiers and dc switchgear and supports are within 18 inches of rectifier or dc switchgear.

C. Fasteners and Hardware:

- 1. The material, coating and finish of fasteners and hardware shall be suitable for the environment and use intended.
- 2. If fasteners or hardware exhibit corrosion, replace with a suitable type as directed by Engineer at no additional cost to the Owner.

D. Damage Touch Up

1. Apply to galvanized surfaces where required due to cutting of hanger rods or channel, or construction damage.
2. Brush on a thick coat of cold galvanizing coating to cut ends. Coating may be sprayed on if at least three coats are applied.

PART 3 EXECUTION

Not Used

END OF SECTION 26 05 29

SECTION 26 05 33
RACEWAY AND BOXES

PART 1 GENERAL

1.01 SUMMARY

- A. Section Includes: Electrical conduit, ducts, cable tray; outlet, junction and pull boxes; and electrical and communications distribution cabinets.
- B. Related Sections:
 - 1. Section 26 05 00 – Common Work Results for Electrical
 - 2. Section 26 05 26 – Grounding and Bonding
 - 3. Section 26 05 29 – Hangers and Supports for Electrical Systems

1.02 REFERENCE STANDARDS

- A. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:
- B. American National Standards Institute (ANSI)
 - 1. ANSI C80.1, Standard for Electrical Rigid Steel Conduit (ERSC)
- C. National Electrical Manufacturers Association (NEMA)
 - 1. NEMA FG 1, Fiberglass Cable Tray Systems
 - 2. NEMA RN 1, Polyvinyl-Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit
 - 3. NEMA TC 14, Reinforced Thermosetting Resin Conduit (RTRC) and Fittings
 - 4. NEMA 250, Enclosures for Electrical Equipment (1000 Volts Maximum)
 - 5. NEMA ICS 2, Industrial Control and Systems Controller, Contactors, and Overload Relays 600 V
- D. National Fire Protection Association (NFPA)
 - 1. NFPA 70, National Electrical Code (with amendments by the Authority Having Jurisdiction)
 - 2. NFPA 130, Fixed Guideway Transit and Passenger Rail Systems

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. List of Materials:
 - 1. Submit a list of materials proposed for use.
 - 2. Give name of manufacturer, brand name, and catalog number of each item.
 - 3. Submit list complete at one time, with items arranged and identified in numerical sequence by Specification Section and Article number.
- C. Compliance with Applicable Standards:
 - 1. Where equipment or materials are specified to conform to standards of organizations such as ANSI, ASTM, and NEMA, submit evidence of conformance. The label or listing of specified agency will be acceptable evidence.
 - 2. Instead of the label or listing, Contractor may also submit a written certificate from an approved, nationally recognized testing organization, stating that items have been tested and units conform to specified standard.
- D. Shop Drawings:
 - 1. Submit shop drawings showing exact location and arrangement of conduits, cabinets, and pullboxes installed under this Contract.
 - 2. Submit drawings with ample time to prevent delays in Work.

PART 2 PRODUCTS

2.01 CONDUIT AND DUCT

- A. Galvanized Rigid Steel (GRS) Conduit and Accessories: ANSI C80.1; hot-dip galvanized inside and out after threading; ensure each length bears UL label.
- B. GRS Fittings and Accessories:
 - 1. Bushings: Nylon-insulated, metallic.
 - 2. Grounding bushings: Nylon-insulated, metallic, with lay-in lugs.
 - 3. Sealing Bushings:
 - a. Galvanized malleable or ductile iron bushings with Bakelite sealing and pressure discs and individual neoprene cable rings.
 - b. Bushings shall seal ends of GRS conduit against the entrance of water, air or dust around emerging cables.

- c. Approved Manufacturer/Product: O-Z/Gedney, type KR.
- d. Substitutions: Per 01 25 00, Substitution Procedures.
- 4. Conduit straps, clamps, and clamp backs: Galvanized malleable iron.
- C. PVC-Coated GRS Conduit (PVC/GRS or PGRS): NEMA RN 1, with corrosion resistant internal coating.
- D. Epoxy Fiberglass Conduit and Fittings: NEMA TC 14; standard or heavy-wall, UL listed.
 - 1. Conduit joints and fittings: Tapered or untapered; all of one type.
- E. Liquidtight Flexible Metallic Conduit and Fittings.
 - 1. Core: Flexible galvanized steel with a continuous copper bonding conductor spiral wound between the convolutions.
 - 2. Jacket: Extruded liquid-tight plastic or neoprene; moisture- and oil-proof, capable of conforming to the minimum radius bends of flexible conduit without cracking; self-extinguishing with low halogen containing material.
 - 3. Fittings: Zinc-coated.

2.02 OXIDE INHIBITING JOINT COMPOUNDS

- A. Petroleum-based compound with evenly suspended zinc particles.
- B. Approved Manufacturer/Product: Burndy, Penetrox A.
 - 1. Substitutions: Per 01 25 00 Substitution Procedures.

2.03 CABLE TRAY

- A. Type: Fiberglass, ladder or solid-bottom type with solid covers and other accessories, NEMA FG 1.
- B. Minimum Dimensions:
 - 1. Width: 6 inches minimum.
 - 2. Loading depth: 3 inches minimum.
 - 3. Inside nominal depth: 5 inches minimum.
 - 4. Radius of curved fittings: 24 inches minimum unless otherwise approved by Engineer.

C. Performance Requirements:

1. 30 inch width or less: Capable of supporting a total cable load of 55 pounds per linear foot on a maximum span of 8 feet, including a 200-pound static load as specified below.
2. Over 30-inch width: Capable of supporting a total cable load of 88 pounds per linear foot on a maximum span of 8 feet including a 200-pound static load as specified below.
3. Requirements shall be independent of type of splice plates or type of span, when tested in accordance with load test procedure specified in NEMA standards.
4. Safety factor: 2, based on destructive load.
5. 200 pound static load: Straight sections and fittings shall not permanently deform under a 200 pound static concentrated load applied vertically along a 4-inch length for both of the following conditions:
 - a. Load applied to center of one tray section having specified cable load and support spacing.
 - b. Load shall be applied at midpoint between supports over a splice connection.
 - c. Load applied to one rung of empty tray section having specified support spacing. Load shall be located at midpoint between side rails and supports.

2.04 CONDUIT HANGERS AND SUPPORTS

- A. Refer to Section 26 05 29, Hangers and Supports for Electrical Systems.

2.05 OUTLET, JUNCTION, AND PULL BOXES

- A. Sheet metal outlet boxes: Steel, galvanized.
- B. Sheet metal junction and pull boxes: Galvanized or stainless steel, hinged or screw-cover with stainless steel screws.
- C. Cast metal boxes: Hot dip galvanized inside and out.
1. Covers: Same thickness as boxes and secured with No. 10-24 stainless steel machine screws.
 2. Neoprene gaskets: 1/8-inch thick.
- D. Nonmetallic boxes: Heavy duty, phenolic, surface-mounted, with threaded nonmetallic conduit hubs, type FD, single- or double-gang as required. Provide non-metallic device covers.
1. Acceptable Manufacturer/Product: Thomas & Betts, Carlon[®] FSC-34.
 2. Substitutions: Per 01 25 00 Substitution Procedures.

2.06 ASSEMBLY

A. Conduit:

1. General:
 - a. Install electrical raceway, boxes and accessories in locations as indicated, in accordance with NFPA 70, NECA 1, local codes and ordinances and as indicated to provide a complete and operable system.
 - b. Where a conduit type indicated on Contract Drawings is in conflict with this Section, refer discrepancy to Engineer.
2. Conduit threading:
 - a. Clean threads with a solvent recommended by coating manufacturer to remove oil.
 - b. Coat threads with organic cold galvanizing coating, in accordance with manufacturer's instructions.
 - c. If spray application is used, provide at least three coats.
3. Factory conduit threads:
 - a. Coat threads with oxide inhibiting compound.
 - b. Take care that compound is not applied to interior of conduit.
4. Conduit caps:
 - a. Provide threaded cap or similar closure designed for the purpose on conduits that are not terminated immediately.
 - b. Prohibited: Tape is not acceptable for temporary cap.
5. Conduit sealing:
 - a. Conduit exposed to different temperatures: Seal conduit to prevent condensation and passage of air from one area to the other.
 - b. Where waterproofing is required, seal conduits with watertight duct sealing system.
6. Liquid tight flexible metal conduit:
 - a. Install so that liquids tend to run off surface and do not drain toward fittings.
 - b. Provide sufficient slack to reduce the effects of vibration.

- B. Conduit Grounding and Bonding: Install metallic conduits to be electrically and mechanically continuous and connected to ground by bonding to the grounding system.
- C. Conduit terminations:
 - 1. Dry areas:
 - a. Provide two locknuts, one inside and one outside of box or enclosure, for rigid conduit terminating at steel box, panelboard, cabinet, or similar enclosure.
 - b. Provide insulating bushing or grounding bushing on conduit end.
 - 2. Exposed, damp and wet locations: Provide threaded, water-tight hubs with sealing o-rings for cabinet connections or threaded connections to tapered threaded hubs for cast boxes and fittings.
 - 3. Terminate the conduit in appropriate boxes at motors, switches, outlets, and junction points.
- D. Conduit Minimum Sizes:
 - 1. GRS: 3/4-inch.
 - 2. Fiberglass Conduit: 3/4-inch.
 - 3. Liquid-tight Flexible Metallic Conduit: 1/2-inch.
- E. Conduit Bends:
 - 1. Install conduit runs with not more than 270 degrees total bends between pull boxes. Where more bends are required in a particular run, install pull boxes as required to facilitate pulling conductors even if not indicated.
 - 2. Minimum Bend Radius: In accordance with NEC Chapter 9 Table 2, "Other Bends" column.
- F. Cable Tray:
 - 1. General:
 - a. Install cable trays using approved fittings and adequately support the complete system. See 26 05 29, Hangers and Supports for Electrical Systems.
 - b. Install cable trays parallel to each other and the building and plumb and level.
 - c. Support cable trays with wall brackets or ceiling-mounted supports from the prefabricated building structure, with anti-sway brackets or braces where necessary.
 - d. Trays shall be located no closer than 2-1/2 inches from the nearest wall, unless otherwise approved.

2. Supports:
 - a. Finish: Hot-dip galvanized after fabrication.
 - b. Ceiling supports: See Section 26 05 29, Hangers and Supports for Electrical Systems.
 - c. End supports: Support terminating sections of cable tray not more than 12 inches from end of tray.
 - d. Wall supports: Capable of sustaining an end-load of 1,600 pounds.
 - e. Spacing:
 - 1) Supports: Space at maximum distance of 5 feet to provide rigidity and adequate strength to support weight of trays and cables.
 - 2) Splices: Each tray splice shall have a support between 6 inches and 24 inches from the splice.
3. Seismic bracing: Provide bracing for cable tray system complying with sealed seismic calculations required in Section 26 05 00, Common Work Results for Electrical.
4. Fasteners:
 - a. Solidly bolt trays to supporting channels using countersunk machine screws, 1/4 inch by 20 threads per inch, minimum.
 - b. After installation of fasteners, tray shall be free from burrs or sharp edges.
5. Separators: Provide separators to isolate cables of different voltages.

G. Boxes:

1. General:
 - a. Provide electrical boxes and cabinets of the material, finish, type, and size indicated and as required for the location, kind of service, number of wires, and function.
 - b. Ensure boxes and support fittings are of suitable and compatible materials that will not corrode when subjected to moisture or standing water.
 - c. Provide brackets, supports, hangers, fittings, bonding jumpers, and other installation accessories as required. Refer to Section 26 05 29, Hangers and Supports for Electrical Systems.
 - d. Securely attach outlet, junction, and pull boxes to the structure. Do not use conduits entering the box as supports for the box.

2. Covers:
 - a. Provide boxes complete with accessible covers designed for quick removal and suitable for the purpose for which they will be used.
 - b. Provide flat or raised blank covers for boxes without devices or fixtures.
 - c. Provide neoprene gaskets for boxes subjected to weather.
3. Installation:
 - a. Mount outlet, junction, and pull boxes so as to prevent moisture from entering or accumulating within the boxes.
 - b. Junction and Pull Boxes: Install so that covers are readily accessible after completion of the installation.
4. Grounding: Ground/bond each box and cabinet as specified in Section 26 05 26, Grounding and Bonding.
5. Dc equipment: For areas within 6 feet of dc rectifier and dc circuit breaker enclosures provide nonmetallic pull-boxes, junction boxes, device boxes, and covers.

PART 3 EXECUTION

3.01 RACEWAY TYPE REQUIREMENTS

- A. Permitted Conduit Types:
 1. Conduits in traction power substations:
 - a. GRS or epoxy fiberglass.
 - b. Within 6 feet of dc rectifier or distribution breaker enclosures: Fiberglass.
 2. Liquid-tight flexible metal conduit:
 - a. Permitted only where required for flexibility such as connections to vibrating equipment and across joints subject to differential movement.
 - b. Not acceptable as a substitute for other conduit types in areas with complicated bending requirements.
 3. Conduit or raceway types not specifically called out in these Specifications or Contract Drawings shall not be used.
- B. Permitted Cable Tray Type: Fiberglass with insulating support hardware.
- C. Prohibited Raceway Types:
 1. Wiring gutters or wireways.

2. Electrical Metallic Tubing (EMT).
3. Intermediate Metal Conduit (IMC).
4. Flexible metal conduit.
5. Conduit running thread.

3.02 BOX AND CABINET TYPE REQUIREMENTS

A. Dry locations:

1. Outlet boxes: Sheet metal outlet boxes.
2. Junction or pull boxes with volume less than 100 inches: Sheet metal junction or pull box.
3. Cabinets: Galvanized steel, NEMA 250 Type 1.

B. Damp locations:

1. Outlet, junction, and pull boxes: Cast metal boxes.
2. Cabinets: NEMA 250 Type 4X stainless steel unless otherwise approved.

C. Within 6 feet of dc switchgear:

1. Cabinets: Fiberglass composite.

END OF SECTION 26 05 33

SECTION 26 12 16
DRY-TYPE TRANSFORMERS

PART 1 GENERAL

1.01 SUMMARY

- A. Section Includes:
 - 1. Low voltage two-winding dry-type transformers.
 - 2. Refer to Section 34 21 23, Transformer-Rectifier Unit for traction power transformer requirements.
- B. Related Sections:
 - 1. Section 26 05 00 – Common Work Results for Electrical
 - 2. Section 26 24 13 – Switchboards
 - 3. Section 34 21 60 – TES Spare Parts and Special Tools

1.02 REFERENCE STANDARDS

- A. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:
- B. Institute of Electrical and Electronics Engineers (IEEE):
 - 1. IEEE C57.12.01, General Requirements for Dry-Type Distribution and Power Transformers Including Those with Solid-Cast and/or Resin Encapsulated Windings
- C. National Electrical Manufacturer's Association (NEMA):
 - 1. NEMA TP 1, Guide for Determining Energy Efficiency for Distribution Transformers
- D. National Fire Protection Association (NFPA)
 - 1. NFPA 70, National Electrical Code (with amendments by the Authority Having Jurisdiction)

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Product Data: Submit manufacturer's product data of manufactured materials and equipment including the following:
 - 1. Outline and support point dimensions of enclosures and accessories.

2. Unit weights.
 3. Voltage, kVA and impedance ratings and characteristics.
 4. Loss data, efficiency at 25, 50, 75 and 100 percent rated load.
 5. Sound level.
 6. Tap configuration.
 7. Insulation system type and rated temperature rise.
- C. Spare Parts and Special Tools:
1. Submit a list of spare parts to be provided under this Section.
 2. Submit at the same time as product data.
 3. Provide part numbers for each part, including a detailed break down of each spare part assembly and set, as defined in Section 34 21 60, TES Spare Parts and Special Tools.
- D. Sizing Calculations: Submit calculations for sizing of the Station Service Transformer. Allow for 20 percent additional future load. At a minimum, the transformer shall be rated 25 kVA.
- E. Operation and Maintenance Data: Submit in accordance with Section 01 78 23, Operation and Maintenance Data, including the requirements identified above for submittal information.

1.04 SPARE PARTS

- A. Submit spare parts in accordance with Section 34 21 60, TES Spare Parts and Special Tools.
- B. List below applies to items in this Specification Section:
1. Station service transformer: Provide 1 spare of each size.

PART 2 PRODUCTS

2.01 DRY TYPE TWO-WINDING TRANSFORMERS

- A. Dry Type Transformers: IEEE C57.12.01; factory-assembled, air cooled dry type transformers; ratings as shown on Contract Drawings.
- B. Insulation system and average winding temperature rise for rated kVA as follows:
1. 1 to 15 kVA: Class 185 insulation, 80 degrees C rise.
 2. 16 to 500 kVA: Class 220 insulation, 115 degrees C rise.

3. 501 to 2000 kVA: Class 220 insulation, 80 degrees C rise.
- C. Load Ratings and Transformer Cooling: Load ratings, unless noted otherwise, are assumed to be AA (air convection cooling). For transformers 500 kVA and larger, provide mounting hardware, internal thermostats, and external fans. Provisions shall be capable of increasing the transformer full-load rating by 50 percent.
 - D. Windings: Copper primary and secondary.
 - E. Winding Taps:
 1. Transformers Less than 15 kVA: Two 5 percent, full-capacity taps below rated voltage on primary winding.
 2. Transformers 15 kVA and larger: IEEE C57.12.01.
 - F. Energy Efficiency: NEMA TP 1
 - G. Sound Levels: IEEE C57.12.01
 - H. Basic Impulse Level:
 1. Low-voltage Dry-Type Transformers: 10 kV for transformers less than 300 kVA, 30 kV for transformers 300 kVA and larger.
 2. Medium-voltage Dry-Type Transformers: 30 kV for transformers rated 5 kV, 95 kV for transformers rated 15 kV, and 125 kV for transformers rated 25 kV.
 - I. Ground core and coil assembly to enclosure by means of a visible, flexible copper grounding strap.
 - J. Mounting:
 1. 75 kVA and less: Suitable for wall, floor, or trapeze mounting, or mounting internal to switchgear.
 2. Larger than 75 kVA: Suitable for floor or trapeze mounting.
 - K. Coil Conductors: Continuous windings with terminations brazed or welded.
 - L. Enclosure: IEEE C57.12.01; Type 1, drip-proof, or ac switchgear cubicle as indicated on Contract Drawings.
 - M. Isolate core and coil from enclosure using vibration-absorbing mounts.
 - N. Nameplate: Include transformer connection data.

2.02 STATION SERVICE TRANSFORMER

- A. Calculate size of the Station Service Transformer as follows:
 - 1. Calculate load per NFPA 70 based on heating, cooling, lighting, and other loads.
 - 2. Allow for 20 percent additional future load.
 - 3. At a minimum, the transformer shall be rated 25 kVA.
 - 4. Provide primary fused disconnect and secondary circuit breaker complying with NFPA 70.

2.03 FACTORY ASSEMBLY

- A. Install transformers plumb and level.
- B. Use copper bus for both primary and secondary connections.
- C. Mount transformers inside substation on vibration isolating pads suitable for isolating the transformer noise from the structure.
- D. Provide restraints for vertical and horizontal seismic motion in accordance with the seismic requirements in Section 26 05 00, Common Work Results for Electrical.
- E. Station Service Transformer: Mount inside ac switchboard enclosure, as described in Section 26 14 13, Switchboards. No station service transformers are required for built-in-place substations.

PART 3 EXECUTION

3.01 FIELD QUALITY CONTROL

- A. Check for damage and tight connections before energizing transformer.
- B. Measure primary and secondary voltages and make appropriate tap adjustments.

END OF SECTION 26 12 16

SECTION 26 24 13

SWITCHBOARDS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Switchboard for service and power distribution in traction power substation.

B. Products Furnished But Not Installed Under This Section:

1. Switchboard with circuit breaker for Operations and Maintenance Facility traction power substation.

C. Related Sections:

1. Section 05 05 00 – Common Work Results for Metals
2. Section 26 12 16 – Dry Type Transformers
3. Section 34 21 05 – Common Work Results for TES

1.02 REFERENCES

A. Definitions:

1. Mimic bus: A series of electrical symbols and designations used on the exterior of switchgear that mimic the wiring scheme within the switchgear.

B. Reference Standards:

1. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:
2. ASTM International (ASTM)
 - a. ASTM A653/A653M, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
3. Institute of Electrical and Electronics Engineers (IEEE)
 - a. IEEE C57.13, Standard Requirements for Instrument Transformers
4. National Electrical Manufacturer's Association (NEMA)
 - a. NEMA AB1, Molded-Case Circuit Breakers, Molded Case Switches, and Circuit-Breaker Enclosures

- b. NEMA PB 2, Deadfront Distribution Switchboards
- 5. National Fire Protection Association (NFPA)
 - a. NFPA 70, National Electrical Code (with amendments by the Authority Having Jurisdiction)

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Product Data:
 - 1. Submit manufacturers' product data for specified equipment and materials. Include the following information for each item:
 - a. Manufacturer's model number or item identification.
 - b. UL listing and rating.
 - c. Critical dimensions and mounting arrangement.
 - d. Replacement parts list.
- C. Shop Drawings.
 - 1. Show materials and methods of construction, door arrangement, conduit hubs and knockout locations.
 - 2. Circuit Breakers: Show circuit for which intended, voltage ratings, insulation level, current rating and interrupting ratings.
 - 3. Single line diagrams.
 - 4. Physical arrangement drawings and weight of equipment and major components.
 - 5. Unit wiring diagrams.
 - 6. Circuit breakers, controls and indications.
 - 7. Show space available for conduit and bus duct entrance and for routing and training of cables.
 - 8. Schematic diagrams for electrically operated equipment.
 - 9. Setting diagrams and templates if anchoring in concrete is required.
 - 10. Assembly and erection diagrams if shipped in sections or if some parts are shipped separately and not installed at the factory.

11. Interconnection diagrams for circuits having externally located instruments, controls, alarms, or similar devices.
- D. Calculations: Submit sizing calculations for protection current transformers and metering current transformers. Obtain Engineer's approval before procuring current transformers.

1.04 QUALITY ASSURANCE

- A. Qualifications: Manufacturer that has been regularly engaged in the manufacture of similar equipment and meets UL requirements.
- B. Conform to NEMA PB 2 and NFPA 70 (with amendments by the Authority Having Jurisdiction), as applicable.
- C. Each item shall be UL labeled.

1.05 DELIVERY, STORAGE, AND HANDLING

- A. Shipping:
 1. If approved by the Engineer, switchboards may be broken down into convenient shipping sections after tests are completed.
 2. Shipping split terminals and connections disconnected for shipping shall be properly identified and protected.

PART 2 PRODUCTS

2.01 GENERAL REQUIREMENTS

- A. Metal-enclosed, self-supporting, dead front, freestanding, circuit-breaker type for indoor service.
- B. Comply with NEMA PB 2, NFPA 70 (with amendments by the Authority Having Jurisdiction), as applicable.
- C. Provide the required number of vertical sections designed for bolting together to form a rigid switchboard.
- D. Switchboards shall be assembled, wired and tested at the manufacturer's plant.
- E. Components of the same type, size, rating, functional characteristics and manufacture shall be interchangeable.

2.02 RATINGS

- A. Current rating: Based on operation in a 25 degree C room ambient.
- B. Bus bracing: 100 kA RMS momentary.

2.03 ENCLOSURE

- A. Type:
 - 1. Freestanding, reinforced with adequate steel framework to form a rigid structure
 - 2. Designed for group assembly as part of complete switchgear.
- B. Physical Size:
 - 1. 90 inches high maximum.
 - 2. Width and depth adequate to accommodate and connect the equipment.
 - 3. Provide adequate space to accommodate bending radius requirements of cables.
- C. Material: Zinc-coated steel sheet conforming to ASTM A 653/A 653M, zinc coating designation G90.
- D. Workmanship: Fabricate with a smooth outer surface free from burrs, ridges and other blemishes.
- E. Finish:
 - 1. Powder coat as specified in Section 05 05 00, Common Work Results for Metals.
 - 2. Color: Refer to Section 05 05 00, Common Work Results for Metals.
- F. Configuration: Align vertical sections front and rear.
- G. Barriers: Switchboards in the same line-up fed electrically from different feeders shall have barriers such that a fire caused by an internal fault at one switchboard shall not spread to another switchboard.
- H. Doors: Equip with front and rear doors, except for built-in-place substations, where there will be no rear access and no station service transformers.
- I. Station Service Transformer:
 - 1. Provide adequate space in rear of enclosure to accommodate station service transformer. For information on transformer, see Section 26 12 16, Dry Type Transformers.
 - 2. Provide front or rear access to transformer.
- J. Mimic bus: Provide on front of each switchboard section.
 - 1. Factory-applied, plastic, 3/8-inch wide, minimum 1/32-inch thick.
 - 2. Color: Red.

K. Nameplates:

1. Provide a nameplate on each switchboard and its components as specified in Section 34 21 05, Common Work Results for TES.
2. Label each control switch and pilot light with one inch wide nameplate showing the function and the number of unit in 1/2- inch high letters.

2.04 SWITCHBOARD BUSES

- A. Bus: Silver-plated copper buses of sufficient size to limit the current density to 750 A per square-inch cross section.
- B. Bracing: Brace distribution switchboard buses for the symmetrical fault current indicated.
- C. Main Buses:
1. Extend main buses horizontally from the incoming line sections to all distribution sections if indicated on the same line-up.
 2. Make provision for extending the main buses for future vertical sections.
- D. Section Buses: Extend section buses vertically from the main bus through each vertical section.
- E. Neutral bus: Fully rated.
- F. Ground Buses:
1. Extend a ground bus through the length of the switchboard.
 2. Firmly bolt to each vertical section in at least two places.
 3. Make provision for connection to the building or station grounding system near each end of the ground bus.
 4. Make provision for future extension of the ground bus.
- G. Phasing: Phase buses A-B-C from left-to-right, top-to-bottom and front-to-rear as viewed from the front of the switchboard.

2.05 SWITCHBOARD CIRCUIT BREAKERS

- A. Type: Draw-out, insulated-case, stored energy, electrically operated, three phase, 60 Hz, in accordance with NEMA AB 1.
- B. Closing time: Maximum five cycles.
- C. Insulation rating of plug shall be the same as the breaker rating.

- D. Circuit breakers shall be capable of performing 4,000 close-open cycles at rated load, 80 percent power factor and rated voltage and 4,000 close-open cycles at no load without maintenance or replacement of parts.
- E. Breakers shall have control power and motor charging device of 120 Vdc.
- F. Breakers shall be equipped with field-replaceable contacts.

2.06 PROTECTIVE RELAYS

- A. Equip breakers with solid-state trip unit with voltage and current sensors as indicated and a minimum of seven time/current systems coordination adjustment, including ground fault and undervoltage settings.
- B. Lockout (Device 86H):
 - 1. Provide on the ac circuit breaker compartment.
 - 2. Lockout relay reset switch:
 - a. Handle type: Heavy-duty, rotary pistol-grip.
 - b. Contacts:
 - 1) Silver-to-silver.
 - 2) Enclosed, with easily removable covers.
 - 3) Current rating: Based on continuous, inrush, or interrupting requirements for the duty category and then derated by at least a factor of four.
 - 4) Voltage rating: Minimum of twice the applied voltage.
 - c. Actuating contacts: Use a cam action or similar positive means.
 - d. Escutcheon plate: Provide with each switch.
 - e. Switch positions: "LOCKOUT" and "RESET" with a spring return to center.
 - 3. Provide indication of "lockout" and "normal" at the reset switch, as described in this Section.
 - a. When the main ac circuit breaker for traction power substations is tripped by the lockout relay, the ac breaker shall be locked out until manually reset.
- C. Provide other protective relaying functions as indicated on one-line diagram in Contract Drawings.

D. Trip Circuit Monitors

1. Provide a trip circuit monitor for monitoring the trip coil on each of the following:
 - a. Main ac circuit breaker for traction power substations.
 - b. Lockout relay.
2. Provide the following:
 - a. Green LED that illuminates when the trip coil is energized and turns off when the coil is de-energized.
 - b. NO and NC Form C contacts for indication of a failed trip coil.
 - c. Red LED that illuminates upon failure of the trip coil.
 - d. 200 millisecond delay to allow for auxiliary contacts to transfer.
 - e. LEDs:
 - 1) Plug-in replaceable with a life of 100,000 hours.
 - 2) Protected against reverse polarity by a diode.
 - f. Control Power: 125 Vdc.

2.07 POWER METER

- A. Provide power meter in each switchboard:
 1. Capable of revenue-accuracy metering of electrical parameters including voltage, current, frequency, power factor, kW, kVAr, kWh, and kVArh, and values of kW and kVAr demand.
 2. MV90 compatible: Programmable to mimic values metered by TEP during a 15-minute sliding window.
 3. Communications: Modbus TCP/IP Ethernet (RJ45).
- B. Approved Manufacturer/Product: Electro Industries/GaugeTech, Nexus 1252.
 1. Substitutions: Per Section 01 25 00, Substitution Procedures.

2.08 CURRENT TRANSFORMERS

- A. Current transformers shall conform to IEEE C57.13, with the additional requirements indicated below.

- B. Current transformers:
1. Shall be capable of withstanding thermal and mechanical ratings of the circuit breaker.
 2. Molded-rubber or epoxy construction, wound-type or bushing-mounted.
 3. Wound-type current transformers:
 - a. Provide separate compartment isolated from the control panel and all other equipment.
 - b. Provide a mounting frame which bolts securely to the switchgear frame.
 - c. Full-wave impulse insulation level: 125 kV.
 - d. Secondary terminal blocks shall have covers with integral shorting bars and secondary wiring shall be run to readily identifiable terminal block points in the control compartment.
 - e. Terminal block points shall also have integral shorting bars for the current transformer leads.
 4. Bushing-type current transformers:
 - a. Low-voltage, ring-core, high-accuracy type designed for secure mounting on the primary contact support bushings.
 5. Accuracy:
 - a. Protective relaying: Relaying accuracy classification, under the burdens imposed by the specified devices.
 - b. Power Meters: Accuracy Class 0.3 at burden B-0.5.
 - 1) If this metering accuracy is not available, perform an analysis of expected accuracy of metering equipment for loads from 10 percent to 100 percent of actual load rating and submit for approval.
 - 2) Bushing current transformers that will not provide accuracy of plus or minus 0.5 percent at 10 percent load and plus or minus 1.0 percent at full load will be rejected and require installation of wound-type current transformers.
- C. Submit sizing calculations for protection current transformers and metering current transformers.

2.09 SOURCE QUALITY CONTROL

- A. In addition to the manufacturer's standard tests, as a minimum perform the following tests at the manufacturer's plant:
1. 60 Hz dielectric tests.
 2. Mechanical operations tests.
 3. Grounding of instruments.
 4. Transformer case tests.
 5. Electrical operation tests.
 6. Control wiring checks.

PART 3 EXECUTION

Not Used.

END OF SECTION 26 24 13

SECTION 26 24 16
LOW-VOLTAGE PANELBOARDS

PART 1 GENERAL

1.01 SUMMARY

- A. Section Includes:
 - 1. Circuit breaker panel boards, including dc distribution panelboard.
 - 2. Enclosed circuit breakers.
- B. Related Sections:
 - 1. Section 05 05 00 – Common Work Results for Metals
 - 2. Section 26 05 00 – Common Work Results for Electrical

1.02 REFERENCE STANDARDS

- A. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:
- B. ASTM International (ASTM)
 - 1. ASTM B187, Specification for Copper Bar, Bus Bar, Rod and Shapes
- C. National Electrical Manufacturers Association (NEMA)
 - 1. NEMA AB 1, Molded Case Circuit Breakers, Molded Case Switches, and Circuit Breaker Enclosures
 - 2. NEMA PB 1, Panelboards
 - 3. NEMA 250, Enclosures for Electrical Equipment (1000 Volts Maximum)
- D. National Fire Protection Association (NFPA)
 - 1. NFPA 70, National Electrical Code (with amendments by the Authority Having Jurisdiction)
- E. Underwriters Laboratories Inc. (UL)
 - 1. U; 67, Panelboards
 - 2. UL 489, Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00.
- B. Shop Drawings.
 - 1. Submit shop drawings and electrical diagrams as follows:
 - a. Panelboards and Load Centers:
 - 1) Show general arrangement, location and identification of the enclosure.
 - 2) Identify each circuit.
 - 3) Show location and identification of terminals.
 - 4) Show location of barriers.
 - 5) Provide wiring diagrams.
 - b. Circuit Breakers: Show circuit for which intended, voltage ratings, insulation level, current rating and interrupting ratings.
- C. Operation and Maintenance Data:
 - 1. Submit data in accordance with Section 01 78 23, Operation and Maintenance Data, including the following requirements:
 - a. Description of the switchboard and its components.
 - b. Manufacturer's operating and maintenance instructions, parts list, illustrations and diagram for components.
 - c. Recommended list of spare parts.
 - d. Wiring diagram.
 - e. Electrical characteristics of each component including relays or solid-state circuitry.
- D. Factory Test Reports: Submit copies of certified reports of factory tests performed in accordance with the applicable referenced standards and specification requirements.
- E. Field Test Reports: Submit copies of field tests performed in accordance with this Section.

1.04 QUALITY ASSURANCE/QUALITY CONTROL

- A. Qualifications: Manufacturer that has been regularly engaged in the manufacture of similar equipment and meets UL requirements.
- B. Conform to UL 489, NEMA PB 1, and NFPA 70 (with amendments by the Authority Having Jurisdiction), as applicable.

- C. Components of the same type, size, rating, functional characteristics and manufacture shall be interchangeable.
- D. Each item shall be UL labeled.

1.05 DELIVERY, STORAGE, AND HANDLING

- A. Ship each unit securely wrapped, packaged and labeled for safe handling in shipment and to avoid damage or distortion.
- B. Store in secure and dry storage facility.

PART 2 PRODUCTS

2.01 PANELBOARDS AND LOAD CENTERS

- A. NEMA PB 1, UL 67.
- B. Enclosure:
 - 1. NEMA 250 Type 1, fabricated from galvanized steel, surface-mounted unless otherwise indicated, tamperproof, with the following additional requirements:

- a. Gutter size.

<u>Main Bus Rating Amperes</u>	<u>End Gutter Size (Inches)</u>	<u>Side Gutter Size (Inches)</u>
225 and below	6	5
400 and over	8	8

- b. Provide backplate of reinforced steel for mounting of interior components.
- c. Provide device or mechanism for enclosure grounding.
- d. Dead-front type.

- C. Cover and Trim:
 - 1. Designed for surface mounting.
 - 2. Door:
 - a. Hinged, fitted with a combination latch and door lock, accommodating a master key.
 - b. Provide one flat key tumbler cylinder-type, nickel-plated door lock conforming to the station master key system, two keys per lock.
 - 3. Circuit Directory: Provide a directory frame with acrylic plastic face mounted on the back of the door.

4. Finish: Powder coat as specified in Section 05 05 00, Common Work Results for Metals.
- D. Bus Bars.
1. ASTM B187, 98 percent conductivity copper, with silver-plated contact surface.
 2. Provide neutral bus of the same rating as that of phase bus.
 3. Provide a full-rated separate grounding bus.
- E. Circuit Breakers: NEMA AB 1, bolt-on type.
- F. Additional Requirements for Dc Panelboards:
1. Designed for two-wire, 125 Vdc ungrounded power distribution service.
 2. Circuit breakers: Two-pole, 10,000 A interrupting rating at 250 Vdc minimum.

2.02 ENCLOSED CIRCUIT BREAKERS

- A. UL 489, molded case, quick-make quick-break bolt-on type, with thermal-magnetic type overload trip, interchangeable unit for frame rated 125 A and above.
- B. Enclosure: NEMA 250 Type 12, fabricated from galvanized steel, surface-mounted unless otherwise indicated.
- C. Finish: Powder coat as specified in Section 05 05 00, Common Work Results for Metals.

2.03 SOURCE QUALITY CONTROL

- A. In addition to the manufacturer's standard tests, as a minimum perform the following tests at the manufacturer's plant:
 1. 60 Hz dielectric tests.
 2. Mechanical operations tests.
 3. Electrical operation tests.

2.04 ASSEMBLY

- A. Mounting Height: Locate top 6 feet, 6 inches above finished floor and the bottom not less than 12 inches above finished floor, unless specifically indicated otherwise.
- B. Anchor in accordance with seismic requirements in Section 26 05 00, Common Work Results for Electrical.
- C. Provide nameplates or other permanent identification for each circuit breaker, mounted on the cover or trim adjacent to each breaker.

- D. Provide each panelboard and load center with an accurate typewritten circuit directory. Install in the factory provided directory frame mounted on the back of the door.

PART 3 EXECUTION

3.01 FIELD QUALITY CONTROL

- A. Provide equipment for testing power and control circuits after delivery of substation. Test under the observation of Engineer.
- B. Panelboards and Enclosed Circuit Breakers.
 - 1. Test circuits for connections in accordance with the wiring diagram.
 - 2. Test that insulation resistance to ground of nongrounded conductors is a minimum of 10 megohms.
 - 3. Test panelboard and load center enclosures for continuity to the grounding system.
 - 4. Test operation of circuits and controls. When testing, operate each control a minimum of 10 times and each circuit continuously for a minimum of 1/2 hour.
 - 5. Test that each panel has a balanced load.
 - 6. Maintain a log of tests.

END OF SECTION 26 24 16

SECTION 26 50 00

LIGHTING

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. Interior substation overhead and emergency lighting.
- B. Exterior substation lighting.
- C. Lighting inside equipment enclosures.

1.02 REFERENCE STANDARDS

- A. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:
- B. American National Standards Institute (ANSI)
 - 1. ANSI C82.4, Standard for Ballasts for High-Intensity-Discharge and Low-Pressure Sodium (LPS) Lamps (Multiple-Supply Type)
- C. Institute of Electrical and Electronics Engineers (IEEE)
 - 1. IEEE C62.41, Guide on Surge Voltages in AC Power Circuits Rated up to 600V
- D. Underwriters Laboratories Inc. (UL)
 - 1. UL 924, Standard for Safety of Emergency Lighting and Power Equipment
 - 2. UL 1570, Fluorescent Lighting Fixtures
 - 3. UL 1598, Standard for Safety of Luminaires

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Product Data:
 - 1. Document that proposed luminaires, ballast and lamps fully comply with Contract Documents.
 - 2. Indicate luminaire construction, photometric performance, installation, and maintenance requirements.

3. Include clear and legible product specifications, drawings and illustrations of sufficient detail to describe the following:
 - a. Luminaire housing, hardware, and finishes.
 - b. Light controlling elements.
 - c. Electrical components, including lampholders, ballast, and provision for conduit entry.
 - d. Support details. Indicate weight of luminaire, complete with lamps.
 4. Include procedures for installation of the complete lighting unit in its final service location.
- C. Shop Drawings: Lighting layout with proposed luminaires indicated by manufacturer and model number.
- D. Calculations: Show that specified lighting levels are achieved with proposed luminaires.
- E. Operations and Maintenance Data: Submit data in accordance with Section 01 78 23, Operation and Maintenance Data, including the following requirements:
1. Materials and components clearly indicated in the parts list.
 2. Relamping methods.
 3. Special tools required.
 4. Frequency of inspection, tightening, or other service recommended for preventative maintenance.

1.04 WARRANTY

- A. Emergency Lights: See Section 01 78 36, Warranties for length of extended warranty required for batteries.

PART 2 PRODUCTS

2.01 PERFORMANCE CRITERIA

- A. Each substation shall have interior and exterior lighting to provide the specified minimum light levels.
- B. Minimum Lighting Levels:
1. Interior: 70 footcandles at 30 inches horizontal above the aisle floor.
 2. Exterior: 2 footcandles, measured at ground level.
 3. Emergency Lighting: Minimum 1 footcandle at 30 inches above the aisle floor.

4. Minimum lighting levels shall be maintained throughout the TPSS. Average lighting level shall not be used to meet this requirement.

2.02 COMPONENTS

A. Ballasts:

1. Mount ballast securely inside luminaire to obtain the necessary heat dissipation.
2. Ballasts for fluorescent lamps shall match the characteristics of the lamps, and have the following characteristics:
 - a. Operate lamps at a frequency of 20 kHz or higher without visible flicker.
 - b. Listed Class P.
 - c. Total Harmonic Distortion: Less than 10 percent at 277 V.
 - d. Current crest factor: Less than 1.5.
 - e. Power factor: 0.98 minimum.
 - f. Audible noise rating: Class A or better.
 - g. Contain no Polychlorinated Biphenyls (PCBs).
 - h. Transient protection: IEEE C62.41, Category A.
 - i. Inherent thermal protection.
 - j. Provide constant light output with input voltage fluctuation of plus or minus 5 percent.
 - k. Provide instant-start for parallel wiring connection of lamps. Allow remaining lamps to maintain full output, in the event of lamp failure on multiple lamp luminaire.
 - l. Provide reliable lamp starting at 50 degrees F for interior luminaires and 0 degrees F for exterior luminaires.
3. HID Ballasts: ANSI C82.4, fused.

B. Lamps:

1. Provide lamps used in the illumination system of standard manufacture, readily available, and of the highest efficiency and life consistent with other requirements of the illumination system.
2. Ensure all lamps of each type are provided by a single manufacturer.

3. Fluorescent Lamps:
 - a. Energy-efficient T8, rapid-start fluorescent lamp rated 265 mA.
 - b. Life: Ensure lamps have a rated minimum average life of 20,000 hours.
 - c. Color Temperature: Minimum 3500 degrees K Correlated Color Temperature (CCT).
 - d. Color Rendering Index (CRI): Minimum 78.
 - e. Environmental: Use lamps for T8 fluorescent lighting that have reduced mercury contents that meet U.S. Environmental Protection Agency (EPA) Toxic Characteristic Leaching Procedure (TCLP) test for nonhazardous fluorescent light waste.
4. Metal Halide Lamps:
 - a. Suitable for all operating positions. Ensure Photometric characteristics provide maximum luminous output while operating in the horizontal position.
 - b. Color temperature: 3700 degrees K.
 - c. Color Rendering Index (CRI): 70.
- C. Reflector Material: Prefinished, copper-free aluminum alloy, minimum thickness 0.032 inch, Architectural Type 1 with Class M1 anodic coating providing 83 percent reflectivity.

2.03 LUMINAIRES

- A. Interior of Substation Enclosure
 1. Ceiling mounted, industrial fluorescent luminaire with clear, prismatic diffuser complying with UL 1570.
 2. Acrylic lens: Manufactured from virgin-acrylic extrusion or injection molding pellets.
- B. Exterior of Substation Enclosure
 1. Wall mounted, high-intensity discharge, single lamp, vandal proof, cut-off type.
 2. UL 1598 listed for 40 degrees C, wet locations.
 3. Housing: Die-cast copper-free aluminum, with a self-hinged door secured by captive stainless steel tamper-resistant screws.
 4. Finish: Epoxy or powder-coat paint.
 5. Refractor: Molded prismatic polycarbonate manufactured from high temperature resin designed for use with HID lamps.

6. Provide integral photoelectric controls.

C. Emergency Lighting:

1. Self contained units containing lamps, a battery, battery charger, controls, test switch, condition pilot light, and low voltage battery disconnect.
2. Lighting Heads: High-output, fully adjustable, sealed beam PAR halogen lamps; minimum two lamps per unit.
3. Battery:
 - a. Nickel-cadmium, 6 V or 12 V, rechargeable, sealed, maintenance free.
 - b. Capacity: Shall supply rated load for 1-1/2 hours with an end voltage of not less than 87.5 percent of nominal battery voltage.
 - c. Life expectancy: 10 years.
4. Battery charger:
 - a. Solid-state, current-limited, temperature-compensated, short-circuit proof, and reverse-polarity protected with plus-or-minus 1 percent regulation.
 - b. Charger shall automatically maintain battery in fully-charged float condition and be capable of providing full recharge in 12 hours.
5. A sealed relaying device within the unit shall energize the lamps automatically upon failure of the ac power supply.
6. Housing: NEMA 1, 18-gage steel, minimum, with a baked enamel finish.
7. UL 924 listed for emergency lighting.
8. Luminaires shall be complete with lamps in place.

2.04 LIGHTING INSIDE EQUIPMENT ENCLOSURES

A. Luminaire:

1. Ceiling mounted, industrial fluorescent luminaire with clear, prismatic diffuser complying with UL 1570.
2. Acrylic lens: Manufactured from virgin-acrylic extrusion or injection molding pellets.
3. Minimum Length: 6 inches less than cubicle width.

2.05 ASSEMBLY

- A. Luminaires shall be supplied from the substation ac panelboard.

- B. Interior Luminaires:
 - 1. Locate to illuminate the vertical surfaces of equipment.
 - a. Coordinate to avoid interference with overhead raceways or other major wiring or blocking of the light.
 - b. Luminaires shall not be mounted directly above equipment.
 - 2. Switch with 3-way switches mounted inside the substation enclosure by each entry door.
- C. Exterior luminaires: Locate as indicated on Contract Drawings, unless otherwise approved by Engineer.
- D. Emergency lighting:
 - 1. Supply from substation ac panelboard.
 - 2. Wire unswitched.
- E. Lighting inside equipment enclosures:
 - 1. Locate on ceiling to light the interior of each equipment enclosure.
 - 2. Switch locally with external switch.
 - 3. Provide an isolation transformer external to the switchgear for both rectifier and dc switchgear lighting.

PART 3 EXECUTION

Not Used.

END OF SECTION 26 50 00

SECTION 34 21 05

COMMON WORK RESULTS FOR TPSS

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Design, build, deliver, pick, and set prepackaged traction power substations (TPSS) on slab provided by others. Substation will be secured to slab by others.
2. Design, furnish equipment for, commission, energize, and test built in place traction power substations installed by others, and provide field engineer time during installation.
3. Miscellaneous materials, equipment, and components including but not limited to fasteners and hardware, insulating materials, relays, contacts, coils, switches, indicators, smoke detector, blue light, Knox box, mobile work station, fire extinguisher, and dc breaker test station.
4. Requirements of this Section apply to all 34 21 xx sections.

B. Products Furnished But Not Installed Under This Section:

1. Two dc breaker test stations, one for Operation Maintenance Facility (OMF) traction power substation (TPSS) and one for King Street TPSS.
2. Two mobile work stations, one for OMF TPSS and one for King Street TPSS.

C. Related Sections:

1. Section 05 05 00 – Common Work Results for Metals
2. Section 09 67 25 – Dielectric Epoxy Flooring
3. Section 22 45 19 – Self Contained Eyewash Equipment
4. Section 26 05 00 – Common Work Results for Electrical
5. Section 26 05 19 – Low-Voltage Conductors and Cable
6. Section 26 05 33 – Raceway and Boxes
7. Section 26 24 13 – Switchboards
8. Section 34 21 12 – TPSS Installation
9. Section 34 21 19 – Dc Switchgear

10. Section 34 21 23 – Transformer-Rectifier Unit.
11. Section 34 21 25 – TPSS Dc Control Power
12. Section 34 21 31 – TPSS Alarm Panel
13. Section 34 21 33 – Rail Voltage Monitoring and Grounding System
14. Section 34 21 46 – Traction Power Dc Contactor Panel
15. Section 34 21 50 – Dc Surge Arresters
16. Section 34 21 60 – TES Spare Parts and Special Tools
17. Section 34 21 73 – TE System Studies
18. Section 34 21 90 – TPSS Testing

1.02 REFERENCES

A. Definitions:

1. Intelligent Electronic Device (IED): Refers to any digital or numerical-based protection, metering, control, or monitoring device that has processing, recording and reporting capabilities and a local human machine interface (HMI).
2. Authority Having Jurisdiction (AHJ): As defined in NFPA 70, Article 100, Definitions.

B. Reference Standards:

1. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:
2. National Electrical Contractors Association (NECA)
 - a. NECA 1, Standard Practice of Good Workmanship in Electrical Construction
3. National Electrical Manufacturers Association (NEMA)
 - a. NEMA 250, Enclosures for Electrical Equipment (1000 Volts Maximum)
4. National Fire Protection Association (NFPA)
 - a. NFPA 70, National Electrical Code (NEC) (with amendments by the Authority Having Jurisdiction)

1.03 ELECTRIC UTILITY COORDINATION

- A. Obtain Seattle City Light (SCL) metering requirements and verify compliance of proposed equipment with SCL.

- B. SCL will provide current transformers (CTs) and metering conductors.
- C. Installation contractor will coordinate installation of CTs and metering wiring with SCL.
- D. See Section 34 21 12, TPSS Installation, for additional coordination requirements.

1.04 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Product Data: Submit manufacturer's product data for products specified in this Section if not submitted under another Section:
 - 1. Current transformer (CT) cabinet.
 - 2. Relays.
 - 3. Switches and indicators.
 - 4. Intrusion detection switches.
 - 5. Terminal blocks.
 - 6. Smoke detector.
 - 7. Exterior blue light, including luminaire, lens, LED light, and flasher.
 - 8. Knox box.
 - 9. Mobile work station.
 - 10. Fire extinguisher.
 - 11. Dc breaker test station.
 - 12. ETS buttons and enclosures.
 - 13. Fasteners.
 - 14. Hardware.
 - 15. Cable ties.
 - 16. Electrical insulating laminate.
 - 17. Software.
 - 18. Identification products.

- C. Spare Parts:
1. Submit a list of spare parts to be provided under this Section.
 2. Submit at the same time as product data.
 3. Provide part numbers for each part, including a detailed break down of each spare part assembly and set, as defined in Section 34 21 60, TES Spare Parts and Special Tools.
- D. Identification Schedule: Submit a proposed schedule of nameplates and labels, including material, size, color, and text, before ordering.
- E. Drawings: Provide the following drawing types for substations. Comply with Owner's drafting standards:
1. One-line Diagrams: Provide for each substation.
 2. Three-line Diagrams: Provide for each substation. See Contract Drawings for a typical three-line diagram.
 3. Schematic Diagrams:
 - a. Format by subsystem, using identical device symbols and wire designators for each subsystem.
 - b. Clearly delineate interfaces, from page to page and subsystem to subsystem.
 - c. These drawings shall include at least the following information:
 - 1) Wire connections, terminations and identification.
 - 2) Nominal voltages, equipment and equipment ratings, currents, frequencies, significant resistance values, and the rating of all loads.
 - 3) All low voltage dc control circuits.
 - 4) Schematic location (page number, for example) of the energization portion of each device (such as the coil in a relay) noted adjacent to the operating portions (such as relay interlocks) of the device.
 4. Wiring diagrams:
 - a. Provide a set of wiring diagrams for each substation.
 - b. Show all wiring, raceways, conduits, and connections.
 - c. Provide equipment connection, intra-cubicle, and inter-cubicle wiring diagrams.
 - d. Connection diagrams: Show the internal wiring and terminal block arrangement within each piece of equipment and identify each outgoing power and control connection and wire.

- e. Interconnection diagrams: Show wiring from the equipment terminal blocks, to external equipment connections, terminal blocks, and devices.
 - f. Show nominal voltages, equipment and equipment ratings, currents, frequencies, significant resistance values, and the rating of all loads.
 - g. Label devices identical to the actual device and show their locations on panels.
 - h. Each terminal block and device shall have its own unique numbers and letters for identification.
 - i. As a minimum, provide the following information for each wire segment:
 - 1) Wire code (schematic designation).
 - 2) Origin (FROM device and terminal).
 - 3) Destination (TO device and terminal).
 - 4) Wire size.
5. Substation Equipment and Raceway Drawings.
 6. Panel schedules.
 7. Equipment arrangement drawings: Show actual equipment to be provided and details of installation, using the layout provided in Contract Drawings.
 - a. Alternate substation equipment layouts may be proposed by Contractor, subject to Engineer's approval.
 - b. Provide the following drawings as a minimum:
 - 1) Certified substation footprint with locations of openings for incoming and outgoing feeders within 45 days of NTP.
 - 2) Substation plans and elevations showing the equipment layout, including equipment numbers, locations, and dimensions.
 - 3) Equipment front elevations and wall elevations showing the location of each piece of equipment and dimensions.
 - 4) Installation and mounting details for all equipment, including installation of the transformer enclosure partitions, method of anchorage for each piece of equipment, and method for providing electrical isolation for the dc switchgear.
 - 5) Raceway layout plans showing cable trays, conduits, including numbers, locations, and dimensions.

F. Substation ANSI Device Table:

1. Provide a set of device tables for substation ANSI devices in a single section at the rear of the schematic book.
2. Arrange the table in a logical fashion by system device type.
3. Provide data for all system and subsystem components including, but not limited to the following:
 - a. Electrical control and power components (groups, panels, pc cards, contactors, relays, circuit breakers, capacitors, inductors, resistors, specialized modules, rectifiers, diodes, fuses and other components, as appropriate).
 - b. Electrical equipment (rectifiers, transformers, switchgear, substation alarm panel, interface terminal board, and the like).
4. Include the following data:
 - a. Equipment and associated number where a device is located.
 - b. Elementary schematic drawing number where the device appears.
 - c. A brief description of the device.
 - d. Manufacturer's model or style number.
 - e. Manufacturer's name and type number of the device.
 - f. Device rating.
 - g. Number, rating, and types of contacts on device, if applicable.
 - h. Remarks on any other relevant features of the device.

G. Bill of Materials (BOM): Provide the following information:

1. Contract number.
2. Supplier number.
3. Provision for Owner's stores number.
4. Other data required for procurement of materials used in the construction of all parts of the electrification system.
5. Cross-reference to related drawings and the BOMs.
6. Generic description or specification.
7. Brand name, where applicable.

8. Manufacturer's part number.
 9. Original manufacturer or supplier, including address, telephone number, e-mail address, FAX number, and contact person.
 10. Notation on parts that are custom manufactured only upon request.
- H. Operations and Maintenance Data: Submit data in accordance with Section 01 78 23, Operation and Maintenance Data, including the following requirements:
1. Submittal information identified above.
 2. Manufacturer's operating and maintenance instructions, parts list, illustrations and diagram for components.
 3. Recommended list of spare parts.
- I. Samples: Submit a sample of each type of identification product.
- J. Substation History Books
1. The substation "history book" shall contain a complete record for each substation, shall be kept up to date throughout the manufacturing process, and may be inspected by the Engineer at any time.
 2. Provide a history book for each substation, including two built-in-place substations, with the following information at a minimum:
 - a. Copy of approved plan review by the City of Seattle, Department of Planning and Development (DPD), if plan review is required.
 - b. Factory production test reports.
 - c. Description and completion dates of substation modifications, and a list of modifications pending with expected completion dates.
 - d. A record of abnormalities that occur during the manufacture of the substation or its subsystems, including their authorized repair procedures.
 - e. List of substation defects that were identified by the Contractor's QA or the Engineer during assembly, commissioning, and testing, and the disposition of each as verified by inspection.
 - f. List of serial-numbered apparatus.
 - g. Shipping documents.
 - h. Field acceptance test reports.
 - i. Integrated testing reports.

- j. Final relay settings.
 - k. Copy of final R2G settings.
 - l. Copy of permit signed off by the City of Seattle, DPD.
 - m. Open items status list.
3. Changes in recorded data that are made during performance of the Contract shall be clearly identified and justified to the satisfaction of the Engineer.

1.05 SPARE PARTS

- A. Provide spare parts in accordance with Section 34 21 60, TES Spare Parts and Special Tools.
- B. List below applies to items in this Specification Section.
 - 1. Blue light lens: Provide 2 spare.
 - 2. Blue light LED light: Provide 2 spare.
 - 3. Blue light flasher: Provide 2 spare.

1.06 QUALITY ASSURANCE

- A. Regulatory Requirements:
 - 1. Comply with current federal, state, and local requirements.
 - 2. See Section 01 41 00, Regulatory Requirements, for permit requirements and conditions.
- B. Qualifications:
 - 1. Electrical work at TPSS manufacturer's plant shall be performed by electrical workers skilled in the installation of electrical equipment and knowledgeable in the requirements of NFPA 70 (with amendments by the Authority Having Jurisdiction) and NECA 1, as certified by manufacturer's Quality Program Plan.
 - 2. Welding shall be done by welders qualified as stated in Section 05 05 00, Common Work Results for Metals.
 - 3. The electrically insulated floor covering shall be installed by approved workers skilled and experienced in the installation of the approved product.
 - 4. The ac and dc coordination studies shall comply with the qualification and software requirements of Section 34 21 73, TE System Studies.

C. General Performance Requirements:

1. Provide electrification equipment proven in similar railroad, rail transit, or heavy industrial service and make use of this experience to prepare a suitable and proven design for this application.
2. Each component, subassembly and assembly provided in this Contract shall be of a proven design with a history of at least 5 years successful operation at the time of Contract award in similar railroad or rail transit service.
3. Systems Integration: Integrate TES elements such that specified requirements are achieved without conflict or error within or between specified elements.
4. Traction Power Substation Expected Service Life: 50 years in continuous service, 24 hours a day, 365 days a year.
5. Use off-the-shelf service-proven equipment and hardware approved by the Engineer to achieve this useful life.
6. Provide replacement spare parts that are functionally and physically interchangeable for each product class.

D. Listed and Labeled Equipment and Material:

1. Provide wherever standards for these products have been established.
2. Materials that are not listed or labeled require approval by Engineer before use.
3. Products which have not been tested or certified for the use intended shall not be used when equivalent listed or labeled materials are available.
4. The label or listing will be acceptable as sufficient evidence that the materials and equipment do conform to the specified standards.
5. Electrical equipment and material not listed or labeled shall be furnished with a Field Evaluation label provided by an approved Testing Laboratory, and certifying that the equipment conforms to the requirements of UL and ANSI.
 - a. This product evaluation may be performed in the factory or on-site as approved by Engineer.
 - b. A request for permission to perform a Field Evaluation in the factory or onsite shall be submitted to Engineer for approval.

1.07 WARRANTY

- A. Provide an extended warranty for unproven equipment in accordance with Section 01 78 36, Warranties.

- B. Unproven equipment means equipment that meets any one of the criteria described below:
1. Equipment that is not service proven in the rail transit industry in the United States. To be service proven equipment shall have been in use for a minimum of five years.
 2. Equipment or assemblies that have not been used before by this manufacturer in the rail transit industry in the United States.
 3. Equipment or assemblies that use software developed from the ground up for this project.

PART 2 PRODUCTS

2.01 TRACTION POWER SUBSTATION DESCRIPTION AND DESIGN CRITERIA

- A. Traction Electrification Substation General Parameters:
1. Provide complete factory assembled traction power substation in weatherproof enclosure
 2. Substation rating: 350 KW, light traction service; OMF, 100 kW.
 3. Substations will be unattended.
 4. Dc System Voltage:
 - a. 795 Vdc at 1 percent load.
 - b. 750 Vdc at rated load.
 - c. Maximum Voltage with Regeneration: 950 Vdc.
- B. Environmental Requirements: Provide substation suitable for operation without impairments at its standard ratings throughout the range of worst values listed below:
1. Ambient Outdoor Temperature: 0 degrees F to 103 degrees F
 2. Maximum Ambient Outdoor Humidity: 100 percent.
 3. Design Wind Speed: 65 mph.
 4. Seismic: Comply with Section 26 05 00, Common Work Results for Electrical.
 5. Altitude: Less than 500 feet above sea level.
- C. Utility Data: Power to the traction power substations will be supplied from Seattle City Light (SCL) at 480 V. Other required utility data may be obtained from SCL.

2.02 GENERAL TRACTION POWER SUBSTATION REQUIREMENTS

- A. All like TPSS equipment shall be identical, including raceways and wiring, and shall be fully interchangeable without modification.
- B. Provide breaker or switch auxiliary contacts where position indications from circuit breakers or disconnect switches are required. Auxiliary relays are not acceptable to monitor position indication of circuit breakers or disconnect switches.
- C. The proposed TPSS equipment shall fit within the space as shown in Contract Drawings.
- D. Material shall be new and in first class condition, suitable for the use intended and of the manufacturer's latest standard design
- E. Provide materials and equipment which are standard products of manufacturers regularly engaged in the production of such material and equipment.
- F. Where two or more units of the same class of material or equipment are required, provide products of a single manufacturer.
- G. Similar component parts of different larger assemblies are not required to be the products of the same manufacturer.
- H. Discontinued materials or products shall not be permitted.
- I. Each type of material and equipment shall be of the same manufacture and quality throughout the Work.

2.03 TPSS COMPONENTS AND PRODUCTS

- A. Utility Metering:
 - 1. Meter base and conduit to the meter base complying with requirements of SCL.
 - 2. CT cabinet: Galvanized steel, complying with requirements of SCL.
- B. Relays:
 - 1. Contacts:
 - a. Current rating: Based on continuous, inrush, or interrupting requirements for the duty category as defined by IEC 60512-15-8 Ed. 1.0 b:1995, whichever is most stringent, and then derated by at least a factor of four.
 - b. Voltage rating: Contacts shall be rated for a minimum of twice the applied voltage.
 - c. Select materials for the actual loads and not solely on the device rating. Silver bifurcated contacts and gold alloy bifurcated cross-bar contacts are preferred on low level and dry circuits, respectively.

2. Coils:
 - a. Coils of all devices shall be suppressed, except where performance may be affected.
 - b. Unsuppressed coils are permitted only with written approval of the Engineer.
 3. Service Life: Relays shall have a guaranteed mechanical service life of at least 50 years.
 4. Protective relays: ANSI C37.90, utility grade, immune from inadvertent operation due to ambient EMI, including radio frequency signals.
 5. Auxiliary and control relays:
 - a. Heavy duty, UL listed.
 - b. Mechanical durability: Minimum 50,000 cycles.
 - c. Electrical durability: Minimum 100,000 cycles for resistive load.
- C. Switches and Indicators:
1. Position switches (Device 33): Roller plunger type switch, rated heavy or medium duty, brass or steel plunger, metallic enclosure, rated for 20,000 operations, minimum.
 2. Indicating Lights:
 - a. Long-life, high-brightness using LED arrays and integral current limiting resistors.
 - b. Indicators shall be selected to permit maximum visibility in direct sunlight from all viewing angles.
- D. Intrusion Detection:
1. Door switches: Magnetic, rated heavy or medium duty, metallic case, screw mounted.
- E. Terminal blocks: Heavy duty, suitable for use with ring terminals, with insulated, removable covers.
- F. Smoke detectors:
1. Ionization photoelectric type.
 2. Plug-in unit with mounting plate hard wired.
 3. Integrally self-monitoring, self-diagnostic, with visual trouble indication.
 4. Designed to reduce false alarms from dust, insects, radio frequency interference (RFI), and external light.

- G. Exterior Blue Light:
 - 1. Luminaire: Wall mount, UL listed for wet locations.
 - 2. Light: LED blue color light, providing 360 degrees illumination.
 - a. Approved Manufacturer/Product: Watt-Man L.E.D, BL60B120M, or approved equal.
 - b. Substitutions: Per 01 25 00, Substitution Procedures.
 - 3. Flasher: Solid state, plug-in style, flash rate of 30 flashes per minute.
 - 4. Lens: Clear color, polycarbonate type, vandal proof.
 - 5. Light shall incorporate a fail safe circuit with an annunciator indicating failure of the lamp, power supply, or fuse.
- H. Knox box with lock: 6 inches by 6 inches by 4 inches. Obtain keying requirements from Seattle Fire Department.
- I. Mobile Workstation:
 - 1. Description: Caster-equipped non-metallic tool cabinet topped with a work surface suitable to hold drawings, tools, or portable test instruments.
 - 2. Construction:
 - a. Heavy-duty plastic.
 - b. Capacity: 750 pounds.
 - 3. Features:
 - a. Wheels: Four 5-inch casters.
 - b. Drawers: Four, with ball bearing door slides.
 - c. Cabinet with adjustable shelf.
 - d. Built-in drawer lock.
 - 4. Nominal Dimensions:
 - a. Width: 49 inches.
 - b. Depth: 26 inches.
 - c. Height: Nominal 38 inches.
 - 5. Approved Manufacturer/Product: Rubbermaid TradeMaster, Model 4533-88.

- 6. Substitutions: Per 01 25 00 Substitution Procedures.

- J. Fire extinguisher: Portable, dry chemical type appropriate for equipment provided, 20 pound, CO₂.

- K. Dc breaker test station:
 - 1. Capable of tripping dc breaker.
 - 2. Umbilical cord:
 - a. For connecting to breaker.
 - b. Provide strain relief where cord connects to cabinet.
 - c. Provide means to conveniently stow umbilical cord when not in use.

- L. Emergency Trip Stations:
 - 1. ETS Buttons: Heavy duty, industrial grade, latching, pushbutton operator and contact block, rated for the load, large mushroom head, red.
 - 2. Protective cover: Provide cover or shield to prevent inadvertent activation. Engineer will determine whether proposed protective cover is suitable for the intended purpose.
 - 3. Interior ETS enclosures: NEMA 250 Type 1, in accordance with Section 26 05 33, Raceway and Boxes, for dry, interior locations.
 - 4. Exterior ETS enclosures: NEMA 250 Type 4X, stainless steel, gasketed, hinged, lockable. Provide padlock keyed as directed by Engineer.

2.04 MATERIALS

- A. Fasteners, Hardware:
 - 1. Fasteners: Stainless steel. Double-sided tape shall not be used for attachment of channel or wire supports.
 - 2. Hardware:
 - a. Corrosion resistant.
 - b. Suitable for the use and environment intended by the manufacturer.
 - c. Unplated steel shall not be used.

- B. Cable ties (tie wraps): Comply with requirements of Section 26 05 19, Low-Voltage Conductors and Cable.

2.05 PROTECTION OF MATERIAL AND EQUIPMENT FROM ENVIRONMENT

- A. Material and equipment shall be designed to ensure satisfactory operation and life in the environmental conditions that exist where the material or equipment is installed.
- B. Material and equipment shall be suitable for its intended environment.
 - 1. Wet locations: NEMA 250 Type 4X corrosion resistant stainless steel enclosures.
 - 2. Indoor damp locations: NEMA 250 Type 12 enclosures fabricated from painted-galvanized or stainless steel.
 - 3. Wet or damp locations: Corrosion resistant fittings or supports, hot-dip galvanized or as otherwise specified.
 - 4. Exposed dry locations: Corrosion resistant painted finishes may be used for equipment and enclosures as approved by Engineer.
- C. Ferrous Metal:
 - 1. Above Grade: Hot dip galvanized, galvanized, or powder coated. Refer to Galvanizing or Shop Applied Coatings in Section 05 05 00, Common Work Results for Metals.
- D. Galvanizing:
 - 1. Wherever "galvanized" or "hot-dip galvanized" is called out in these Specifications, the material shall be coated in accordance with galvanizing requirements in Section 05 05 00, Common Work Results for Metals.

2.06 INSULATING MATERIALS

- A. Wherever "electrical insulating laminates", "laminates" or "glastic barrier" are called out in the Contract Documents, use the following:
 - 1. Approved Manufacturer/Product: Roehling Glastic Composites, Glastic 1494.
 - 2. Substitutions: Per 01 25 00, Substitution Procedures.
 - 3. Thickness: 1/4 inch.
- B. Electrically Insulated Floor Covering: Specified in Section 09 67 25, Dielectric Epoxy Flooring.
- C. Sheet rubber: Minimum thickness 0.8 mm.
- D. Prohibited insulating materials.
 - 1. Electrical insulating paper, also called "fish paper".
 - 2. Electrical tape of any type.

2.07 BUILT-IN-PLACE TRACTION POWER SUBSTATIONS

- A. Design complete OMF and King Street traction power substations, including the following:
1. Provide installation drawings showing furnished equipment, interconnecting wiring, raceways, insulating laminate, emergency trip stations in TPSS, and other elements for a complete, fully functional substation.
 2. Provide wiring diagrams and schematic diagrams.
 3. Provide seismic equipment anchoring design sealed by an engineer registered in the State of Washington.
 4. OMF Substation Only:
 - a. Feed from dc breaker to dc contactor panel. Design does not include feeds from contactor panel to OCS or interlocking wiring from dc contactor panel to interlocked equipment in the OMF.
 - b. OMF emergency trip stations (ETS): Design includes wiring of ETSs within the substation. Design includes connection but not wiring of OMF ETSs not within the substation.
- B. Furnish the following equipment for installation by others:
1. Ac switchboard and breaker as shown on Contract Drawings, complying with Section 26 24 13, Switchboards.
 2. Dc switchgear, including positive disconnect switch (89P), negative disconnect switch (89N), and feeder breakers as shown on Contract Drawings, complying with Section 34 21 19, Dc Switchgear.
 3. Transformer-rectifier unit, complying with Section 34 21 23, Transformer-Rectifier Unit.
 4. Battery charger eliminator, batteries, enclosed low voltage switch, and fuses, complying with Section 34 21 25, TPSS Dc Control Power.
 5. Dc panelboard with circuit breakers, complying with Section 34 21 25, TPSS Dc Control Power.
 6. TPSS alarm panel, complying with Section 34 21 31, TPSS Alarm panel.
 7. R2G (King Street only), complying with Section 34 21 33, Rail Voltage Monitoring and Grounding System.
 8. Traction power dc contactor panel (OMF only), complying with Section 34 21 46, Traction Power Dc Contactor Panel.
 9. Dc surge arresters and enclosures (King Street only), complying with Section 34 21 50, Dc Surge Arresters.

10. Dc breaker test station, complying with this Section.
 11. Mobile work station, complying with this Section.
 12. Eyewash station complete with eyewash fluid, complying with Section 22 45 19.
- C. Provide equipment identification nameplates on furnished equipment, complying with this Section.
- D. Provided by others: Other material and equipment required for a complete and operating substation such as ac auxiliary power, HVAC, insulated floor, room lighting, emergency lighting, fire alarm system, convenience outlets, electrical insulating laminate, wire, raceways, ETS, and fire extinguisher.

2.08 SOFTWARE

- A. Provide interface and configuration software for uploading settings to and downloading event history from intelligent electronic device (IED).
- B. Provide software that will work with each type of IED provided under a Division 34 Specification Section.
- C. Software shall work on a standard laptop with Microsoft Windows XP and 7 operating systems.

2.09 RADIO FREQUENCY INTERFERENCE

- A. Design TPSS equipment, protective relays meters, instruments and devices to minimize the radio frequency generated and to be immune from inadvertent operation by ambient radio frequency signals.

2.10 IDENTIFICATION

- A. Equipment Identification
1. Provide a number for each major piece of equipment such as switchgear sections, circuit breakers, and devices.
 - a. Prefix: Traction power substation number, as indicated on Contract Drawings.
 - b. Suffix: Indicates the type of equipment or device.
 2. Use the Owner's numbering scheme on submitted Contractor drawings and submittals.
 3. Place the Owner's part number on as-built drawings.
 4. Develop equipment designation scheme compatible with KC Metro substation standards. Engineer will furnish numbering standard.

- B. Wire and Cable:
1. Develop an identification scheme for wires and cables for use on Contractor drawings.
 2. For wire and cable tag requirements, see Section 26 05 00, Common Work Results for Electrical.
- C. Nameplates:
1. Engraved three-layer melamine laminated plastic, not less than 3/32-inch thick. Provide nameplates with black letters on a white background unless otherwise noted.
 2. Equipment nameplates: 1-5/8 inches high with 7/8-inch high characters minimum.
 3. Device nameplates: 7/8-inch high and have 1/4-inch high characters.
 4. Other equipment nameplates shall be sized and lettered according to the equipment and application as approved by the Engineer.
- D. Permanently identify equipment with engraved metal labels containing the following:
1. Supplier's name.
 2. Part number.
 3. Revision level.
- E. Serial Numbers:
1. Assign discrete serial numbers in sequential, numerical order for the total quantity of each component, including spares.
 2. Serial numbers are subject to the Engineer's approval.
 3. Duplicate serial numbers shall not be used within the type or model.
 4. Present to the Engineer as each portion of the installation is completed or when spare components are received.
 5. Track serial number transfers and prepare a list of all serial-numbered apparatus installed in each TPSS for inclusion in the TPSS history book.
- F. At a minimum, the following equipment shall have serial numbers applied:
1. Ac Main Breaker.
 2. Rectifier Transformer.
 3. Rectifier Assemblies.

4. Interphase Transformers.
5. Dc Feeder Breakers.
6. Auxiliary Power Transformer.
7. TPSS Display.
8. Motors within Equipment.
9. Electronic Cards.
10. Enclosures.
11. Manual Operated Disconnect Switches.

2.11 PROGRAMMING

- A. Make provisions for future transfer trip.

2.12 ASSEMBLY

- A. General:

1. Torque bolted connections with a calibrated torque wrench in accordance with manufacturer's recommendations and apply torque marks.
2. Conveniently locate devices requiring regular calibration, resetting or operation within easy reach of personnel.

- B. Utility metering: Install in compliance with SCL requirements.

- C. Relays:

1. Wire Terminations: Terminate a maximum of two wires on relay or contactor terminals.
2. Orientation: Mount and orient relays and contactors as recommended by the supplier or manufacturer.

- D. Switches and Indicators:

1. Position switches (Device 33):
 - a. Provide at the following door locations to trip and lock out the ac main breaker and annunciate the opening of a door. :
 - 1) Top and bottom of the rectifier interior enclosure doors.
 - 2) Top and bottom of the transformer interior enclosure doors.

- 3) Top of positive and negative disconnect switch doors.
 - 4) Top of each exterior equipment door.
 - b. Separate control compartments do not require Device 33.
 - c. Provide on negative and positive switches to indicate switch position.
 - 2. Position Indication:
 - a. Breaker Closed: Illuminated red light.
 - b. Breaker Open: Illuminated green light.
 - c. Lockout relay normal position: Illuminated red light.
 - d. Lockout relay tripped: Illuminated green light.
 - 3. Indicating lights:
 - a. LEDs used on the switchgear sections shall be of the same manufacturer and model.
- E. Intrusion Detection:
- 1. Door switches:
 - a. Provide at each entry door and at each exterior equipment access door.
 - 2. Wire two zones as follows:
 - a. Zone One: Entry doors.
 - b. Zone Two: Exterior equipment access doors.
- F. Smoke detectors:
- 1. Operation: Provide alarm contact to operate lockout trip relay, ANSI Device 86 upon detection of smoke.
 - 2. Location: Provide at strategic locations to detect smoke or products of combustion such that operation of the circuit breakers will not activate smoke detection system.
 - 3. Smoke detector in OMF traction power substation, provided by others, shall not operate lockout trip relay.
- G. Exterior Blue light:
- 1. Install flasher in blue-light circuit.

2. Blue Light shall illuminate for alarms indicated in Section 34 21 31, TPSS Alarm Panel.
 3. Provide one blue light for each TPSS.
 4. Mount such that passing streetcars can see it, in a location approved by the Engineer.
 5. Make provisions at each TPSS for the connection of a second blue light, 120 Vac, to be provided on another structure by others, including the following:
 - a. Wall-mounted box complete with cover. Coordinate location with Engineer.
 - b. Wiring to the box such that the OCS-mounted blue light will operate in parallel with TPSS blue light when connected to this wiring.
 - c. Flasher wired into the circuit.
- H. Mobile Workstation: Provide one in each substation.
- I. Fire extinguisher:
1. Mount to the inside wall of the substation enclosure near each entry door.
 2. Provide two per substation.
- J. Dc breaker test station:
1. Provide one wall mounted unit per substation.
 2. Install each test station in close proximity to circuit breakers to be tested.
- K. Emergency Trip Stations:
1. Provide on the interior of each TPSS building next to both entrances and one on the exterior as shown on Contract Drawings.
 2. Wire emergency trip station pushbuttons in a loop circuit of series wired contacts that energize a summary relay.
 3. Interruption of the series circuit shall cause the TPSS to shutdown by:
 - a. Tripping and locking out the main ac breaker.
 - b. Tripping and locking out all dc feeder breakers.
- L. Cable ties (tie wraps):
1. Secure cable tie mounting blocks with a screw.
 2. Adhesive type mounting blocks shall not be used unless secured with a screw.

M. Dissimilar material connections:

1. Not permitted at electrical connections or connections requiring disassembly for maintenance or for removal and replacement of equipment.
2. Not permitted except at permanent connections.
3. Provide suitable electrochemical isolation.
4. Isolation treatments shall be permanent and not require maintenance or replacement for the life of the equipment or installation.

N. Insulating Materials:

1. Insulate the following with electrical insulating laminate:
 - a. Walls:
 - 1) If the clearance between the dc switchgear and wall is less than 6 feet, cover wall to full height.
 - 2) Exception: Omit electrical insulating laminate on inside surfaces of rear equipment access doors.
 - b. HVAC ducts: Cover all parts of duct with clearance from dc switchgear less than 6 feet.
 - c. Between traction power transformer and rectifier.
 - 1) Provide a continuous piece of laminate to isolate the traction power transformer from the rectifier, as indicated on Contract Drawings.
 - 2) Extend full height barrier into the room far enough to make it physically impossible for a person to touch both the traction power transformer and the dc equipment at the same time.
 - 3) Reinforce edge with a non-metallic angle or channel fastened to the floor and ceiling for stiffness.
 - d. Between rectifier and negative cubicle.
 - e. Between negative cubicle and dc feeder breakers.
 - f. Metallic surfaces:
 - 1) Within 6 feet of rectifier or dc switchgear.
 - 2) For metallic surfaces not suitable for electrical insulating laminates, such as curved surfaces, provide sheet rubber.
 - g. Arc chutes: Provide a continuous piece of laminate on the ceiling over arc chutes of dc breakers if conductive surfaces are within 3 feet of top of dc switchgear.

2. Fasteners: Secure laminate in place using non-conductive and non-metallic fasteners, in accordance with manufacturer's instructions.
- O. Identification:
1. Nameplates: Fasten nameplates to the equipment or device enclosure door with stainless steel machine screws.
 2. Labels: Attach with rivets or other approved permanent method. Adhesive attached labels are prohibited.

PART 3 EXECUTION

3.01 BUILT-IN-PLACE TPSS FIELD ENGINEERING, COMMISSIONING, AND TESTING

- A. During installation of OMF and King Street TPSS equipment by others, provide 200 hours of field engineer time to advise installation contractor, verify that equipment and wiring are installed correctly, and document changes made for as-built drawings.
- B. Commission and test substation in accordance with Section 34 21 90, TPSS Testing.
- C. Submit as-built drawings in accordance with Section 01 78 39, Project Record Documents

END OF SECTION 34 21 05

SECTION 34 21 12

TRACTION POWER SUBSTATION INSTALLATION

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. Delivering and setting traction power substations (TPSS).
- B. Temporary power and heat for TPSS.

1.02 REFERENCE STANDARDS

- A. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:
- B. National Fire Protection Association (NFPA)
 - 1. NFPA 70, National Electrical Code (with amendments by the Authority Having Jurisdiction)

1.03 COORDINATION

- A. Coordinate delivery of prefabricated substation with Engineer and installation contractor.
 - 1. See Section 01 65 00, Product Delivery Requirements for substation shipment and delivery requirements.
 - 2. Before picking substation off truck, obtain approval to partially or completely restrict a city street, sidewalk, or alley with Seattle Transportation, Traffic Management Division. (Seattle Municipal Tower, 37th floor, 206-684-8482.)
- B. Permanent Electric Utility Power:
 - 1. Installation contractor will coordinate connection of permanent power to substations.
 - 2. Cooperate with installation contractor and Engineer as needed for connection of permanent power and energization.
 - 3. Owner will pay utility bill for permanent power at each substation from the time of connection of permanent power.

1.04 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Submit substation setting plan, including diagram showing position of truck and crane and description of steps involved.

- C. Product Data: Sealing strip.

PART 2 PRODUCTS

- A. Sealing Strip: Water and humidity resistant moisture barrier.
 - 1. Neoprene rubber pad, durometer hardness Shore A 60, tensile strength 900 psi, elongation 300 percent, 1/4 inch by 6 inches.
 - 2. Approved Manufacturer/Product: Biltrite Commercial Neoprene, Style 10.

PART 3 EXECUTION

3.01 SETTING PREFABRICATED TPSS IN PLACE

- A. Before setting TPSS in place, provide a sealing strip between TPSS base and concrete slab.

3.02 TEMPORARY POWER AND HEAT

- A. Provide temporary heat within 24 hours of setting substation to prevent condensation inside the substation until permanent power is connected.
- B. Provide sufficient heat to maintain substation at 65 degrees, day and night.
- C. Provide temporary power to heater.
- D. A portable generator may be used as an alternate to temporary utility power.

END OF SECTION 34 21 12

SECTION 34 21 16
TPSS ENCLOSURES

PART 1 GENERAL

- A. Section Includes:
 - 1. Prefabricated enclosures for traction power substations (TPSS).
 - 2. Optional architectural cladding for prefabricated enclosures.
 - 3. HVAC for prefabricated enclosures.

- B. Related Sections:
 - 1. Section 05 05 00 – Common Work Results for Metals
 - 2. Section 09 67 25 – Dielectric Epoxy Flooring
 - 3. Section 26 05 26 – Grounding and Bonding
 - 4. Section 34 21 05 – Common Work Results for TPSS
 - 5. Section 34 21 19 – Dc Switchgear
 - 6. Section 34 21 23 – Transformer-Rectifier Unit
 - 7. Section 34 21 31 – TPSS Alarm Panel
 - 8. Section 34 21 80 – TES Spare Parts and Special Tools
 - 9. Section 34 21 90 – TPSS Testing

1.02 REFERENCE STANDARDS

- A. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:

- B. American Institute of Steel Construction (AISC)
 - 1. AISC 303, Code of Standard Practice for Steel Buildings and Bridges
 - 2. AISC 325, Steel Construction Manual

- C. ASTM International (ASTM)
 - 1. ASTM A36/A36M, Structural Steel, Standard Specification for Carbon Structural Steel

2. ASTM A653/A653M, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
 3. ASTM D635, Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position
 4. ASTM D638, Standard Test Method for Tensile Properties of Plastics
 5. ASTM D696, Standard Test Method for Coefficient of Linear Thermal Expansion of Plastics Between -30°C and 30°C With a Vitreous Silica Dilatometer
 6. ASTM D790, Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
 7. ASTM D1929, Standard Test Method for Determining Ignition Temperature of Plastics
 8. ASTM D2843, Standard Test Method for Density of Smoke from the Burning or Decomposition of Plastics
 9. ASTM E136, Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C
 10. Seattle Mechanical Code
- D. Institute of Electrical and Electronics Engineers (IEEE)
1. IEEE 1653.2, Standard for Uncontrolled Traction Power Rectifiers for Substation Applications Up to 1500 Vdc Nominal Output
- E. National Fire Protection Association (NFPA)
1. NFPA 70, National Electrical Code (with amendments by the Authority Having Jurisdiction)
- F. State of Washington
1. International Building Code (with amendments by the Authority Having Jurisdiction)
 2. International Mechanical Code (with amendments by the Authority Having Jurisdiction)
 3. Washington State Energy Code

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Product Data:
 1. Doors and door hardware.

2. HVAC units.
- C. Spare Parts:
1. Submit a list of spare parts to be provided under this Section.
 2. Submit at the same time as product data.
 3. Provide part numbers for each part, including a detailed break down of each spare part assembly and set, as defined in Section 34 21 80, TES Spare Parts and Special Tools.
- D. Shop Drawings:
1. Detailed drawings of substation enclosure complete with all equipment and accessories in place, including layouts, arrangements, plans, sections and elevation views.
 2. Wiring and schematic diagrams of lighting, power receptacles, and heating and ventilating equipment.
 3. Detailed equipment interconnection diagrams and wiring and raceway schedules
 4. Structural details of building including support points and accessories.
 5. Structural and architectural plans, elevations, sections, floor framing plan, lifting and anchorage details, erection diagrams and other prefabricated enclosure details.
 6. Enclosure base anchorage plans, floor plate, and details.
 7. Cable entrance locations and cable support system plans and details
 8. Enclosure and equipment grounding details, including ground grid connections
 9. Identification:
 - a. Exterior substation number designation and location.
 - b. Interior manufacturer's identification and location, if any.
- E. Bill of Materials: All components, indicating quantity, description and part number
- F. Compliance Certificates: For enclosure materials and performance
- G. Calculations:
1. Capacity of heating and ventilating units for ventilation rates, and for cooling and heating loads, certified by a mechanical engineer registered in the State of Washington.

2. Calculations shall include tabulation of interior equipment heat gains, infiltration gains/losses, conductive gains/losses and solar gains.
 3. Structural analysis calculations for roof, wind, and seismic loadings, and of any temporary supports, certified by a structural engineer registered in the State of Washington.
 4. Structural design calculations for the enclosure, anchorage and supports, certified by a Professional Engineer registered in the State of Washington.
- H. Certified Test Results: Thermal, electrical and acoustical insulation, including weather stripping.
- I. Samples:
1. Enclosure shop applied coating color samples.
- J. Substation installation instructions.
- K. Submit test procedures and test reports in accordance with Section 34 21 90, TPSS Testing.
1. Design Tests: Provide design test reports within 30 Days after completion of testing.
 2. Production Tests: Provide production test reports within 30 Days after completion of testing.
- L. Operations and Maintenance Data: Submit data in accordance with Section 01 78 23, Operation and Maintenance Data, including the following requirements:
1. Building: Repair procedure for powder coat finish.
- M. Submit the following for evaluation of optional architectural cladding:
1. Product data for siding panels.
 2. Color selections for siding panels.
 3. Color selections for roof.
 4. Sample of siding panel.
 5. Sample of enclosure and accessory paint color to match siding.
 6. Shop drawing of roof assembly.
 7. Product data for construction adhesive.

1.04 SPARE PARTS

- A. Provide spare parts in accordance with Section 34 21 80, TES Spare Parts and Special Tools.
- B. List below applies to items in this Specification Section.
 - 1. Lock cylinders: Keyed for traction power substation doors; provide 4 spare.
 - 2. Padlocks: Keyed for traction power substation equipment access doors: Provide 6 spare.

PART 2 PRODUCTS

2.01 GENERAL REQUIREMENTS

- A. Each traction power substation enclosure shall be a shop assembled, free-standing, self supporting, steel building, utilizing channel perimeter framework and rigidly braced with channel and angle cross members.
- B. Completed assembly shall be designed for shipment for installation at site.
- C. The enclosure shall be a totally integrated weatherproof unit which houses the indicated traction power substation equipment. The enclosure shall provide a dry, vermin proof, condensation free, stable internal ambient temperature environment.
- D. Design enclosure for securing to a reinforced concrete slab as indicated on the Contract Drawings.
- E. Ratings:
 - 1. Complete enclosure shall have a NEMA 4 rating.
 - 2. Doors, removable panels, joints, walls, roofs, floors, vents, louvers and outdoor accessories shall be weatherproof under environmental conditions specified in 34 21 05, Common Work Results for TES.

2.02 DESIGN CRITERIA

- A. Washington State Department of Labor & Industries (L&I):
 - 1. Design shall comply with requirements of WAC 296-150F, Factory-built housing and commercial structures.
 - a. Design plan shall be approved by L&I, and each building shall have passed inspection by L&I.
 - b. Obtain and apply gold seal insignia to each building indicating that it has been inspected and approved by L&I before it enters the State of Washington.

B. Structural Design:

1. Design enclosures and components for the service life specified in Section 34 21 05, Common Work Results for TES.
2. Design enclosure in accordance with AISC 303 and 325 and the International Building Code with Washington State amendments to withstand live roof loading, wind loading, and seismic loading based on the service conditions specified in 34 21 05, Common Work Results for TES and the stresses caused during loading, transportation, unloading and installation.

C. Materials:

1. Enclosure, including doors and removable panels, shall be constructed of not less than No. 11 gage galvanized sheet steel meeting the requirements of ASTM A653/A653M.
2. Interior panels shall be constructed of not less than 14 gage sheet steel.
3. Base Frame: Structural steel to permit jacking, rolling and skidding.
4. Structural steel shall have a minimum allowable yield as specified in ASTM A36/A36M. Roof and wall panel steel shall have a minimum allowable yield as specified in ASTM A653/A653M for Grade D.
5. Reinforce doors, walls, and roof panels with braces, stiffeners, and structural members to provide a rigid module.

D. Dimensions:

1. Overall substation dimensions shall not exceed those indicated on the Contract Drawings, and shall accommodate future equipment where indicated.
2. Variations of the size and general layout of equipment shall be approved by the Engineer.
3. Height: As low profile as possible with a minimum interior clear height of 9 1/2 feet and a maximum exterior roof height as indicated on the Contract Drawings.
4. Interior working spaces and clearances: Comply with NFPA 70 (with Washington and Seattle amendments), Article 110, both in size and arrangement.

2.03 BASE

- A. Lifting: Design base for lifting the complete enclosure, with all equipment in place, with a deflection not exceeding 1/240 of span.
- B. Level: Within 1/8 inch maximum in all directions.
- C. Removable lifting lugs: Provide on the base to permit lifting a fully equipped substation.

2.04 FLOOR

- A. The enclosure shall have an integral floor that shall be level and flat with 1/8-inch maximum tolerance in all directions.
- B. Loading design: Provide for support of the heaviest replaceable equipment item that may be skidded or slid across the floor.
- C. Material: Steel plate, 1/4-inch minimum thickness, stitch welded to the floor structure, rated for a minimum of 250 pounds per square foot.
- D. Construction shall allow for repeated use of equipment glide bars or skids to replace the equipment without damage to the floor.
- E. Penetrations:
 - 1. Provide access to cables or conduits that penetrate floors as indicated on the Drawings or as otherwise necessary.
 - 2. Provide insulated protection on edges for cable penetrations to prevent damage to cable insulation.
 - 3. Provide removable cover plates for openings:
 - a. Ac switchgear: 11 gage steel.
 - b. Dc switchgear: 1/4-inch glastic.

2.05 WALLS

- A. Exterior wall panels shall be interlocking type.

2.06 ROOF

- A. Style: Shed type with a pitch as shown on the Contract Drawings.
- B. Construction: Interlocking metal, with rain caps over roof seams sealed to prevent water entry.
- C. Provide gutters and provide down spouts at each end.
- D. Roof penetrations:
 - 1. Shall be used only with approval of the Engineer.
 - 2. If used, shall be minimal, with each flashed and waterproofed.

2.07 FINISHES

A. Exterior metal surfaces:

1. Shall be galvanized or galvanized in accordance with Section 05 05 00, Common Work Results for Metals.
2. Surfaces other than floor bottom and support structure: Powder coat in accordance with Section 05 05 00, Common Work Results for Metals.
3. Floor bottom and support structure: Inorganic zinc primer base coat, one coat of alkyd primer, followed by at least two coats of alkyd resin industrial enamel for a dry film thickness of 6 mils, all applied in accordance with the paint manufacturers' specifications.
4. Color: RAL 7042, Traffic Gray A, or as directed by Engineer.

B. Interior metal walls and ceiling:

1. Shall be galvanized or galvanized.
2. Powder coat in accordance with Section 05 05 05, Common Work Results for Metals.
3. Color: See Section 05 05 00, Common Work Results for Metals.

C. Interior floor surfaces:

1. One coat of alkyd primer and at least two coats of alkyd resin industrial enamel for a dry film thickness of 6 mils.
2. Floor shall have a non-skid finish.
3. Color: Match color of dielectric epoxy flooring. See Section 09 67 25, Dielectric Epoxy Flooring.

2.08 OPTIONAL ARCHITECTURAL CLADDING

A. Siding Panels - Replica Masonry:

1. Style: Brick.
2. Size: 44 1/4" inch by 18 5/8 inch.
3. Nominal Panel Thickness: 0.090 inches with side interlock and nailing flange
4. Color: Provide color choices to Engineer for selection of color.
5. Material: Mineral filled polypropylene meeting or exceeding the following physical properties:
 - a. Tensile Strength: 2900 psi, per ASTM D638.

- b. Tensile Modulus: 241,000-340,000 psi, per ASTM D638.
 - c. Flexural Modulus: 180,000 psi, per ASTM D790.
 - d. Coefficient of Linear Thermal Expansion: 0.000053 in/in/degree F, per ASTM D696.
 - e. Deflection Temperature: 144 - 202 degrees F, under load of 264 psi.
 - f. Self-Ignition Temperature: 809 degrees F, minimum, when tested in accordance with ASTM D1929.
 - g. Flammability: Rate of burning not greater than 4 inches (100 mm) per minute, when tested in accordance with ASTM D635.
 - h. Smoke Density: 6.3 percent - 9.4 percent, when tested in accordance with ASTM D2843.
6. Siding Accessories:
- a. As recommended by manufacturer, painted to match adjacent siding.
 - b. J-Channel: Extruded plastic, colored to match siding.
7. Construction Adhesive:
- a. Architectural grade, suitable for outdoor application and the materials used.
 - b. Flexible, to allow the expansion and contraction of siding material without losing bond.
8. Approved Manufacturer: Nailite.
- a. Substitutions: Per 01 25 00 Substitution Procedures.
- B. Roof:
- 1. Provide a hip style roof over the watertight prefabricated substation enclosure roof.
 - 2. Roof pitch: 4:12.
 - 3. Color: Provide color choices to Engineer for selection of color.
 - 4. Framing: Pre-engineered steel roof trusses, designed for wind and snow conditions specified in Section 34 21 05, Common Work Results for TPSS, when covered with approved roof sheeting.
 - 5. Roof Sheeting:
 - a. "Vertical-seam" or "standing-seam" style manufactured sheet steel.

- b. Minimum 18 gage steel.
 - c. Galvannealed, meeting the requirements of ASTM A 653/A 653M.
 - d. Finish: Powder coat in accordance with Section 05 05 00, Common Work Results for Metals.
 - e. Color: Provide color choices to Engineer for selection of color.
6. Architectural Details: As shown in drawing at the end of this Section.
- a. Finish: Powder coat in accordance with Section 05 05 00, Common Work Results for Metals.
 - b. Color: To match roof color.
7. Design roof to drain into gutter and downspout system provided on substation enclosure.

2.09 IDENTIFICATION

- A. Substation Number: Factory stencil substation number designation in permanent black ink on two sides of the enclosure
- 1. Number Designation: "TPSS – XX," where "XX" is a number that will be provided by the Engineer.
 - 2. Lettering height: 6 inches, minimum.
 - 3. Location: As approved by Engineer.
- B. Manufacturer's Name: Shall not be placed on the exterior of the enclosure. It will be allowed on the interior of the enclosure but shall be approved by the Engineer.

2.10 DOORS

- A. Entry doors:
- 1. Enclosure shall have a minimum of two entry doors, located as indicated on the Contract Drawings.
 - 2. Entry doors shall not be smaller than as shown on the Contract Drawings.
 - 3. Size and build one set of doors with a removable transom to permit removal of the largest piece of equipment in the substation that is not removable through wall access panels.
 - 4. Warning Signs: Provide a sign on each entry door stating 'DANGER; HIGH VOLTAGE' and "DO NOT ENTER."

- B. Entry Door Hardware:
 - 1. Panic hardware: Provide one or three point crash-bar safety latches to permit opening doors from within under all conditions.
 - 2. Locks: Provide tamper proof locks integrated with entry handles.
 - 3. Keying: Key substations alike with master keyed locks and provisions for re-keying. The Engineer will provide final keying requirements.
- C. Exterior Equipment Access Doors:
 - 1. Provide behind equipment requiring access for cable makeup or maintenance, and as required by Sections 34 21 19, Dc Switchgear and 34 21 23, Transformer-Rectifier Unit.
 - 2. Doors 36 inches or wider shall include vertical stiffeners, minimum 3 stiffeners for a 36-inch door, with one additional stiffener for each additional 12 inches of door width.
- D. Exterior Equipment Access Door Hardware & Relays
 - 1. Operating handles: Padlockable, located at working height referenced to actual final grade elevation at site.
 - 2. Padlocks: Provide a master keyed padlock for each rear equipment access door.
 - 3. Door closers: Provide door closers for each entry door.
 - 4. Door stops: Provide a door stop for each door to hold it in the open position.
 - 5. Provide ANSI device No. 33E microswitch on doors. Upon opening of a door, provide the following:
 - a. Alarm to annunciator.
 - b. Trip the ac lockout relay, ANSI Device 86.

2.11 ENTRY STEPS

- A. If required, entry steps will be provided by others.

2.12 CORNER GROUNDING PADS

- A. Provide four copper grounding pads, on the interior corners of the complete enclosure and grounded to the frame of the enclosure, for connection of 2-hole cable lugs. Provide access in floor for connecting grounds.
- B. Connect enclosure grounding pads to enclosure interior perimeter ground specified in Section 26 05 26, Grounding and Bonding.

2.13 HEATING AND VENTILATION

- A. Interior Environment: Provide thermostatically controlled heating and ventilating system to prevent condensation and maintain the interior temperature between 60 degrees F and 77 degrees F, except when ambient exterior air temperature exceeds 77 degrees F.
- B. Ventilation:
 - 1. Design system for heat gain in the substation under the following simultaneous conditions:
 - a. Maximum loading of the traction power transformer per IEEE 1653.2 for Light Traction Service.
 - b. Maximum solar heat gain.
 - 2. Redundancy: Provide two fans for ventilation system, each fan capable of maintaining the required interior temperature without the other fan in service.
 - 3. Positive Pressure: Design system for slight positive pressure.
 - a. Negative pressure in building is not permitted.
 - 4. Hydrogen: Ventilation system shall provide sufficient air changes during heating periods to prevent battery-evolved hydrogen gases from exceeding a 1 percent concentration level.
 - 5. Air Intakes:
 - a. Grill: Provide over filter to prevent entrance of foreign objects.
 - b. Filters: Provide micro-glass, high-efficiency disposable filters in filter frames.
 - c. Exterior: Provide tamper-proof hardware for filters located on exterior of enclosure.
 - 6. Code: Design shall comply with the International Mechanical Code with Washington amendments and Seattle amendments (Seattle Mechanical Code).
 - 7. Finish color: Match finish color of substation enclosure.
- C. Heating: Design based on conduction and infiltration heat loss with substation de-energized (no heat gain from interior equipment).
- D. Supply voltage: Either 120 Vac or 240 Vac, single-phase.
- E. High Temperature Alarm:
 - 1. If substation interior temperature reaches 85 degrees F send alarm to alarm panel. See Section 34 21 31, TPSS Alarm Panel.

2. Alarm temperature set point shall be field adjustable.

2.14 THERMAL AND ACOUSTICAL INSULATION

- A. Thermal Insulation:
 1. Comply with Washington State Energy Code for Climate Zone 1.
 2. Floor: Solid insulating panels complying with Washington State Energy Code.
- B. Use acoustical insulation, vibration isolation, and structural design techniques to control continuous sound levels. Sound levels shall comply with applicable noise regulations, measured from the substation on all sides, with the substation equipment operating at rated full load capacity.
- C. Insulating materials shall have a certified classification of “non combustible” as defined by ASTM E136, with the additional requirement that no flaming shall be permitted during test period.
- D. Flame proofing of insulating materials will not be acceptable. Proof of certification shall be by one of the following:
 1. UL label or listing
 2. National Bureau of Standards test results
 3. Certified test report from a nationally recognized testing laboratory.

PART 3 EXECUTION

3.01 INSTALLATION

- A. Installation of fan units after building delivery shall comply with the following:
 1. International Mechanical Code with Washington amendments and Seattle amendments (Seattle Mechanical Code).
 2. NFPA 70 with Seattle amendments.

END OF SECTION 34 21 16

SECTION 34 21 19

DC SWITCHGEAR

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Work included in this Section is for the following dc switchgear sections for traction power substations:
 - a. Negative and positive switch sections.
 - b. Feeder breaker sections.
2. Number of dc circuit breakers and the configuration of each traction power substation and section tie breakers are shown on the Contract Drawings.

B. Products Furnished But Not Installed Under This Section:

1. Dc switchgear for Operation and Maintenance Facility (OMF) traction power substation (TPSS) and King Street TPSS, including positive disconnect switch (89P), negative disconnect switch (89N), and feeder breaker as shown on Contract Drawings.

C. Related Sections:

1. Section 05 05 00 – Common Work Results for Metals
2. Section 34 21 05 – Common Work Results for TPSS
3. Section 34 21 25 – TPSS Dc Control Power
4. Section 34 21 31 – TPSS Alarm Panel
5. Section 34 21 73 – TE System Studies
6. Section 34 21 80 – TES Spare Parts and Special Tools
7. Section 34 21 90 – TPSS Testing

1.02 REFERENCES

A. Definitions:

1. Intelligent Electronic Device (IED): See definition in Section 34 21 05, Common Work Results for TES.

B. Reference Standards:

1. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:
2. International Electrotechnical Commission (IEC)
 - a. IEC 60077-1, Railway applications – Electric equipment for rolling stock – Part 1: General service conditions and general rules
 - b. IEC 60077-3, Railway applications – Electric equipment for rolling stock – Part 3: Electrotechnical components – Rules for d.c. circuit-breakers
3. Institute of Electrical and Electronics Engineers (IEEE)
 - a. IEEE C37.14, Standard for Low-Voltage Dc Power Circuit Breakers Used in Enclosures
 - b. IEEE C37.16, Standard for Preferred Ratings, Related Requirements, and Application Recommendations for Low-Voltage Ac (635 V and below) and Dc (3200 V and below) Power Circuit Breakers
 - c. IEEE C37.20.1, IEEE Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Product Data: Complete manufacturer's product descriptions and catalog data, including information on the following:
 1. Design and application ratings.
 2. Details of circuit breaker, internal components, arc chute, contacts, and closing and tripping mechanisms.
 3. Details of switchgear, drawout mechanism, interlocks, and shutters.
 4. Relays, controls, switches, indicators, load measuring devices, resistors and cubicle heaters.
 5. Key Operated Mechanical Interlock: Kirk key catalog data.
 6. Certified service performance, reliability and 5-year proven service history record, including a complete device history of the following:
 - a. Multi-function relays.
 - b. Circuit breakers.

- C. Spare Parts and Special Tools:
 - 1. Submit a list of spare parts to be provided under this Section.
 - 2. Submit at the same time as product data.
 - 3. Provide part numbers for each part, including a detailed break down of each spare part assembly and set, as defined in Section 34 21 80, TES Spare Parts and Special Tools.
 - 4. Submit a list of special tools to be provided under this Section, as defined in Section 34 21 80, TES Spare Parts and Special Tools.
- D. Shop Drawings:
 - 1. Arrangement drawings.
 - 2. Schematic wiring diagrams.
 - 3. Interconnection diagrams.
- E. Complete details of transfer trip scheme.
- F. Kirk key scheme, including description, and detailed arrangement drawings.
- G. Submit test procedures and test reports in accordance with Section 34 21 90, TPSS Testing.
 - 1. Test procedures for each test to be conducted.
 - 2. Design tests for each type of switchgear.
 - 3. Production tests for each type of switchgear.
- H. Operations and Maintenance Data: Submit data in accordance with Section 01 78 23, Operation and Maintenance Data, including the following requirements:
 - 1. Submittal information identified above.
 - 2. Manufacturer's operating and maintenance instructions, parts list, illustrations and diagram for components.
 - 3. Wiring diagram.
 - 4. Recommended list of spare parts.

1.04 SPARE PARTS

- A. Provide spare parts in accordance with Section 34 21 80, TES Spare Parts and Special Tools.

- B. List below applies to items in this Specification Section.
1. Dc circuit breaker: Complete with truck and accessories. Provide 5 spares.
 2. Main contacts for dc circuit breaker: Provide 7 spare assemblies.
 3. Secondary contacts for dc circuit breaker: Provide 7 spare assemblies.
 4. Dc circuit breaker charging motors: Provide 7 spares.
 5. Dc circuit breaker solenoids: Provide 7 spares.
 6. Dc circuit breaker springs: Provide 7 spares.
 7. Positive disconnect switch (no cubicle required): Provide 1 spare assembly.
 8. Negative disconnect switch (no cubicle required): Provide 1 spare assembly.
 9. Dc protective relays (non-IED): Provide 2 spare sets.
 10. Dc switchgear IEDs: Provide 1 spare set.
 11. Dc ammeter and voltmeter: Provide 1 spare set, if separate from IEDs.
 12. Dc switchgear control and auxiliary relays: Provide 2 spare sets.
 13. LEDs for dc switchgear: Provide 4 spare sets.
 14. Transducers: Provide 1 spare set.
 15. Dc switchgear control circuit fuses (if used): Provide 10 spare sets.
 16. Dc mini circuit breakers (if used): Provide 1 spare of each rating.
 17. Mechanical interlocks: Provide 1 spare set.

1.05 QUALITY ASSURANCE

- A. Dc Switchgear:
1. UL labeled or furnished with a Field Evaluation label in accordance with Section 34 21 05, Common Work Results for TES.
 2. Dc switchgear including circuit breaker shall have 5 years successful operation in service at a transit application.
- B. Manufacturers of dc switchgear and components used in the dc switchgear shall be ISO 9001 certified.

PART 2 PRODUCTS

2.01 GENERAL

- A. Dc Switchgear: Dead-front, self-ventilated, metal enclosed, free standing, sheet steel enclosures suitable for indoor service.
- B. Circuit Breakers: Provide switchgear with individually enclosed, draw out type, high speed, power circuit breakers rated for use with the transformer-rectifier unit.
- C. Rear Access: Provide through exterior equipment doors and design such that positive feeder cables and negative return cables can be landed from the rear.
- D. Front Access: Provide access to removable components of the switchgear from the front.
- E. Bus and Power Wiring: Locate in the rear.
- F. Complete Assembly: Include dc buses and connections, positive and negative feeder cable terminal connections, indicating lights, terminal blocks, protective and auxiliary relays, control circuitry, wiring and all other devices necessary to make a complete and operable switchgear assembly.
- G. Workmanship: Avoid wiring congestion, train wires neatly, protect wiring from sharp edges.
- H. Standards: Design, materials, construction, and tests shall be in accordance with IEEE C37.14, IEEE C37.20.1, and as further described or modified in this Section.
- I. Finish: Powder coat and color in accordance with Section 05 05 00, Common Work Results for Metals.

2.02 RATINGS

- A. The switchgear assembly and circuit breakers shall have the following minimum ratings in accordance with IEEE C37.14 and IEEE C37.16:

Full-Load Voltage	750 Vdc
Maximum Voltage	1000 Vdc
Continuous Current	1000 A
Minimum Frame Size	1000 A
Insulation Level:	
60 Hz withstand	3.7 kV rms
Short circuit rating	30 kA, peak

2.03 SWITCHGEAR ENCLOSURE

- A. Switchgear Structure:
1. Steel, rigid, self-supporting, self-contained, conforming to IEEE C37.20.1 and to requirements indicated below:
 2. Fabricated of electrically welded or bolted sheet steel, 11 gage minimum.
 3. Provide enclosures sufficiently rigid to support equipment under normal loads, short-circuit conditions, and specified seismic conditions.
 4. Apply coating to switchgear assembly in accordance with Section 05 05 00, Common Work Results for Metals.
- B. Doors: Sheet steel, 11 gage minimum, properly reinforced against distortion by suitable flanges and stiffening members.
1. Hinges: Heavy duty stainless steel.
 2. Latches: Minimum of three latches shall securely fasten door in the closed position and shall be easily opened without the use of tools.
 3. Handle: Heavy duty, padlockable, opens all three latches, easily operated with one hand-motion, one for each door.
 4. Door stops: Heavy duty to hold door securely in the open position. Not easily bent if an attempt is made to close door without releasing door stop.
- C. Heaters: Provide two thermostatically-controlled strip-type heaters in each switchgear cubicle to prevent condensation.
1. Operating Voltage: Shall not exceed 50 percent of heater rated voltage.
 2. Thermostat:
 - a. Provide an individual thermostat for each cubicle.
 - b. Locate thermostat in a general area of each cubicle so that cool air at the lower portion of the enclosure can be sensed by the thermostat.
 3. Digital Heater Ammeter: Provide on the front of each cubicle enclosure to indicate current and operation of heaters.
 4. Power Source: 120 Vac auxiliary power system; use an isolation transformer.
- D. Warning Signs:
1. Provide signs on front, rear, and side access doors of cubicles where 750 Vdc wiring is present: "DANGER: LIVE PARTS" and "DANGER: HIGH VOLTAGE"

2. Provide signs on removable rear access doors: "DANGER: HIGH VOLTAGE".
- E. Dc circuit breaker cubicle:
1. Suitable for accommodation of drawout circuit breakers.
 2. Supporting Guide Rails: Provide for positioning removable elements as an integral part of equipment.
 3. Design such that circuit breakers are easily drawn in or out of their housings.
 4. Include stationary disconnecting device contacts for the circuit breakers.
 5. Breakers shall connect or disconnect from buses and auxiliary circuits by means of self-aligning, self-coupling, primary disconnecting devices.
 6. Provide self alignment mechanisms such that misalignment of contact is not possible when circuit breaker elements make contact with stationary contacts.
 7. Control Wiring: Connection to the dc breaker may be by movable contacts or by a plug-style disconnect.
 - a. Plug style disconnect:
 - 1) It shall not be mechanically possible to rack breaker into the connected position with the plug disconnected.
 - 2) Locate where easily accessible. Engineer will make final determination whether location is easily accessible.
 - 3) Provide heavy-duty connection hardware not easily bent or broken due to mishandling.
 8. Provide suitable shrouds or automatic safety shutters on devices to prevent accidental contact with live parts.
 9. Provide each enclosure with protective shutters that cover live high-voltage terminals when the access door is opened or a dc feeder breaker is racked out of the cubicle.
 10. Provide each compartment with a hinged door or full width drawout panel for front access to the circuit breakers, instruments and terminal blocks.
 11. Provide rear access doors to facilitate access to the dc power bus. Doors shall swing fully open against the adjacent door or enclosures.
 12. Provide connections to the dc feeder cables in the rear compartment.

13. Construct switchgear enclosures to allow for the dissipation of ionized gas from the circuit breaker arc chutes without hazard to personnel from the discharge of hot gas or other materials.
 - a. Release gas from the units to the outside of the switchgear enclosure by means of suitable stacks, louvered vent openings, or vent openings covered with grilles.
 - b. Provide adequate clearance to ground to prevent the possibility of establishing a conducting path to grounded structure or objects when interrupting maximum short-circuit energy at rated maximum voltage.
 - c. Line enclosure surfaces exposed to arcs or ionized gases with flame resistant, high dielectric insulating materials.
 - d. This paragraph is not intended to require the use of arc-resistant switchgear.
14. Stacking of dc circuit breakers in cubicles is not permitted.

F. Negative and Positive Switch Cubicles:

1. Mount positive and negative switches in separate isolated cubicles, either stacked or side by side.
2. Negative switch may be provided as part of rectifier but must be isolated from rectifier.
3. Cubicles shall have a hinged door with a clear window for viewing negative or positive switch position.

G. Separate high voltage devices from low voltage controls:

1. If high voltage devices and low voltage controls are located in the same cubicle, identify high and low voltage by color coding mounting panels.
2. No controls are allowed in rear cable and bus compartment.

H. The control devices can share the same compartment with the protection devices.

1. Control/protection compartment shall be dead-front and shall consist of hinged swinging panels mounted on the switchgear frame.
 - a. Construct swinging panel doors to support flush and semi-flush mounted devices.
 - b. Swinging panel doors shall not distort from a plane surface in any position.
 - c. Swinging panel doors of control/protection compartment shall be supported by stainless steel hinges.
 - d. Panel doors shall swing open and provide free access to the area behind the panel, the rear of the devices mounted on the panels, wiring, terminal blocks, and auxiliary devices mounted within the compartment.

- e. Secure swinging panel doors in the closed position with two positive latching or screwed fasteners that can be operated by hand without tools.
- f. Swinging panel doors shall open 90 degrees and be held with heavy duty stops.

2.04 BUS AND BUS CONNECTIONS

- A. Main horizontal dc switchgear bus shall be an extension of the rectifier bus, run the length of the dc switchgear. Tap to serve each circuit breaker.
- B. Bus: Electrical grade copper with high electrical conductivity, rated 1000 A.
- C. Bolted bus connections: Silver plated copper.
 - 1. All connections to the bus shall be bolted.
 - 2. Applies to bus taps, circuit breaker connections, cable connections, and connections of devices such as transducers and shunts.
 - 3. Bolts: Silicon bronze of sufficient number and size for application. minimum two bolts and per joint.
 - 4. Washers: Provide a Belville washer for each bolt.
 - 5. Conductivity: Each joint shall have conductivity at least equal to that of the bus bar and shall be so clamped that no loss of conductivity will occur during the life of the switchgear.
- D. Insulation:
 - 1. Insulate main bus and feeder bus from each other with electrical insulating laminate barrier or other approved means.
 - 2. Mount bus bars on barrier-type insulation or post-type insulators.
- E. Strength: Bus, bus connections, and bus insulation shall withstand thermal and mechanical stresses resulting from maximum available short-circuit current or rms interrupting rating of circuit breakers whichever is greater, without damage or permanent distortion.

2.05 POSITIVE AND NEGATIVE DISCONNECT SWITCHES

- A. Provide a negative dc disconnect switch (Device 89N) and a positive dc disconnect switch (Device 89P) in each substation dc switchgear assembly, as shown in Contract Drawings. Each switch shall meet the following requirements:
 - 1. Type: Manually-operated, single-pole, bolted-pressure-type, solid copper blade with silver plated contacts.
 - 2. Rating: 1000 A continuous current at 1000 Vdc and withstand twice the expected rms bolted short circuit currents.
 - 3. Insulation level: Sufficient to pass 1 minute 60 Hz dry withstand test at 3.7 kV, rms.

4. Handle: Provide an insulated operating handle.
 5. Switch Position Indication: Provide a green and a red indicating light on the front panel of cubicle for each switch:
 - a. Green illuminated: Switch open.
 - b. Red illuminated: Switch closed.
 - c. See Section 34 21 05, Common Work Results for TPSS, for requirements for Device 33 position switch.
 6. Instructions: Provide a simple operation instruction nameplate on each cubicle door.
- B. Negative Disconnect Switch – 89N
1. Connection: Install between the negative return cable and the rectifier negative pole.
 2. Interlock with Positive Switch:
 - a. Provide key interlock with positive disconnect switch to ensure negative switch can be opened only when positive switch is open.
 - b. Key removal from the negative disconnect switch shall be possible only when the negative disconnect switch is closed.
 - c. Opening of negative disconnect switch shall require the key to be inserted in the negative disconnect switch.
 3. Interlock with Dc Circuit Breakers:
 - a. If negative switch is in the open position it shall not be possible to close a dc circuit breaker.
- C. Positive disconnect switch – 89P
1. Connection: Install between the rectifier output and the dc feeder breakers.
 2. Interlock with Negative Switch:
 - a. Key interlock with the negative switch to prevent positive switch from closing when the negative disconnect switch is open.
 - b. Key shall not be removable from the positive switch when the negative disconnect switch is closed.
 - c. With the key removed from the positive switch it shall be mechanically locked open.
 3. Interlock with Ac Switchgear: Key interlock to ensure no-load opening.

2.06 CIRCUIT BREAKERS

- A. Dc circuit breakers: Single-pole, air-break, high-speed, removable type.
 - 1. Manufacture in accordance with IEEE C37.14, and rate according to the preferred ratings listed in IEEE C37.16, except as indicated in this Section.
 - a. As an alternate, provide dc circuit breakers tested according to IEC 60077 Parts 1 and 3.
 - 2. Suitable for local and remote supervisory control.
 - 3. Electrically operated and electrically and mechanically trip-free with the mechanism insuring full contact pressure until time of opening.
 - 4. Insulated to withstand 3.7 kV, rms at 60 Hz for 1 minute.
 - 5. Peak rated momentary current: 30 kA, minimum.
- B. Instantaneous (Device 76): Provide each dc feeder circuit breaker with a direct-acting, bi-directional, instantaneous overcurrent tripping device adjustable between 150 percent and 350 percent of the breaker rating.
- C. Contacts:
 - 1. Surfaces of the moving and stationary contact members of the main contacts shall be silver, non-welding silver alloy, or equivalent which combines high conductivity and necessary arc-resistant properties.
 - 2. Main and secondary contacts of breaker shall be removable for replacement.
- D. Operating mechanism:
 - 1. Solenoid-operated or motor-charged stored-energy, spring-operated type.
 - a. Connect solenoid operated mechanisms such that the control voltage is removed from the closing coil after a preset time.
 - b. In the event the breaker does not close or the closing control circuit is not opened, a trip sequence shall be initiated to open the closing control circuit and restore all closing sequence relays to their normal position.
 - c. Motor-charged and spring-operated mechanisms:
 - 1) Mechanism shall be designed to prevent overcharging.
 - 2) The mechanism shall ensure that the release of stored energy for closing the circuit breaker main contacts is prevented unless the mechanism has been fully charged.
 - 3) The stored-energy closing mechanism shall automatically charge itself within 15 seconds after closing of the breaker.

- 4) Energy storage shall be sufficient for an open-close-open cycle at maximum rated short circuit current.
2. Mechanism shall be non-pumping.
 3. Design shall ensure positive opening of the moving contacts and circuit interruption when the tripping impulse is received at the fully closed or any partially open position.
 4. Provide control with a shunt trip device with the necessary auxiliary control equipment.
- E. Breaker Position: Make provisions for moving each breaker to a "connected", "test" and "disconnected" position with positive stops in each position.
1. "Connected" position: Both the primary disconnecting devices and the secondary disconnecting devices shall be in full contact and the breaker shall be in position for normal operation.
 2. "Test" position: Primary disconnecting devices shall be open and separated by a safe distance and the secondary disconnecting devices shall be in full contact.
 3. "Disconnected" position: Both primary and secondary disconnecting devices shall be open and separated by a safe distance and shutter closed.
 4. Position Indicator: Provide an indicator to show the location of the circuit breaker in "connected," "test," or "disconnected" positions.
- F. Mechanical and Electrical Interlocks:
1. Mechanical:
 - a. Provide interlock to prevent moving circuit breaker in or out of the "connected" position when circuit breaker main contacts are in the closed position.
 - b. Provide interlock to prevent closing the circuit breaker manually unless the breaker is in the "test" or "disconnected" position.
 2. Electrical:
 - a. Provide interlock to prevent closing circuit breaker electrically, unless the circuit breaker is in the "connected" position with the primary disconnecting devices in full contact, or in the "test" position.
- G. Breaker Control:
1. Breaker control switch: Incorporate into Alarm Panel HMI. See Section 34 21 31, TPSS Alarm Panel for additional information.
 - a. Request to close a dc feeder breaker shall be governed by the load measure reclose system. See Protective Devices article, below, for details of the load measure reclose system.

- b. Provide sufficient logic to ensure that a response to an HMI or remote supervisory closure request will not result in an unsafe condition or cause damage to the substation or any of its components.
 - 2. Bypass Load Measuring:
 - a. Provide control on Alarm Panel HMI that allows an authorized operator to bypass load measure system when closing breaker.
 - b. See Section 34 21 31, TPSS Alarm Panel for details of operation.
 - 3. Manual trip:
 - a. Provide each circuit breaker with mechanical means for manually tripping the circuit breaker in the "test" and "connected" positions.
 - b. This function shall be available with the compartment door closed.
 - 4. Control power: Provide from 125 Vdc control power system per Section 34 21 25, TPSS Dc Control Power.
- H. Indication:
 - 1. Electrical: Provide red and green indicating lights on each breaker unit for electrical closing and opening of the breaker while in the "test" or "connected" positions.
 - a. Red light illuminated: Breaker closed.
 - b. Green light illuminated: Breaker open.
 - c. Provide long life, high brightness and high visibility, LED array lights.
 - 2. Mechanical: Provide a mechanical indicator, visible when the door is closed, to show when the circuit breaker is in the "open" and "closed" condition.
- I. Auxiliary Contacts:
 - 1. Provide a minimum of four electrically separate sets of reversible auxiliary contacts, in addition to those required for the circuit breaker control circuit.
 - 2. Auxiliary contacts shall be operated by the breaker mechanism in both the "connected" and "test" position.
 - 3. Spare auxiliary contacts shall be wired to the outgoing terminal blocks.
- J. Arc chutes:
 - 1. Metal plate or magnetic coil type.
 - 2. Suitable for bidirectional current flow.

3. Designed for positive interruption of currents from 0 V to circuit breaker maximum rating.
 4. Provide with an air puffer device to extinguish low-current arcs.
- K. Operations Counter: Provide four digit, non-resettable, register type mechanical operations counter on each circuit breaker to record tripping operations.
- L. Lockout Provisions: Provide means to permit padlocking the dc breaker in the open position to prevent inadvertent closure without having to withdraw the breaker element.
- M. Breaker Truck Wheels:
1. Provide circuit breakers with approved wheels to remove element from cubicle.
 2. Fifth Wheel:
 - a. If breaker truck cannot be easily turned when outside the breaker cubicle, provide a fifth wheel.
 - b. Engineer will make the determination whether breaker truck can be easily turned.
 - c. Wheels shall not damage epoxy floor coating.
- N. Interchangeability:
1. Removable elements of the same type and rating shall be completely physically and electrically interchangeable.
 2. Removable elements not of the same type of rating shall not be physically interchangeable.

2.07 TPSS DC CABLE CONNECTIONS

- A. Bottom or top feed for negative and positive dc feeders, as required.
- B. Provide ample space for pulling and terminating the feeder cables entering or leaving the switchgear without requiring a less than specified cable bending radius.
- C. Provisions shall be made for the termination of up to four 250 kcmil, 2 kV dc positive cables in each feeder breaker section.
- D. Provide for the termination of up to eight 250 kcmil, 2 kV dc negative return cables on load side of the negative disconnect switch.

2.08 PROTECTIVE DEVICES

A. General Requirements:

1. Protective relays provided in dc switchgear shall be Intelligent Electronic Devices (IED) equipped with communication function.
2. Alarm Communication: Send alarms to TPSS alarm panel via Modbus TCP/IP Ethernet (RJ45). See Section 34 21 31, TPSS Alarm Panel.
3. Built-in Functions: Control, measurement and fault recording.
4. Screens: LCD.
5. Time Synchronization: Protective IEDs shall synchronize time with substation alarm panel.
6. Protective Device Coordination: Perform a coordination study for the dc system in accordance with Section 34 21 73, TE System Studies to obtain preliminary relay settings.
7. Final Settings: Make final adjustments to relaying systems and protective devices during TPSS Field Acceptance Testing and Integrated Testing specified in Section 34 21 90, Traction Power Substation Testing.
8. Contact Wire Thermal Rise: Set instantaneous and sustained current curves to limit the contact wire thermal rise to less than 165 degrees F.
9. Complete Installation: Provide additional components such as auxiliary relays, isolating diodes and similar devices not shown in the Contract Drawings, but required for a complete installation.

B. Arrangement and Appearance:

1. Arrange devices such as auxiliary relays, indicating lights and test plugs to be conveniently accessible and easily visible.
2. IED meters and displays shall be located such that they are easy for a person standing at floor level to operate and read.
3. The grouping shall be modular and place related functions in proximity.
4. Mount devices plumb and square with the lines of the panels and mount as recommended by the manufacturer and approved by Engineer.
5. Auxiliary devices shall match the general appearance as far as possible with frames of a compatible approved color and finish.
6. Devices of the same general type shall be manufactured by the same company and shall be similarly arranged and mounted.

7. Refer to substation one-line diagram in the Contract Drawings for arrangement of protective relays and devices.
- C. At a minimum, provide the following protective functions/devices as shown on the substation one-line diagram in the Contract Drawings. Additional protective functions/devices recommended by equipment manufacturers may be installed with Engineer approval.
1. Overcurrent: As a minimum, provide the following overcurrent protection functions, which shall operate in the forward and reverse current directions:
 - a. Instantaneous Overcurrent Trip.
 - b. Low Level Fault Trip.
 - c. Timed Overcurrent Trip:
 - 1) Provide timed overcurrent trip function with inverse time characteristic that can be graphed with the set current, I_{tmd} , as the y-axis, and the time delay, T_{mdDel} , as the x-axis.
 - 2) Tripping shall be initiated when the load current exceeds the set current during the period of time t such that (t / T_{mdDel}) and (I_{load} / I_{tmd}) correspond to a point on the curve.
 - d. Rate of Rise Trip: Shall be initiated if all of the following conditions are met:
 - 1) Current di/dt exceeds the trip limit, di/dt .
 - 2) Di/dt stays above the trip limit during the delay time, $Delay$.
 - 3) During the delay time current exceeds the current rise limit.
 2. Load Measure and Reclose:
 - a. Provide each dc feeder cubicle with a set of automatic reclosing functions and equipment, including the following:
 - 1) Load measuring function (Device 82).
 - 2) Adjustable time delay reclosing function (Device 83).
 - 3) Load measuring resistors mounted on the top of the circuit breaker cubicle;
 - 4) Associated accessories.
 - b. Initiate the load measuring and automatic reclosing cycle when either the dc circuit breaker receives a "close" command (from the local or remote control), or when the circuit breaker is tripped automatically and attempts to reclose.
 - c. A "lockout" status or intentionally initiated trip of the dc lockout relay shall disable the load measuring and automatic reclosing cycle.

- d. Precede initiation of the load measuring cycle by an adjustable time delay to permit the faulted line section to become fully deenergized.
 - e. At the commencement of the load measurement cycle, a voltage sensor shall determine whether there is no voltage on the section.
 - f. If the voltage measuring circuit detects potential on the section, it shall reclose the associated circuit breaker immediately, providing that this potential is greater than a preset value.
 - 1) The pickup setting shall be adjustable over the range of 60 to 750 Vdc.
 - 2) Initially the pickup voltage shall be set to 700 Vdc.
 - g. If the voltage measuring circuit detects no potential on the section, the load measuring function shall make repeated load measurements at suitable adjustable time intervals.
 - h. If a load measurement determines that no fault is present, initiate automatic reclosing of the circuit breaker.
 - i. A successful reclosure with no automatic trip within five seconds shall complete the measurement cycle and reset the devices to their initial state.
 - j. Make provision for selection of up to six attempts to complete a successful load measurement and automatic reclosing cycle at 15 second intervals, within a 3 minute period. Set initially at three attempts.
 - k. If no successful reclosure takes place in the three minute period, the automatic reclosing and load measuring system shall lock out the feeder breaker from closing.
 - l. Provide each automatic reclosing and load measuring function with test facilities that shall check the functioning of all devices.
 - 1) Initiate test cycle with a local "test" push-button which shall be functional only when the circuit breaker removable element is in the "test" position.
 - 2) Circuit breaker shall not close until after completing automatic reclosing and load measuring test when the breaker is in the "connected" position.
 - m. Monitor condition of reclosure device.
3. High Resistance Frame Fault:
- a. Insulate dc switchgear enclosure from ground.
 - b. Single-point ground enclosure through a separate high resistance ground IED device 64HS (hot structure) and 64GS (grounded structure).
 - 1) Connect IED with insulated 4/0 AWG copper conductor directly to substation ground mat.

- 2) The 64HS and GS relay shall be the only ground path to the enclosure.
 - 3) The occurrence of any other ground path must be detected and shall alarm.
4. Incomplete Sequence (Device 48):
 - a. This function shall detect the failure of a dc circuit breaker to clear a fault within a predetermined time.
 - b. This function shall actuate the ac lock-out relay (Device 86) when actuated.
5. Transfer Trip:
 - a. Provide two types of transfer trip:
 - 1) The first type shall be automatically resettable (Device 85). Automatic resetting shall be controlled by the load measure reclose relay and occurs on di/dt faults.
 - 2) The second type shall require manual resetting (Device 85L). It shall trip the dc lockout relay (Device 186H) in both the originating and receiving substations, and is required for dc instantaneous over-current, frame faults, rail-to-earth potential faults, incomplete sequence faults, and emergency shutdowns.
 - b. Fiber optic cable shall be the communication media between substations for transfer trip function, which will be provided in the future.
 - c. Provide fiber distribution panel (FDP) to terminate fibers in accordance with Section 34 21 05, Common Work Results for TES.
 - d. Monitor the condition of the fiber optic cable continuously.
 - e. Generate an alarm if a fault condition is detected.
 - f. Tripping of a dc breaker shall initiate tripping of the remote active breaker feeding the same section.
 - g. Fiber optic monitoring and transfer trip shall be integral to protection relays.
6. Reverse Current:
 - a. Provide reverse current detection (Device 32).
 - b. The protection shall detect current flow from the distribution bus into the rectifier unit and trip and lock out the dc feeder breakers and ac circuit breaker.
 - c. The trip level shall be initially set to 15 percent of the rated current or as approved by Engineer.

D. Instruments and Meters:

1. Instruments and meters shall be integrated into intelligent electronic devices (IEDs).
 - a. Voltmeters and ammeters shall be rated for use with the corresponding transformer.
 - b. Scales shall be of a suitable range, equal to the associated potential or current transformer primary rating.
2. Provide protective IEDs with capability of communicating with TPSS Alarm Panel as specified in Section 34 21 31, TPSS Alarm Panel.
3. Instruments for measuring dc values shall receive their inputs from isolation converters that shall be provided within the bus compartment of the switchgear.
 - a. Provide auxiliary devices required for operation of the converters.
 - b. Provide suitable isolation and insulation in order to ensure safe operation in contact with personnel.

2.09 MIMIC BUS

- A. See Section 26 24 13, Switchboards for requirements.
- B. Color: Red.
- C. Provide mimic bus across the entire front of the switchgear.

2.10 MANUFACTURE

- A. Manufacture switchgear unit in accordance with the referenced IEEE standards.

2.11 INSULATION

- A. Completely insulate dc switchgear enclosure and rectifier from ground and from the traction power transformer and the ac switchgear.
 1. Insulate and isolate dc switchgear and rectifier from the floor using an epoxy floor covering in accordance with Section 09 67 25, Dielectric Epoxy Flooring.
 2. Insulate and isolate dc switchgear and rectifier from the transformer using electrical laminate in accordance with Section 34 21 05, Common Work Results for TES.
 3. Insulate walls using electrical laminate in accordance with Section 34 21 05, Common Work Results for TES and as shown on Contract Drawings.

PART 3 EXECUTION

Not Used

END OF SECTION 34 21 19

SECTION 34 21 23

TRANSFORMER-RECTIFIER UNIT

PART 1 GENERAL

1.01 SUMMARY

- A. Section Includes:
 - 1. Traction power transformers (TPT) and rectifiers, which are referred to in this Section as the "Transformer-Rectifier Unit," for the traction power substations.
- B. Products Furnished But Not Installed Under This Section:
 - 1. Two transformer-rectifier units, one for Operation Maintenance Facility (OMF) traction power substation (TPSS) and one for King Street TPSS.
- C. Related Sections:
 - 1. Section 05 05 00 – Common Work Results for Metals
 - 2. Section 09 67 25 – Dielectric Epoxy Flooring
 - 3. Section 26 05 19 – Low-Voltage Conductors and Cable
 - 4. Section 26 24 13 – Switchboards
 - 5. Section 34 21 05 – Common Work Results for TPSS
 - 6. Section 34 21 31 – TPSS Alarm Panel
 - 7. Section 34 21 80 – TES Spare Parts and Special Tools
 - 8. Section 34 21 90 – TPSS Testing

1.02 REFERENCE STANDARDS

- A. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:
- B. National Electrical Manufacturers Association (NEMA)
 - 1. NEMA 260, Safety Labels for Padmounted Switchgear and Transformers Sited In Public Areas
 - 2. NEMA TR 1, Transformers, Regulators and Reactors
 - 3. NEMA SG 6, Power Switching Equipment

- C. American Society for Testing and Materials (ASTM)
 - 1. ASTM D116, Vitrified Ceramic Materials for Electrical Applications
- D. Institute of Electrical & Electronics Engineers (IEEE)
 - 1. IEEE 519, Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
 - 2. IEEE 1653.2, Standard for Uncontrolled Traction Power Rectifiers for Substation Applications Up to 1500 Vdc Nominal Output
 - 3. IEEE C37.20.3, Standard for Metal-Enclosed Interrupter Switchgear
 - 4. IEEE C57.12.01, General Requirements for Dry-Type Distribution and Power Transformers Including Those with Solid-Cast and/or Resin Encapsulated Windings
 - 5. IEEE C57.12.91, Standard Test Code for Dry-Type Distribution and Power Transformers

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Product Data:
 - 1. Manufacturer's product descriptions and catalog data.
 - 2. Bus and bus insulators.
 - 3. Core steel.
 - 4. Transformer winding insulation system.
 - 5. Interphase transformer
 - 6. Relays, protective devices, control switches, over temperature devices and failed diode indication device.
 - 7. Information concerning design and application ratings.
 - 8. Information concerning service, performance and reliability.
 - 9. Documents confirming the substation system rating.
- C. Spare Parts and Special Tools:
 - 1. Submit a list of spare parts to be provided under this Section.
 - 2. Submit at the same time as product data.

3. Provide part numbers for each part, including a detailed break down of each spare part assembly and set, as defined in Section 34 21 80, TES Spare Parts and Special Tools.
4. Submit a list of special tools to be provided under this Section, as defined in Section 34 21 80, TES Spare Parts and Special Tools.

D. Shop Drawings:

1. Manufacturer's arrangement and outline dimensions for each item of transformer-rectifier unit.
2. Detail drawings for each item of transformer-rectifier unit, including interphase transformer, TPT insulation system details, and surge arrestor arrangement, mounting, and protective shield.
3. Transformer and power rectifier circuit diagrams.
4. Wiring, schematic, and connection diagrams.
5. Transformer nameplate drawing with nameplate details.
6. Rectifier nameplate drawing.
7. Transformer outline drawing showing dimensions, front, back and side elevations of enclosure, overall dimensions, lifting lugs, and transformer data, including weight, impedance, and primary and secondary BIL.
8. Transformer primary and secondary busing arrangements showing bus construction details and bill of materials.
9. Transformer temperature monitor/protection device schematic and wiring diagram including the location of the temperature sensor.
10. Rectifier monitoring and protection schematic and wiring diagram.
11. Transformer tap changer arrangement details.
12. Transformer enclosure and door latch details.
13. Rectifier enclosure and door latch details.

E. Calculations:

1. Transformer design calculations, including hottest spot temperature rise in accordance with IEEE C57.12.01.
2. Transformer calculation of winding temperature during a short circuit in accordance with IEEE C57.12.01.
3. Bus sizing calculations.

4. Transformer design optimization calculations.
 5. Proof the transformer rectifier design and construction conforms to IEEE 519.
- F. Submit the following upon completion of transformer manufacture:
1. Measured present worth of transformer energy losses, including the following:
 - a. Table 1, with actual measured losses from the transformer.
 - b. Table 2 calculation, using the new value from Table 1.
 2. Comparison of calculated and measured present worth of transformer energy losses, as described in the Article titled "Transformer Design Optimization."
- G. Submit test procedures and test reports in accordance with Section 34 21 90, TPSS Testing.
1. Design Tests: Provide design test reports for each type of transformer-rectifier unit within 30 Days after completion of testing.
 2. Production Tests: Provide production test reports for each transformer-rectifier unit within 30 Days after completion of testing.
- H. Operations and Maintenance Data: Submit data in accordance with Section 01 78 23, Operation and Maintenance Data, including the following requirements:
1. Submittal information identified above.
 2. Manufacturer's operating and maintenance instructions, parts list, illustrations and diagram for components.
 3. Wiring diagram.
 4. Recommended list of spare parts.
 5. Diagram showing recommended safety grounding during maintenance.

1.04 SPARE PARTS

- A. Provide spare parts in accordance with Section 34 21 80, TES Spare Parts and Special Tools.
- B. List below applies to items in this Specification Section.
 1. Traction power transformer: Provide 1 spare.
 2. Transformer temperature monitor complete with temperature sensors: Provide 1 spare assembly.
 3. Rectifier diodes: Provide 7 spare.

4. Rectifier diode protection fuses: Provide 7 spare.
5. Rectifier over-temperature: Provide 7 spare assemblies.
6. Interphase transformer: Provide 1 spare.

1.05 QUALITY ASSURANCE

- A. Traction power transformer (TPT) shall be UL labeled or shall be furnished with a Field Evaluation label in accordance with Section 34 21 05, Common Work Results for TES.
- B. Rectifier shall be UL labeled or shall be furnished with a Field Evaluation label in accordance with Section 34 21 05, Common Work Results for TES.

1.06 WARRANTY

- A. See Section 01 78 36, Warranties for length of extended warranty required for traction power transformers.

PART 2 PRODUCTS

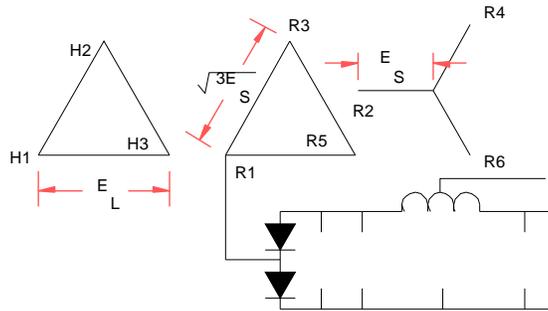
2.01 TRANSFORMER-RECTIFIER UNIT - GENERAL REQUIREMENTS

- A. Transformer-rectifier unit consists of a separate traction power transformer and a rectifier, as shown on Contract Drawings.
 1. Provide each unit complete with auxiliaries, controls, wireways, interconnecting ac and dc buses, enclosures and necessary hardware, wiring and devices from the high voltage side of the transformer to the dc bus connections to the dc switchgear and negative enclosure.
 2. Except as otherwise specified, the transformer-rectifier shall conform to IEEE C57.12.01, C57.12.91, 519, and 1653.2, and NEMA SG 6 and TR 1.
- B. Dc output of the transformer-rectifier unit shall feed the metal enclosed dc switchgear that controls and protects the power supply to the Overhead Contact System (OCS).
- C. Enclosures for Transformer and Rectifier
 1. Construct from sheet steel, 11 gage minimum, properly reinforced against distortion by suitable flanges and stiffening members.
 2. Doors:
 - a. Minimum 11 gage sheet steel.
 - b. Doors 36 inches or wider shall include vertical stiffeners, minimum 3 stiffeners for a 36-inch door, with one additional stiffener for each additional 12 inches of door width.
 3. Finish: Powder coat in accordance with 05 05 00, Common Work Results for Metals.

4. Color: In accordance with Section 05 05 00, Common Work Results for Metals.

D. Design Loading Condition: Transformer-rectifier units shall meet the duty cycle specified in IEEE 1653.2 for light traction service.

CIRCUIT 31 (FROM IEEE 1653.2)



E. Efficiency: Overall efficiency of each transformer-rectifier assembly shall be greater than 98 percent at its continuous rating.

F. Power Factor: Displacement power factor of each transformer-rectifier assembly shall be 0.95 or greater from 25 percent to full load at rated ac voltage.

G. Voltage Regulation:

1. Voltage on the dc bus shall be within the following limits with the nominal ac voltage maintained at the transformer primary and the transformer set at the rated voltage tap:

Output Dc Voltage (Volts)			
Output Current	Maximum	Nominal	Minimum
No load (1 percent)	795		
100 percent full load	753	750	747
150 percent full load	730	727	724
200 percent full load	711	705	699

2. Engineer may allow minor variations in regulation based upon submitted design curve.

H. Dummy Load:

1. Limit the no-load voltage to the value specified.

- 2. Provide a bleeder resistance dummy load, if required, to prevent excessive voltage rise at no-load.
- I. Provide protection against transient surge voltages on the dc side of the rectifier. If fuses are used in suppression networks, they shall be monitored by visual indicators and equipped with indication devices wired to local Annunciator.
- J. Short Circuit Ratings:
 - 1. Design transformer, including terminal connections and buswork, to withstand a full short circuit with shorted low-voltage terminals and rated voltage on the high-voltage terminals, in accordance with IEEE C57.12.01. The duration of the short-circuit current shall be minimum 1 second.
 - 2. Design all parts of the rectifier unit, including the terminal connections and buswork, to withstand a maximum dc fault on the dc positive bus, without damage, for the period required for the back-up protection to operate and open the ac circuit breaker.
- K. Audible Sound: 60 dBA at 100 percent load measured 3 feet away from assembly.
- L. Mimic Bus:
 - 1. See Section 26 24 13, Switchboards for requirements.
 - 2. Provide on front of rectifier and transformer enclosures.
 - 3. Color: Red for dc and low-voltage ac.

2.02 TRANSFORMER-RECTIFIER UNIT RATINGS AND CONFIGURATION

- A. Mainline transformer-rectifier units:
 - 1. Rating: 350 kW, measured at 750 Vdc at the output terminals.
 - 2. 12-pulse, double-way, in accordance with IEEE 1653.2.
 - 3. Convert 480 V (208 V for King St. TPSS), 60 Hz ac, three-phase, three-conductor primary power to 750 Vdc at 100 percent of full load.
 - 4. Shall receive ac power from the 480 Vac switchboard. See Section 26 24 13, Switchboards.
- B. OMF transformer-rectifier unit:
 - 1. Rating: 100 kW, measured at 750 Vdc at the output terminals.
 - 2. 6-pulse, in accordance with IEEE 1653.2.
 - 3. Shall convert 480 V, 60 Hz ac, three-phase, three-conductor primary power to 750 Vdc at 100 percent of full load.

4. Shall receive ac power from the 480 Vac switchboard. See Section 26 24 13, Switchboards.

2.03 PROTECTIVE DEVICES AND RELAYS FOR TRANSFORMER-RECTIFIER UNIT

- A. Coordinate protection to prevent false tripping or malfunction.
- B. Supply an insulating dust cover for each internally-mounted device or the chamber that accommodates these devices.
- C. Compartment: Mount control devices, relays and protective devices within the rectifier and transformer enclosure within a separate barriered compartment in compliance with IEEE C37.20.3.
 1. Devices shall be readily accessible without disassembling interior portions of the rectifier assembly.
 2. Control wiring shall be contained within the cubicle.
 3. Control wiring shall be barriered from and not intermixed with 750 Vdc power wiring.
 4. No 750 Vdc devices shall be mounted in control compartment.
 5. Locate devices such that heat from other equipment does not affect operation.
- D. Control Power:
 1. Power supply for protective devices and relays shall use 125 Vdc dc auxiliary power system.
- E. Transformer Temperature Monitor:
 1. Transformer Temperature Monitor (TTM): Device 49:
 - a. Shall be manufactured for the purpose.
 - b. Shall have a service proven history.
 2. The TTM shall incorporate a hot spot winding temperature indicator:
 - a. Location shall be that of the highest temperature reading obtained during the System Design testing.
 3. TTM shall be provided with two-step, electrically independent contacts which close on rising temperatures for alarm (first step) and tripping (second step).
 - a. First stage of TTM temperature supervision, 49T1, shall initiate an alarm on the TTM and the TPSS alarm panel. Refer to Section 34 21 31, TPSS Alarm Panel.

- b. The first stage shall initially be set at the temperature reached during the 2-hour heat run at 150 percent rated output, and annunciate when this temperature is reached.
 - c. Second stage, 49T2, shall initiate an alarm on the TTM and the TPSS alarm panel and shall also trip and lock out the main ac breaker and open the main dc circuit breaker.
 - d. Set Points:
 - 1) Temperature set points, T1 and T2, shall be field adjustable.
 - 2) Set points shall be factory-preset value when transformer is provided, as recommended by the manufacturer and approved by Engineer.
4. Display temperature continuously on a digital display mounted on the surface of transformer panel.
- a. Accuracy: Within 1.5 percent of the full-scale reading.
 - b. Scale: Degrees Celsius.
 - c. Peak Temperature:
 - 1) Peak temperature shall be displayed when requested by the activation of a front panel mounted pushbutton.
 - 2) Peak temperature shall be resettable via a separate front panel mounted pushbutton.
 - 3) TTM shall store the peak temperature reached by the traction power transformer.
5. Enclosure: NEMA 1 enclosure for low voltage terminals.
- a. Cover: Hinged or screw cover
6. Terminal strips: Provide covers and mount on back panel.
7. Barriers: Provide where necessary to separate conductors with different voltage insulation ratings, such as thermocouple wiring and 125 Vdc control wiring.
8. Mounting: Securely mount enclosure to the transformer frame.
- a. Mount in a location readily accessible from the front as indicated, but not to restrict access to the transformer coils for maintenance.
 - b. Do not mount the enclosure in removable panels.

9. Control Wiring:
 - a. Control wiring shall be 600 V switchboard wire per Section 26 05 19, Low-Voltage Conductors and Cable, minimum 14 AWG, except for temperature sensor wiring.
 - b. Provide control wiring in GRS conduit securely strapped to the transformer frame.
 10. Contacts: Electrically separate and suitable for operation at 125 Vdc.
- F. Provide the following protective devices for the rectifier. Contacts on these devices shall be electrically separated:
1. Rectifier over-temperature (Device 26):
 - a. Over temperature device shall be factory set, two stages (26R1 and 26R2).
 - b. Shall detect first an abnormal rise in diode heat sink or diode temperature and initiate local and remote annunciation.
 - c. Set-point for the alarm shall be set during the factory systems test to the level recorded during the two hour 150 percent heat run.
 - d. An additional rise in heat sink temperature will trip and lock out the ac main breaker, open the main positive circuit breaker and shall alarm on the traction power substation alarm panel. Refer to Section 34 21 31, TPSS Alarm Panel.
 - e. Devices shall be isolated from the bus voltage.
 2. Frame fault protection for the rectifier: Provide high resistance frame fault protection for the rectifier cubicles.
 3. Provide failed diode indications 98R1 and 98R2.
 4. Refer to Contract Drawings for additional protective devices.

2.04 RECTIFIER

- A. General:
1. Provide rectifier assembly as an integral part of the dc switchgear.
 2. Rectifier assembly shall be constructed in accordance with IEEE C37.20.3, Standard for Metal-Enclosed Interrupter Switchgear, except as modified in this Section.
 3. Rectifier shall include silicon diodes, internal buses, terminals for connection to external power and control wiring or buses, shunts, base or bleeder load resistors, protective devices, control wiring, terminal blocks, compartments, cubicles, and all other necessary accessories.

4. All rectifier assemblies shall be identical, except for necessary differences in the OMF rectifier.
- B. Rating and configuration:
1. IEEE 1653.2 light traction service.
 2. Dc Insulation: 1200-Volt Class.
 3. Mainline rectifiers:
 - a. Rated 350 kW at 750 Vdc with natural convection air cooling.
 - b. Continuous current rating at 100 percent: 467 A.
 - c. Twelve-phase, double-way, 12-pulse rectification.
 4. OMF rectifier:
 - a. Rated 100 kW at 750 Vdc with natural convection air cooling.
 - b. Continuous current rating at 100 percent: 133 A.
 - c. Six-phase, double-way, 6-pulse rectification.
 5. Cooling fans:
 - a. Provide fans for forced air cooling, controlled by heat sink temperature.
 - b. Fans shall increase rating of rectifier to 133 percent of continuous current rating.
 - c. Rectifier shall not suffer loss of life when operated at the IEEE 1653.2 light traction service overload.
- C. Enclosure:
1. Mount rectifier assembly in a metal fully-enclosed switchgear section or compartment.
 2. The switchgear section shall be indoor, self-ventilated, metal enclosed structure with barriers, compartments, hinged doors as required by IEEE C37.20.3, except as modified in this Section.
 3. Assemble enclosure with a rigid self-supporting structural steel framework.
 - a. Structural members shall be of sufficient strength to support the buswork under short circuit conditions.
 - b. Principal structural members shall be electrically welded or bolted together.
 - c. Provide lifting eyes for lifting the rectifier unit from the top.

- d. The completed package shall be capable of being skidded or rolled any direction.
- e. Provide jacking lugs at each base corner.

4. Doors:

- a. Provide convenient access doors on the front and rear of the section for normal maintenance and inspection.
- b. Latches: Equip each door with a heavy duty latch to hold the door fully and securely closed.
- c. Hinges: Stainless steel heavy-duty type.
- d. Door Stops:
 - 1) Provide heavy duty door stops to hold the door in the open position.
 - 2) Not easily bent if an attempt is made to close door without releasing door stop.
- e. Window: Provide an ample sized, wired glass, gasketed observation window on each door to observe diode blown fuse indicators.
- f. Install front-mounted indicating and control devices without damaging the exposed finished surfaces.

D. Bus and Connections:

- 1. Rectifier buses shall be made of rigid, high conductivity, electrical grade copper.
- 2. Buses shall be suitably braced between each other and to the enclosure with high-strength, non-tracking porcelain or fiberglass insulators.
- 3. Buses shall be braced to safely withstand the available short-circuit current without damage to the bus or the rectifier.
- 4. Where an aluminum heat sink is used and a copper bus connection is required to the aluminum, apply oxide inhibitor to the joint.
- 5. Bus connections shall be bolted using a minimum of four bolts per joint.
 - a. Wherever bolted together, the mating surfaces of copper buses shall be silver-plated.
 - b. Bolted connections shall be made with Belleville washers.
- 6. Buses shall extend through the compartment walls to rear bus compartment and connected to the dc switchgear.

7. Rectifier section shall be designed as an integral part of the dc switchgear line up and shall be insulated from the ac and dc switchgear, substation grounds, or other enclosures.
 8. Metal barriers, electrically bonded to the frame, shall be provided between dc positive and negative buses and terminal connections within the rectifier.
- E. Dc surge arrestor:
1. Rectifier unit shall be equipped with dc surge arrestors.
 2. The arresters shall limit the reverse voltage across rectifier silicon diodes to a value less than 75 percent of the peak-reverse-voltage rating of the diode by limiting the rise of the transient on the positive to negative bus.
 3. Ensure that arresters will fail in a safe manner without damage to equipment and will self extinguish. Install in separate enclosure if necessary.
- F. Silicon Diodes:
1. Silicon diodes shall be hermetically sealed and mounted on adequate heat sinks.
 2. Diodes shall be rated and tested in accordance with IEEE 1653.2 for light traction service.
 3. Rectifier shall be able to withstand a bolted fault on the dc switchgear bus without exceeding the safe diode junction temperature on the active diode for the time it takes the ac breaker to clear the fault.
 4. Each diode shall be capable of withstanding, at its maximum operating temperature during blocking periods, repetitive voltages having a value 250 percent of its working peak reverse voltage without a permanent change in diode characteristics.
 5. Each individual diode shall have a peak inverse voltage rating equal to at least 266 percent of the applied peak inverse voltage at no load.
 6. Parallel stacks of diodes, when used, shall be electrically and geometrically similar and as symmetrical as practical to help balance the normal and surge electrical characteristics of each.
 7. Design rectifier to maintain current balance between parallel-connected diodes, if used, in each phase.
 - a. The current for each diode of a parallel-connected stack shall not differ from its proportionate share of the total current by more than plus or minus 10 percent, between 50 percent and 150 percent of the rated capacity.
 - b. This current balancing scheme shall hold individual diode currents within tolerances with one fuse in each phase arm open.
 - c. Current balancing shall not be achieved by use of selectively matched diodes.

G. Fuses:

1. Provide current limiting fuses with adequate interrupting capacity in series with each diode.
 - a. Provide a visual fuse failure indication.
 - b. Fuse failure indication shall be visible from outside rectifier through observation window.
2. Size fuses to the diode current rating. Diodes shall not open or fail on an external dc fault or rated overload condition.
 - a. Only the fuse connected to a failed (shorted) diode shall open.
 - b. No other rectifier diodes or fuses shall fail or be damaged when one diode fails.
3. Fuses: 750 V minimum, indicating type, affixed with micro switches for Device 98.

H. Diode Failure:

1. Diode failure 1 (98R1): If one diode fails, or if one entire leg fails, send alarm to TPSS alarm panel.
2. Diode failure 2 (98R2): If one leg has failed, and a second leg fails, trip the ac lockout relay (Device 86).

I. Special Tools: Provide special tools to remove or install the diodes and/or diode fuses and/or hardware with each substation rectifier.

J. Internal Wiring: 2000 V switchboard wire, per Section 26 05 13, Medium Voltage Conductors and Cable.

K. Heating and Cooling System:

1. Auxiliary heating will be by a thermostatically-controlled space heater within the Substation. Heaters mounted within the rectifier enclosure are not necessary.
2. Rectifier shall be natural convection air-cooled.
 - a. Circulation of ambient air shall do all necessary cooling at the IEEE 1653.2 light traction service loading specified.
 - b. Cooling ducts shall not be used.
3. All rectifiers shall be equipped with fans and thermostats for future forced air cooling.

L. Maintenance: Heat transfer surfaces and characteristics shall be designed for easy cleaning and to minimize accumulations of dust and other contaminants expected in the operating environment.

- M. In accordance with this Specification, voltages other than 125 Vdc control power are not permitted within the enclosure unless a specific requirement is stated in this Contract.
- N. Nameplate:
 - 1. Provided each rectifier with a corrosion resistant metal nameplate containing the following information at a minimum:
 - a. Name of Manufacturer.
 - b. Descriptive Name.
 - c. Type Designation.
 - d. Serial Number(s).
 - e. Output Rated Power.
 - f. Output Rated Voltage.
 - g. Output Rated Current.
 - h. Overload Currents - Magnitude and Duration.
 - i. Weight.
 - j. Schematic Diagram Number.

2.05 TRACTION POWER TRANSFORMER

- A. Provide dry-type traction power transformer of VPI (Vacuum Pressure Impregnation).
- B. Ratings and Configuration:
 - 1. Ventilated, self-cooled Class AA/FA.
 - 2. Transformer capacity shall be as required to achieve the specified transformer-rectifier unit rating.
 - 3. IEEE 1653.2 light traction service duty cycle.
 - 4. Transformer shall not suffer loss of life when operated at the specified duty cycle overload.
 - 5. Insulation Class: 220 degrees C class.
 - 6. Temperature Rise: Limit winding hottest-spot temperature rise and average winding temperature rise to the values given in IEEE C57.12.01 for the specified insulation class.

7. Cooling fans:
 - a. Provide fans for forced air cooling, controlled by transformer temperature monitor.
 - b. Fans shall increase the rating of traction power transformer to 133 percent of its rated output current without exceeding specified temperature rise.
 8. Select the transformer impedance to provide the rectifier output voltage specified.
- C. Windings:
1. High-voltage and low-voltage windings shall be copper.
 2. Windings shall not absorb moisture and shall be suitable for both storage and operation in adverse environments, including prolonged storage in 100 percent humidity at temperature from minus 30 degrees C to 40 degrees C.
 3. High-voltage windings mainline and Yard:
 - a. Delta-connected.
 - b. 30 kV BIL.
 4. Low-voltage windings mainline and Yard:
 - a. Connected for 12-pulse rectification.
 - b. 30 kV BIL
 5. High-voltage windings OMF:
 - a. Delta connected.
 - b. 30 kV BIL
 6. Low-voltage windings OMF:
 - a. Connected for 6-pulse rectification.
 - b. 10 kV BIL.
- D. Taps:
1. Provide five full-capacity taps on the high-voltage windings: Two above rated voltage in 1.25-percent steps and two below rated voltage in 2.5 percent steps and one at rated voltage.
 2. Tap changing shall be by movable silver plated copper bus links for de-energized tap changing.

3. Taps shall be brought out the side of the transformer, not the top.
 4. Insulate jumpers from the transformer taps to the tap changer board and primary bus and keep as short as possible so as not to interfere with access to the coils for maintenance.
 5. Tap connections shall be accessible through the front hinged enclosure doors.
 6. Identify tap connections so that the tap selected is clearly visible through the observation window.
 7. Securely bolt the tap-changing bus links in position.
 8. Design of links and connectors shall make it impossible to short out sections of windings, or to select taps outside the prescribed range, by incorrectly connecting the links.
- E. Connections:
1. Switchboard: Connect the high-voltage side using electrical grade copper bus with silver plated joints.
 2. Rectifier: Connect the low voltage side using electrical grade copper bus with silver plated joints.
- F. Supports:
1. Porcelain insulators: ASTM D116.
 - a. Insulators shall be rated for the line-to-line voltage application, free of imperfections.
 - b. Insulators that have been re-touched with paint shall not be used.
 2. Securely support bus from transformer frame using porcelain insulators.
 - a. Size bus supports for mechanical strength and ability to withstand a bolted fault without distortion.
- G. Bus Bars:
1. Size:
 - a. Minimum 1/4-inch by 2-inch, sized for mechanical strength and ability to withstand a bolted fault without distortion.
 - b. Size bus for a current density of 750 A per square inch, or a maximum temperature of 90 degrees C at a 40 degree C ambient, whichever results in a larger size.
 2. Bolted connections: Use a minimum of two silicon bronze bolted connections with Belville washers on high and low voltage ac and dc buses.

- H. Cable jumpers:
 - 1. Jumpers from the secondary taps on the coil to the bus shall be rated for 105 degrees C maximum at loading for IEEE 1653.2 light traction service.
 - 2. Jumpers shall be insulated for 2 kV at 133 percent insulation level at the maximum bus design temperature 105 degrees C.
- I. Maintainability:
 - 1. Design transformer so that parts which require maintenance are readily accessible from the front and rear.
 - 2. Ensure that bottom and top of coils are readily accessible for cleaning without removing buswork, panels, or obstructions of any kind.
- J. Transformer Enclosure and Base:
 - 1. Enclosure:
 - a. Enclose transformer in a rigid, self-supporting and self-contained, electrically welded or bolted, indoor, steel enclosure.
 - b. Enclosure shall not rely on transformer frame for support. Avoid attachments to transformer frame.
 - c. Vibration isolation: If enclosure is attached to transformer at any point, provide vibration isolation at attachment points.
 - 2. Front door: The entire front of the transformer shall open by padlockable hinged double doors secured by three-point latches.
 - a. Window: Provide an ample sized, wired glass, gasketed observation window in the front-hinged doors positioned such that the tap connections are readily visible.
 - 3. Ventilation louvers: Design for maximum cooling from the bottom to top.
 - 4. Rear panels:
 - a. The rear of the transformer shall be accessible by removable panels with stainless steel handles and lifting means.
 - b. Secure panels with 3/8-inch minimum stainless steel vandal-proof machine screws tapped into machined bosses.
 - 5. Transformer base:
 - a. Construct from structural steel members suitable for rolling or skidding in any direction.
 - b. Make provisions for pulling along the centerlines perpendicular to each side.

- c. Provide jacking facilities at each of the four corners of the base to permit insertion of rollers between floor and base.
 - d. Base construction shall firmly secure the core to prevent relative motion of the core during shipment, handling, or seismic shock.
- 6. Transformer frame:
 - a. Provide lifting hooks or eyes on the transformer frame with a safety factor of four to facilitate lifting the unit.
 - b. The structure shall be sufficiently rigid to withstand maximum transformer short circuit currents without deformation.
- 7. Transformer Mounting: Design to minimize vibration by using vibration isolation dampers.
- 8. Nameplate:
 - a. Provide traction power transformer with a corrosion-resistant metal nameplate marked in accordance with IEEE C57.12.01.
 - b. Securely fasten to the front of the enclosure.
- K. Ac Surge Arrester:
 - 1. Provide ac surge arresters on the traction power transformer primary side.
 - 2. Provide a separate compartment for ac surge arresters within transformer enclosure.
 - 3. Compartment shall be rigid steel, self-supporting and self-contained, electrically welded or bolted.

2.06 TRANSFORMER DESIGN OPTIMIZATION

- A. Optimize the transformer design and select appropriate materials to provide transformers with the lowest possible life cycle cost.
 - 1. Definition of Life Cycle Cost: The sum of the cost of procurement and the cost of energy losses over the equipment's expected life.
 - 2. Calculate cost of energy losses over the transformer's expected life by:
 - a. First, calculating annual cost of transformer energy losses (see Table 1, below);
 - b. Second, using the calculated annual cost of transformer energy losses to calculate the present worth of transformer energy losses over the 30-year expected life (see Table 2, below).

TABLE 1 – TRANSFORMER ENERGY LOSS SCHEDULE			
Column 1	Column 2	Column 3	Column 4
Transformer Load (as percentage of rated power)	Transformer Energy Losses (at Column 1 Loads) (kW)	Estimated Annual Hours (of operation at given loads) (Hrs)	Annual Transformer Energy Losses (kWh)
0 percent		4380	
20 percent		2190	
60 percent		1314	
100 percent		788	
150 percent		88	
220 percent		0	
300 percent		0	
Total Transformer Annual Energy Losses E_L (kWh)			

B. Using Table 1 – Transformer Energy Loss Schedule

1. In Column 2, enter transformer energy losses in kW for each indicated transformer load in Column 1. Include energy losses in the transformer windings, steel core, and busbars, and demand requirements of auxiliary equipment such as cooling fans.
2. In Column 4 calculate the Transformer Annual Energy Losses in kWh by multiplying the Transformer Energy Losses entered in Column 2 by the Estimated Annual Hours provided in Column 3.
3. Total the numbers in Column 4 and enter in the box at the bottom of Table 1 for the Transformer Annual Energy Losses, E_L .
4. Use this number to calculate the Present Worth of Transformer Energy Losses in Table 2.

TABLE 2 – PRESENT WORTH OF TRANSFORMER ENERGY LOSSES		
Equation:	$PW = N \cdot E_L \cdot e \cdot [1/(1+i) + (1+k)/(1+i)^2 + \dots + (1+k)^{n-1}/(1+i)^n]$	
Symbol	Description	Value
PW	Present worth of transformer energy losses (Dollars)	\$ _____
N	Number of transformer units	5 (mainline only)
E_L	Transformer annual energy losses (kWh)	from Table 1
e	Utility energy rate (Dollars/kWh)	0.09
i	Interest rate	0.04 (4 percent)
k	Average energy cost escalation factor	0.04
n	Transformer expected life (years)	30

C. Using Table 2 – Present Worth of Transformer Energy Losses

1. Calculate the Present Worth of Energy Losses, PW, in dollars over a 30-year period using the equation and values in Table 2.
2. Insert the calculated Present Worth of Transformer Energy Losses into the Request for Proposal Bid List, where indicated.

D. Measured Present Worth of Transformer Energy Losses

1. After transformer is manufactured, measure the actual losses for the transformer at the load levels specified in Table 1.
2. Update Table 1 with the measured values and recalculate Transformer Annual Energy Losses.
3. Calculate the Present Worth of Transformer Energy Losses using Table 2, with the new value of Transformer Annual Energy Losses based on measured values.

E. Comparison of Calculated and Measured Present Worth of Transformer Energy Losses

1. Compare the Calculated Present Worth of Transformer Energy Losses (entered on the Price Page) with the Measured Present Worth of Transformer Energy Losses (calculated using measured values of a transformer manufactured for this project).
2. If the Measured Present Worth of Transformer Energy Losses exceeds the Calculated Present Worth of Transformer Energy Losses, the Engineer will issue a unilateral deductive Change Order to deduct the dollar value of the difference between the two.
3. If the Measured Present Worth of Transformer Energy Losses is equal to or less than the Calculated Present Worth of Transformer Energy Losses, no action will be taken.

2.07 INTERPHASE TRANSFORMER

- A. Design interphase transformer in coordination with transformer-rectifier unit to meet the specified voltage regulation and maximize efficiency, under City of Seattle service conditions.
- B. Design, submit product data and shop drawings, and test in accordance with IEEE 1653.2.

2.08 MANUFACTURE

- A. Transformer-rectifier unit shall be manufactured in accordance with the referenced standards.

2.09 INSULATION

- A. Completely insulate rectifier from ground and from the traction power transformer and the ac switchgear.
 - 1. Insulate and isolate rectifier from the floor using an epoxy floor covering in accordance with Section 09 67 25, Dielectric Epoxy Flooring.
 - 2. Insulate and isolate rectifier from the transformer using electrical laminate in accordance with Section 34 21 05, Common Work Results for TES.

PART 3 EXECUTION

Not Used

END OF SECTION 34 21 23

SECTION 34 21 25
TPSS DC CONTROL POWER

PART 1 GENERAL

1.01 SUMMARY

- A. Section Includes:
 - 1. Battery charger/eliminator and batteries.
 - 2. Enclosed low-voltage switches and fuses.
 - 3. Dc distribution panelboard.
 - 4. Dc control circuit overcurrent protection.
 - 5. 24 Vdc power supply.

- B. Products Furnished But Not Installed Under This Section:
 - 1. Battery charger/eliminator and batteries for Operation and Maintenance Facility (OMF) traction power substation (TPSS) and King Street TPSS.
 - 2. Enclosed low voltage switch and fuses for OMF TPSS and King St TPSS.
 - 3. Dc distribution panelboard and circuit breakers for OMF TPSS and King St. TPSS.

- C. Related Sections:
 - 1. Section 26 24 16 – Low-Voltage Panelboards
 - 2. Section 34 21 05 – Common Work Results for TPSS
 - 3. Section 34 21 80 – TES Spare Parts and Special Tools
 - 4. Section 34 21 90 – TPSS Testing

1.02 REFERENCE STANDARDS

- A. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:

- B. Institute of Electrical and Electronics Engineers (IEEE)
 - 1. IEEE 1106, Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications

2. IEEE 1115, Recommended Practice for Sizing Nickel-Cadmium Batteries for Stationary Applications
- C. National Electrical Manufacturers Association (NEMA)
1. NEMA FU 1, Low Voltage Cartridge Fuses
 2. NEMA KS 1, Enclosed and Miscellaneous Distribution Equipment Switches (600 Volts Maximum)
 3. NEMA 250, Enclosures for Electrical Equipment (1000 Volts Maximum)
 4. NEMA PE 5, Utility Type Battery Chargers

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Product Data:
1. Submit manufacturers' product data for specified equipment and materials.
- C. Spare Parts and Special Tools:
1. Submit a list of spare parts to be provided under this Section.
 2. Submit at the same time as product data.
 3. Provide part numbers for each part, including a detailed break down of each spare part assembly and set, as defined in Section 34 21 80, TES Spare Parts and Special Tools.
 4. Submit a list of special tools to be provided under this Section, as defined in Section 34 21 80, TES Spare Parts and Special Tools.
- D. Calculations:
1. Battery capacity calculations, including load calculations.
- E. Operations and Maintenance Data: Submit data in accordance with Section 01 78 23, Operation and Maintenance Data, including the following requirements:
1. Submittal information identified above.
 2. Manufacturer's operating and maintenance instructions, parts list, illustrations and diagram for components.

1.04 SPARE PARTS

- A. Provide spare parts in accordance with Section 34 21 80, TES Spare Parts and Special Tools.

B. List below applies to items in this Specification Section.

1. Battery cells: Provide 4 spares of each type.
2. Battery charger/eliminator: Provide 1 spare.
3. Mini circuit breakers: Provide 2 spare sets.
4. 24 Vdc power supply: Provide 2 spares.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Ship batteries separate from substation.

PART 2 PRODUCTS

2.01 GENERAL

- A. Batteries and associated charger/eliminators shall operate in parallel, with the charger charging the battery while supplying the continuous connected loads.
- B. Batteries shall supply peak short time current demands and, when the ac supply to the charger is interrupted, supply the entire connected load.
- C. Batteries and charger/eliminators shall be rated for operation within the temperature range specified in Section 34 21 05, Common Work Results for TES and shall be capable of operation up to 100 degrees F.
- D. After a continuous 10 hours of battery charger outage, trip and lockout the high-voltage ac circuit breaker, via the 86H relay and trip and lockout the dc circuit breakers via the 186H relays.

2.02 BATTERY CHARGER/ELIMINATOR

- A. Charger/eliminators: solid-state, constant voltage, automatic, fully regulated, with output voltage temperature compensation, silicon controlled rectifier, convection cooled, complying with NEMA PE 5. Provide battery charger/eliminators to meet the following requirements:
 1. Rated for continuous operation, float-charging the battery, and for recharging the battery from a cell voltage of 1.1 V to 85 percent of battery capacity in a maximum of 8 hours, while simultaneously supplying the load demands.
 2. Rated for an input voltage of 240 Vac, 60 Hz, single phase.
 3. Output voltage and current: matched to the requirements of the battery and the load.
 4. Output voltage regulation: plus or minus 0.25 percent of output voltage over its complete load range with a plus or minus 10 percent variation of input ac voltage. Output ripple shall not exceed 30 mV rms.
 5. Output current limiting, adjustable from 90 percent to 115 percent of output nominal current rating, and factory set at 110 percent.

6. Filtered output to maintain ripple within the specified limits when the battery is disconnected.
 7. Adjustable 0 to 72 hour equalizing time charger, manually set for supplying an equalizing voltage per cell as recommended by battery manufacturer.
 8. Ac Input and Dc Output circuit breakers: Molded-case type complying with the requirements in NEMA AB1.
 9. Enclosures: NEMA 250, Type 12 with hinged covers, lockable handles and two point (minimum) latches.
- B. Provide the following additional features/options:
1. Dc voltmeter with 0 V to 200 V range.
 2. Dc ammeter.
 3. Ac input pilot light marked "AC POWER ON."
 4. Two-position selector switch marked "FLOAT" and "EQUALIZE."
 5. Output ground fault pilot lights for positive and negative poles.
 6. Input line surge and transient-protective devices.
 7. Battery charger failed alarm.
 8. Battery undervoltage alarm.
 9. Battery overvoltage alarm.
 10. Ground fault alarm.

2.03 BATTERIES

- A. Construction: Low-maintenance, valve-regulated, nickel-cadmium, pocket-plate, stationary type with a minimum of 10-year design life under normal usage for the intended duty, and designed for float service.
- B. Ratings:
1. Ampere-hour capacity: Select in accordance with IEEE 1115 taking into account the calculated loads from all devices, as indicated on the Contract Drawings, for a 10-hour discharge rate to a final cell voltage of 1.0 V for the specified duty cycle.
 2. Battery duty cycle:
 - a. Duration: Period of 10 hours with the battery charger/eliminator out of service, assuming batteries are in a fully charged state at the beginning of the 10 hours.

- b. Load:
 - 1) Normal continuous demand of the substation auxiliary loads, including relays, indicating lamps, dc-connected lights, and alarm panel.
 - 2) Trip and reclose cycle of one dc feeder breaker every hour.
 - 3) Trip and reclose of the ac breaker after two hours and again after eight hours.
- C. Lockout: Provide a timer such that after a continuous 10 hours of battery charger outage, timer shall trip and lockout the main ac circuit breaker via the 86H relay and trip and lockout the dc circuit breakers via the 186H relays.
- D. Cells:
 - 1. Provide cell assemblies suitable for the required battery duty and a long life-cycle. Support cell elements away from projections in the bottom of the cell container or from the cover.
 - 2. Clearly and permanently mark polarity of cell terminal posts.
 - 3. Cell containers: heat and impact resistant translucent or transparent plastic.
 - 4. Cell filler openings: fitted with an explosion-resistant vent. Mark electrolyte level lines on all four sides of each container.
 - 5. Provide inter-cell connector buses.
- E. Battery Racks:
 - 1. Provide a four tier structural steel battery support racks.
 - 2. Include insulating plastic strips to cover all supports, hold downs, and restraining rails that are in contact with cells.
 - 3. Finish with a caustic-resistant paint coat.
- F. Provide an insulating, electrolyte-resistant, plastic mat under each battery rack, extending a minimum of 12 inches outside the rack.
- G. Provide battery bank with a stainless steel nameplate. Nameplate shall be attached to the battery rack using stainless steel rivets and marked with the following information:
 - 1. Manufacturer's name.
 - 2. Month and year of manufacture.
 - 3. Battery and cell type.
 - 4. Ampere rating: 1 minute, 1 hour, and 5 hour.

- H. Provide nickel plated solid copper terminal plates, connectors, plates, and lugs.
- I. Provide accessories for normal operation and maintenance, including:
 - 1. Cell lifting sling complete with strap and spreader bar.
 - 2. Battery log book.
 - 3. Quart of terminal grease, if recommended.
 - 4. Set of special tools for maintenance.
 - 5. Set of cell identification numbers.

2.04 FUSED DISCONNECT SWITCH

- A. Provide 2-pole, NEMA 12, fused disconnect switch for isolation of the battery with the following requirements:
 - 1. Rating: 250 Vdc, current rating to match batteries.
 - 2. NEMA KS 1: Quick-make, quick-break, load interrupter enclosed knife switch with externally operable handle interlocked to prevent opening front cover with switch in ON position.
 - 3. Handle lockable in OFF position.
- B. Fuse Clips: Suitable for Class R or J fuses with fuse rejection devices installed.
- C. Fuses: NEMA FU 1 rated to provide short circuit protection for the battery and battery cables.
- D. Coordinate fuse and switch ratings with the output circuit breaker in the battery charger.
- E. Install disconnect switches where indicated on Contract Drawings or required by Codes with external handle centered 60 inches above finished floor or grade level.
- F. Install fuse-rejection devices in fuse clips if required.
- G. Install fuses in fusible disconnect switches.

2.05 DC DISTRIBUTION PANELBOARDS

- A. Comply with requirements of Section 26 24 16, Low-Voltage Panelboards.
- B. Circuit breakers: 125 Vdc, 2-pole.

2.06 DC CONTROL CIRCUIT OVERCURRENT PROTECTION

- A. Within switchgear, dc control circuits shall be protected by mini circuit breakers. Fuses shall not be used.

- B. Mini circuit breakers: 125 Vdc, 2-pole.

2.07 24 VDC POWER SUPPLY

- A. 24 Vdc power supply shall be powered from 125 Vdc power.
- B. 24 Vdc power supply shall be redundant:
 - 1. Provide a main power supply with automatic transfer to a backup power supply, or operate two power supplies in parallel.
 - 2. Power each 24 Vdc power supply with a separate circuit from the 125 Vdc distribution panelboard.

2.08 ASSEMBLY

- A. Install charger, battery rack, and other specified equipment within each substation enclosure secure, plumb and level and in true alignment with related adjoining work.
- B. Install supporting members, fastenings, framing, hangers, bracing, brackets, straps, bolts, and angles as required to set and rigidly connect the Work.
- C. Temporarily install batteries to conduct factory testing, then remove before shipping.
- D. Anti-oxidants and other solvents that can cause cracking of cell jars shall not be used on batteries.

2.09 SOURCE QUALITY CONTROL

- A. Factory test:
 - 1. Cell voltages.
 - 2. Pressure-relief vent operation and reseal.
 - 3. Cell jar leakage.

PART 3 EXECUTION

3.01 INSTALLATION

- A. Following installation of the prefabricated TPSS at site, install battery cells on battery racks.
- B. Provide an equalizing charge as recommended by battery manufacturer.
- C. Mount battery rack and batteries per seismic requirements.

3.02 FIELD QUALITY CONTROL

- A. Test function of batteries and charging system and test resistance of connections in conformance with Section 34 21 90, TPSS Testing.

END OF SECTION 34 21 25

SECTION 34 21 31
TPSS ALARM PANEL

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Alarm panel in traction power substations (TPSS) including programmable logic controller (PLC) (or industrial computer) and Human Machine Interface (HMI).
2. TPSS exterior blue light.

B. Related Sections:

1. Section 26 05 19 – Low Voltage Conductors and Cable
2. Section 34 21 05 – Common Work Results for TPSS
3. Section 34 21 90 – TPSS Testing
4. Section 34 21 25 – TPSS Dc Control Power
5. Section 34 21 80 – TES Spare Parts and Special Tools
6. Section 34 21 90 – TPSS Testing

1.02 REFERENCES

A. Definitions:

1. Intelligent Electronic Device (IED): See definition in Section 34 21 05, Common Work Results for TES.
2. Failure: When the alarm panel or one of its components does not operate as designed.
3. Repeated failure: Two or more failures of the same component; whether IED, communications interface hardware, related hardware, or software.

B. Reference Standards:

1. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:

2. Institute of Electrical and Electronics Engineers (IEEE)
 - a. IEEE C37.90.2, Standard for Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers
 - b. IEEE 730, Standard for Software Quality Assurance Plans
3. International Electrotechnical Commission (IEC)
 - a. IEC 60529, Degrees of protection provided by enclosures (IP Code)
 - b. IEC 60255-21, Electrical Relays – Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment
 - c. IEC 61000-4, Electromagnetic compatibility (EMC)
 - d. IEC 1131-2, Programmable Controllers – Part 2: Equipment Requirements and Tests
 - e. IEC 61131-3, Programmable Controllers – Part 3: Programming Languages
4. National Fire Protection Association
 - a. NFPA 70, National Electrical Code (with amendments by the Authority Having Jurisdiction)

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Design Submittals:
 1. Detailed design of the alarm panel and related components.
 2. Detailed design documents describing the method of communication and implementation of the selected communications protocol for the alarm panel and related components.
 3. List of inputs.
 4. Submit a detailed design of the Human Machine Interface (HMI), including full-scale color views of each screen shot.
 5. Provide documentation demonstrating that specified requirements for service proven design have been met. Include contact information for transit agencies where units are in service.

- C. Product Data: Include technical details and operating manuals of the system and subsystems including hardware, software, MTBF information, communications protocol specifications and show compliance with the specified requirements.
 - 1. PLC (or industrial computer)
 - 2. HMI
 - 3. Terminal blocks
 - 4. Control components
 - 5. Ethernet switch
- D. Spare Parts and Special Tools:
 - 1. Submit a list of spare parts to be provided under this Section.
 - 2. Submit at the same time as product data.
 - 3. Provide part numbers for each part, including a detailed break down of each spare part assembly and set, as defined in Section 34 21 80, TES Spare Parts and Special Tools.
 - 4. Submit a list of special tools to be provided under this Section, as defined in Section 34 21 80, TES Spare Parts and Special Tools.
- E. Shop Drawings:
 - 1. Ladder logic diagrams
 - 2. Input/output maps
 - 3. Flow charts
 - 4. Equipment layout drawings
 - 5. Wiring schematics
 - 6. Interconnection diagrams with detailed labels for components and contacts
 - 7. Bill of Materials
- F. Software:
 - 1. Provide development software for the alarm panel, including any software required to program, maintain, and download events/records for the PLCs and HMI.
 - 2. Provide source code developed for the PLCs and HMI in electronic format as directed by the Engineer.

3. Provide software licenses for application, interface, development software and all software.
- G. Submit test procedures and reports in accordance with Section 34 21 10, TPSS Testing for the following:
1. Factory Design Tests
 2. Operational Tests
- H. Support: System Support Plan for support during commissioning and warranty period.
- I. Operations and Maintenance Data: Submit data in accordance with Section 01 78 23, Operation and Maintenance Data, including the following requirements:
1. Submittal information identified above.
 2. Manufacturer's operating and maintenance instructions, parts list, illustrations and diagram for components.
 3. Wiring diagram.
 4. Recommended list of spare parts.

1.04 SOFTWARE INTELLECTUAL PROPERTY RIGHTS

- A. Application software developed under this Contract, including source code, shall become the property of the Owner.
- B. Interface software for alarm panel components shall be the property of the Owner.
- C. Development software for alarm panel components and HMI shall be property of the Owner.

1.05 SPARE PARTS

- A. Provide spare parts in accordance with Section 34 21 80, TES Spare Parts and Special Tools.
- B. List below applies to items in this Specification Section.
 1. HMI: Provide 1 spare.
 2. PLC (or industrial computer): Provide 1 spare of each type used.
 3. Ethernet switch: Provide 1 spare.

1.06 QUALITY ASSURANCE

- A. Alarm panel components, including PLC or industrial computer and HMI shall be UL labeled.

- B. Alarm panel components that are not UL certified may be furnished with a Field Evaluation label provided by a third party testing laboratory. The testing laboratory shall be approved by the Engineer.
- C. Alarm panel component manufacturers shall be ISO 9001 certified.
- D. A software quality assurance plan shall be used in accordance with IEEE Standard 730. The plan shall describe a mechanism for orderly software development.

1.07 REQUIREMENTS FOR SERVICE PROVEN DESIGN

- A. Alarm panel components and software shall be of a proven design. Provide evidence of at least 15 identical units that have been in successful operation in rail transit projects for a minimum of 3 years.

1.08 RELIABILITY AND MAINTAINABILITY

- A. Alarm panel shall be fail-safe, such that a hardware or software failure condition shall not result in an unsafe equipment state.
- B. Failure of an alarm panel component shall not damage other equipment or inhibit status indication of the equipment.
- C. Investigate repeated failure in the alarm panel and provide a failure analysis report outlining the root cause of failure. Provide recommendations for correcting the failure and apply the corrective action at no cost to the Owner.
- D. The following components shall have a minimum mean time between failure (MTBF):
 - 1. PLC – 100,000 hours
 - 2. HMI – 50,000 hours
- E. Alarm panel shall be capable of accommodating upgrades, bug-fixes, patches and modifications.
 - 1. Monitor the need for system modifications and supply such changes at no additional cost to the Owner for a period of 5 years.
 - 2. Fully document changes and submit documentation to the Engineer.

1.09 ENVIRONMENTAL REQUIREMENTS

- A. Alarm panel components shall be designed to operate in the environment in which they will be installed and shall comply with and fully function in the environmental conditions specified in Section 34 21 05 Common Work Results for TES.
- B. Electrical interfaces shall meet the applicable ANSI and IEEE Standards for service, EMI immunity, and surge-withstand requirements.
- C. The presence of transients on communication interfaces shall not cause misoperation or blocking of critical communications.

1.10 WARRANTY

- A. Provide on-site and remote support for the specified alarm panel throughout the entire warranty period. Support shall include assistance with operation and maintenance of the system.
- B. Develop a comprehensive System Support Plan and submit to Engineer.

PART 2 PRODUCTS

2.01 GENERAL

- A. Provide an alarm panel for monitoring and control of traction power substation equipment at each TPSS.
- B. Alarm panel shall consist of the following components:
 - 1. Programmable logic controller (PLC) or industrial computer.
 - 2. HMI panel.
 - 3. Ethernet switch.
 - 4. Voiceband dial-up/leased line modem.
- C. Devices shall utilize commercial off-the-shelf products to minimize integration and future maintenance efforts.
- D. Devices shall be of the same brand and model with similar modules and programming to achieve similarity between substations.
- E. Provide terminal blocks, in accordance with Section 34 21 05, Common Work Results for TES, and wiring as required for alarms.
- F. Alarm panel components shall comply with the following requirements:
 - 1. Mechanical shock and bump withstand level: IEC 60255-21-2, Response and Withstand Section, Class 1.
 - 2. Vibration withstand level: IEC 60255-21-1, Response and Withstand Section, Class 2.
 - 3. Seismic withstand level: IEC 60255-21-3, Class 2.
 - 4. Electromagnetic field impulse withstand level: IEC 61000-4-3, 10V/m.
 - 5. Electromagnetic field radio frequency withstand level: ANSI C37.90.2, 35V/m.
 - 6. Storage Temperature: Minus 20 degrees to 60 degrees C.
 - 7. Operating Temperature: Zero degrees to 40 degrees C.

8. Maximum humidity: 90 percent without condensation.
 9. Provide product data verifying compliance.
- G. Alarm Panel I/O Design
1. Provide a list of all alarm panel component inputs and incorporate in the design for monitoring and indication to the HMI.
 2. Contractor shall provide 10 additional I/O points at each TPSS for indication or monitoring upon request at no additional cost to the Owner.
- H. Alarm panel component memory and removable storage shall be solid-state, non-volatile, and shall not utilize mechanically-driven (hard-drive based) components.
- I. Alarm panel shall be designed such that no supply power fault will result in loss of data or require any manual re-work such as programming or reconfiguration.

2.02 POWER REQUIREMENTS

- A. Alarm panel and PLC shall be powered by 125 Vdc plus or minus 15 percent or 24 Vdc plus or minus 20 percent. See Section 34 21 25, TPSS Dc Control Power for requirements.

2.03 PLC

- A. Provide a PLC at each TPSS for interfacing with other alarm panel components, equipped with the following modules:
1. Chassis or backplane.
 2. Power supply.
 3. Primary central processing unit (CPU): Minimum 32 MB user memory.
 4. I/O modules
 5. Communications: RJ45, RS232/RS485, TCP/IP, Ethernet.
 6. Storage memory: Minimum 2 GB.
 7. Removable flash memory.
 8. Resident executable program and code.
- B. PLC shall provide the following functions:
1. Log IED data, alarms, and events.
 2. Communicate alarms to the display panel.

3. Operate independently of a failure of any other PLC or IED in the substation or their intercommunications.
 4. Retain programming, configuration and memory (including data logs) even with loss or degradation of supply power.
 5. Provide monitoring and control of TPSS equipment.
- C. Repair and Replacement:
1. PLC and associated modules shall be replaceable on site without requiring factory rewiring.
 2. PLC modules shall have free-standing terminals to allow changing modules without disturbing field wiring.
- D. Programming facilities (logic, available functions and supported data types) shall be non-proprietary and shall either be compliant with IEC 61131-3 or shall use the C or C++ standard programming languages.

2.04 HUMAN MACHINE INTERFACE (HMI) HARDWARE

- A. Provide a HMI panel for controlling TPSS equipment and monitoring TPSS events and alarms.
- B. HMI and ancillary devices shall be flush mounted in a door of the dc switchgear.
1. Locate at a height appropriate for easy access by a person of average height.
 2. Locate such that a person standing in front of the HMI is not standing in front of a circuit breaker.
- C. Memory:
1. Configuration memory: 256 MB minimum
 2. Non-volatile memory: 256 MB minimum
- D. Screen:
1. TFT 18-bit Color LCD minimum
 2. Resistive touch screen
 3. Size: 15-inches diagonal minimum
 4. Resolution: 1024 x 768 pixels minimum
- E. Interfaces:
1. RS485

2. Two USB
 3. RJ 45 Ethernet
 4. RS232
 5. Media Card Slot
- F. Approved Manufacturer/Product:
1. Allen Bradley PanelView Plus CE 1500 Color.
 2. Substitutions: Section 01 25 00, Substitution Procedures.

2.05 HMI SCREEN USER INTERFACE DESIGN

- A. Provide the following screens: Desktop screen, one-line diagram screen, alarm screen and event log screen.
1. Show substation equipment and devices in a layout similar to layout shown on Contract Drawings.
 2. Buttons and text shall be sized appropriately for ease of use.
 3. Each screen shall have navigation tabs to access all screens from any other screen.
- B. Desktop Screen:
1. Screen shall be visible at all times above the other screens, as shown on Contract Drawings, and show time, date, and configuration button.
 2. Time and Date:
 - a. Time shall be synchronized with PLC.
 - b. Time format: 00:00:00.
 - c. Date format: December 10, 2011.
 3. Configuration Button: Provides screen(s) for setting and changing passwords, time, and date.
- C. One-Line Diagram Screen:
1. Show equipment status and provide local control of TPSS equipment.
 2. Status (including color) of traction power equipment on touch screen shall be displayed in real time and updated at least every 2 seconds.

3. Color Code:
 - a. Color shall indicate the energized, de-energized, or uncertain state of each piece of equipment, including the busbar and feeder cables.
 - b. There are no exceptions to the following color code on the one-line diagram and no other colors are permitted:
 - 1) Energized Equipment: Red.
 - 2) De-energized Equipment: Green.
 - 3) Uncertain Equipment State: Grey.
 - c. Display red color text "Energized" beside each piece of equipment while it is energized.
4. Open/close control operation:
 - a. Open/close operations shall not be direct and shall include multiples steps.
 - b. Selection of object:
 - 1) Select object.
 - 2) Confirm object selection.
 - c. Selection of control operation:
 - 1) Select operation (close/open).
 - 2) Confirm operation.
 - 3) Execute operation.
 - d. A combined message window shall not be used; each step shall have an individual window.
 - e. Selection, confirmation, and execution information shall be displayed completely without abbreviations.
 - f. Selection and confirmation of operation shall be automatically cancelled after 60 seconds if the operation is not executed.
 - g. Provide a cancel button for each control step.
5. Bypass Load Measuring: Provide option for dc breaker close operation that allows selection of bypass mode, which bypasses the load measuring system.
 - a. Upon confirmation of this operation, a warning shall flash on the screen stating "LOAD MEASURING BYPASSED."

6. Password Protection:
 - a. Selection of an object shall be password protected.
 - b. Selection of bypass load measuring shall require an additional level of password protection.
 - c. Automatically display a numeric/alphanumeric screen keyboard when a password must be entered to continue.
 7. If a protection function is triggered, the related equipment alarm field shall flash until it is acknowledged.
- D. Alarm Screen:
1. Annunciate alarms shown in Alarm Points List, at the end of this Section.
 2. Layout: See Contract Drawings.
 3. Alarm: Flashing red.
 4. Acknowledged alarm: Solid red.
 5. Alarms resolved before acknowledgment: Flashing yellow.
 6. Default: Grey.
 7. Alarms shall be acknowledged by touching the flashing alarm.
- E. Event Log Screen:
1. Indicate each alarm event with time and date.
 2. Event log shall display a minimum of 200 events.
 3. Events shall be retained in memory for minimum 7 days.
 4. Events shall be downloadable to a laptop or a USB flash drive without deletion from the alarm panel.

2.06 ETHERNET SWITCH

- A. Provide industrial Ethernet switch for connecting IEDs to alarm panel for annunciation and future SCADA.
- B. Ports:
 1. Six 10/100 switched RJ45 ports.
 2. Two 100 Mb fiber ports full duplex.

- C. Ambient temperature: minus 40 to 70 degrees C.
- D. Case: High strength 18-gage steel.
- E. Approved Manufacturer/Product:
 - 1. GarrettCom P62F 8-port 10/100 switch.
 - 2. Substitutions: Per 01 25 00 Substitution Procedures.

2.07 VOICEBAND DIAL-UP/LEASED LINE MODEM

- A. Provide at each TPSS a PSTN/POTS (Public Switched Telephone Network/Plain Old Telephone Service) based voiceband dial-up/leased line modem equipped with the following features:
 - 1. Support of full and half duplex operation modes for data transmission.
 - 2. Automatic dial and automatic answer.
 - 3. Automatic dial on signal from PLC/IC or other device.
 - 4. Ports:
 - a. RJ45 Ethernet with PLC/IC.
 - b. RJ11 with transmission level between minus 9 and minus 15 dB, receiver sensitivity minus 43 dBm.
 - 5. Steel enclosure: NEMA 1, 18-gage, with mounting flanges.

2.08 DEVELOPMENT SOFTWARE

- A. Provide a user-friendly PC/Windows based development environment suitable for PLC/HMI application software updating and modification.
- B. The environment shall be dedicated solely to creating control/monitoring software. It shall use familiar, standardized editors bundled into a single application.
- C. The environment shall include a graphics editor and online help that simplifies development of PLC/HMI application software.
- D. The environment shall comply with Microsoft Windows Graphical User Interface (GUI) and IEC 61131-2 standards for programmable logic controllers.
- E. Provide de-bug, documentation and machine startup facilities in the environment.
- F. Provide complete user training for the application of development environment in accordance with Section 01 79 00, Demonstration and Training.

- G. Provide complete user documentation for the environment complying with Section 01 78 23, Operations and Maintenance Data.

2.09 ENCLOSURES

- A. Enclosures shall be designed and provided by the Contractor.
- B. Installation of alarm panel components in a compartment within either the switchgear or negative cubicle is permissible if the devices can be readily accessible without disassembling interior portion of the switchgear assembly, control wiring is contained within the cubicle, and the layout and location are approved by the Engineer.
- C. Construction: NEMA Type 12 dust-tight single hinged door enclosure, fabricated from 11 gage steel, with continuously welded or bolted seams.
- D. Door:
 - 1. Gasket with neoprene.
 - 2. Provide with a pad-lockable handle with a three point latch system.
- E. Finish: Prime and finish paint to match the switchgear.
- F. Hardware and accessories: Stainless steel.
- G. Internal back-panel: Removable, stud-mounted, and located as shown for the mounting of relays and terminal strips.
- H. Dimensions: As required by Contractor's layout.

2.10 INTERIOR BLUE LIGHT AND RESET SWITCH

- A. Provide a blue light LED for TPSS alarm indication located above the HMI panel.
- B. The blue light shall have a label "SUBSTATION TROUBLE ALARM."
- C. The light shall operate as follows:
 - 1. Light flashes when an alarm panel alarm/event occurs.
 - 2. Light is solid when all alarms are acknowledged.
 - 3. Light turns off when all alarms are resolved.
- D. Alarm acknowledgement shall be provided by HMI.
- E. Blue light shall be fail safe.

2.11 EXTERIOR BLUE LIGHT

- A. Activate exterior blue light (see Section 34 21 05, Common Work Results for TES) for the following alarms:
 - 1. Smoke alarm
 - 2. Intrusion Zone 1 alarm (entry doors)
 - 3. Intrusion Zone 2 alarm (exterior equipment access doors)
 - 4. Ac breaker trip
 - 5. Dc breaker trip without reclose
 - 6. Traction power transformer over temperature (first stage)
 - 7. Rectifier over temperature (first stage)
 - 8. Substation high temperature.
 - 9. Diode failure.
 - 10. Frame fault.
- B. For Intrusion Zone 1 alarm, provide a time delay, and an override in the HMI only, to allow authorized persons to enter the substation and override the alarm without activating the exterior blue light.

2.12 ASSEMBLY

- A. Alarm panel hardware installation shall be identical and interchangeable between substations, including wire numbering, and marking.
- B. Wiring: Interconnecting wiring shall be 14 AWG 600 V switchboard wire in accordance with Section 26 05 19, Low Voltage Conductors and Cable.
- C. Wire and Cable Identification:
 - 1. Wire and cables shall be identified whenever they enter or leave a housing or enclosure, and at all terminals.
 - 2. Provide labels in accordance with Section 26 05 19, Low-Voltage Conductors and Cable.
- D. Terminals: DIN rail mounted.

- E. Spare Capacity:
 - 1. Design system with a minimum of 30 percent spare capacity. This shall include:
 - a. Wiring terminals.
 - b. Inputs and outputs of same kind per modular controller unit.
 - c. Spaces for additional modules for each modular PLC unit.

- F. Workmanship:
 - 1. Install equipment, enclosures, wire, cable, conduits and wireways in a neat and secure manner, level and plumb, and in true alignment with adjoining work.
 - 2. Equipment enclosures and installation shall comply with local and national codes including, but not limited to UL 508A and NFPA 70.

2.13 TESTING

- A. The alarm panel components shall be factory tested in accordance with Section 34 21 90, Traction Power Testing.

2.14 ALARMS POINTS LIST

- A. Provide the following points for monitoring by the alarm panel and future SCADA at each TPSS.

Device	Description	Device No
Ac Circuit Breaker and Protective Relay	Breaker closed/open status	52
	Undervoltage	27
	Overvoltage	59
	Loss of Control power	27ac
	Phase Sequence	47
	Time Delay Overcurrent Phase	51
	Instantaneous Overcurrent Phase	50
	Time Delay Overcurrent Neutral	51N
	Instantaneous Overcurrent Neutral	50N
	Local/Remote Indication	
	Access Door	33ac
	Ac Breaker Trip Healthy Coil	
	Ac Lockout Relay Healthy Coil	
	Ac Protective Relay Status	
	Ac Lockout Relay	86

Power Meter	V, A, kW, kVAr, kWh	
Dc Feeder Breaker and Protective Relay (for each feeder breaker)	Breaker closed/open status	172
	Remote Trip Command	
	Remote Close Command	
	Local/Remote Indication	43
	Overvoltage	159
	Undervoltage	127
	Rate of Rise di/dt	151
	I _{max}	150
	Loss of Control power	27dc
	Dc Voltage	
	Dc Current	
	Transfer Trip	85
	Transfer Trip Lockout	85L
	Access Door	33dc
	Positive Disconnect Switch	Open Indication
Close Indication		
Negative Disconnect Switch	Open Indication	
	Close Indication	
Traction Power Transformer	Over Temperature 1 Alarm	49T1
	Over Temperature 2 Trip	49T2
Rectifier	Over Temperature 1 Alarm	26R1
	Over Temperature 2 Trip	26R2
	Temp Monitor Status	
	Diode Failure 1 Alarm	98R1
	Diode Failure 2 Trip	98R2
	Rear Access Door	33R
	Reverse Current	32
Battery Charger	Undervoltage	27Batt
	Overvoltage	59Batt
	Charger Summary Alarm	
TPSS General	ETS	5
	High Temperature Alarm	
	Smoke alarm	
	Intrusion Zone 1 (access doors)	

	Intrusion Zone 2 (exterior equipment access doors)	
	HVAC 1 Status Alarm	
	HVAC 2 Status Alarm	
Rail-to-Ground Monitor	Stage 1 Voltage Alarm	
	Stage 2 Voltage Alarm	
	Stage 1 Current Alarm/Trip	
	Stage 2 Current Alarm/Trip	
	R2G Status	
Ground Fault Detector	Grounded Structure Alarm	64GS
	Hot Structure Trip	64HS
Alarm panel	PLC Fault	
	HMI Fault	

PART 3 EXECUTION

Not Used.

END OF SECTION 34 21 31

SECTION 34 21 33

RAIL VOLTAGE MONITORING AND GROUNDING SYSTEM

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:

1. Requirements for the Rail Voltage Monitoring and Grounding System for each traction power substation.
2. Rail Voltage Monitoring and Grounding System includes a bi-directional hybrid switching device and an integrated Device 64V protective relay function for tripping of dc feeder circuit breakers.

B. Related Sections:

1. Section 34 21 05 – Common Work Results for TPSS
2. Section 34 21 80 – TES Spare Parts and Special Tools
3. Section 34 21 90 – TPSS Testing

1.02 DEFINITIONS

A. Rail Voltage Monitoring and Grounding System:

1. This is also referred to as Rail-to-Ground System or R2G.

B. Controller:

1. A programmable logic controller (PLC) and human machine interface (HMI) device.

C. Rail voltage:

1. Zero potential is equal to ground potential.
2. Positive voltage is defined as rail potential positive with respect to ground potential.
3. Negative voltage is defined as rail potential negative with respect to ground potential.

D. Current:

1. Positive current is current that flows from rail to ground.
2. Negative current is current that flows from ground to rail.

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Product Data:
 - 1. Manufacturer's product descriptions and catalog data for system components.
 - 2. Information concerning design and application ratings.
 - 3. Description of measures used to prevent burning of contactor.
 - 4. Information concerning service, performance and reliability and locations where units are currently in service.
- C. Spare Parts and Special Tools:
 - 1. Submit a list of spare parts to be provided under this Section.
 - 2. Submit at the same time as product data.
 - 3. Provide part numbers for each part, including a detailed break down of each spare part assembly and set, as defined in Section 34 21 80, TES Spare Parts and Special Tools.
 - 4. Submit a list of special tools to be provided under this Section, as defined in Section 34 21 80, TES Spare Parts and Special Tools.
- D. Submit the following shop drawings for approval within 120 Days after NTP:
 - 1. Manufacturer's arrangement and outline dimensions for each device.
 - 2. Rail Voltage Monitoring and Grounding System wiring, schematic, and connection diagrams.
- E. Submit measures used to prevent failure of thyristor and burning of contactor to Engineer for review and approval.
- F. Submit test procedures and test reports in accordance with Section 34 21 90, TPSS Testing.
 - 1. Production Tests: Provide production test reports for each device within 120 Days after NTP.

1.04 SPARE PARTS

- A. Provide spare parts in accordance with Section 34 21 80, TES Spare Parts and Special Tools.

- B. List below applies to items in this Specification Section.
 - 1. Rail to ground complete assembly, including PLC and HMI: Provide 1 assembly.
 - 2. Enclosure door key: Provide 2 spare keys for each substation.

PART 2 PRODUCTS

2.01 RAIL-TO-GROUND SYSTEM (R2G)

- A. General Requirements:
 - 1. R2G shall be of proven design with minimum 3-years successful operation in a light rail application.
 - 2. Provide an R2G at each traction power substation for monitoring and protecting against rail-to-ground overvoltages and overcurrents.
 - 3. R2G shall be a self contained unit with a bi-directional hybrid switching element, voltage transducer, current transducer, and PLC/HMI controller suitable for use in a 750 Vdc traction power system.
 - 4. PLC/HMI controller shall be used only for R2G and shall not be used for other substation operations.
 - 5. Bi-directional hybrid switching element shall consist of a thyristor and contactor for grounding the rail.
 - a. Continuous Current Rating: 800 A minimum.
 - b. Current Withstand: 30 kA for 100 ms and 50 kA for peak value half sine wave.
 - 6. Enclosure: Steel, with a latching access door that is lockable, all enclosures keyed alike.
- B. R2G shall have the following features:
 - 1. Monitor and display voltage and current values exhibited in real time.
 - 2. Record all switching, alarm, and fault events and retain an event history for seven days minimum in non-volatile memory.
 - a. Events shall be downloadable onto a laptop computer.
 - b. See Section 34 21 05, Common Work Results for TES for requirement to supply software.
 - 3. Waveform capturing capabilities for display and recording.
 - a. This information shall be downloadable onto a laptop computer.

- b. Provide all necessary hardware and software for connection to the R2G via laptop computer.
 - 4. Output contacts for circuit breaker tripping and alarms (Device 64V).
 - 5. LED indicator lights mounted on the enclosure:
 - a. A red LED shall illuminate when the switch is closed.
 - b. A flashing yellow LED shall indicate that an event has occurred. LED will remain flashing until acknowledged.
 - 6. Push button on the outside of the enclosure for the local acknowledgement of the yellow LED event alarm.
- C. HMI shall provide the following:
 - 1. Event notification, voltage and current information, and device configuration.
 - 2. Means of field programming time and date, voltage and current triggers, and communications settings.
 - 3. Password protection for functions related to changing the configuration of the device.
 - 4. Recorded events shall be viewable on the HMI display.
 - 5. Current date and time on display.
 - 6. Indication of status of SCR/contactors.
- D. Control power: 125Vdc
- E. Communications: Modbus over Ethernet TCP/IP, RJ45, and RS485.
 - 1. Device shall be capable of being remotely monitored.
 - 2. R2G shall communicate alarms and switch status to the alarm panel.

2.02 DETAILED OPERATION REQUIREMENTS

- A. R2G shall have at minimum two stages of voltage protection (64V):
 - 1. First stage:
 - a. Voltage setting range: 0 to 200V, positive or negative, in 1V increments.
 - b. Time delay setting range: 0 to 20 seconds in 0.1-second increments.
 - c. Default setting: +/-50V and 10-second delay.

2. Second stage:
 - a. Voltage setting range: 0 to 200V, positive or negative, in 1V increments.
 - b. Time delay setting range: 0 to 10 seconds in 0.1-second increments.
 - c. Default setting: +/-95V and 2-second delay.
- B. Each voltage stage shall trigger the R2G bi-directional switch.
- C. R2G bi-directional switch operation:
 1. Time duration of closure shall be adjustable.
 - a. Setting range: 1 second to 10 seconds in 0.1-second increments.
 - b. Default setting: 2 seconds.
 2. Operation:
 - a. Thyristors shall be fired and become conductive before contactor is closed.
 - b. Contactor shall be opened before thyristors are extinguished and become nonconductive.
 - c. Submit measures used to prevent burning of contactor to Engineer for review and approval.
- D. When activated, the R2G shall monitor current through the switch and provide two stages of overcurrent protection:
 1. First stage:
 - a. Current setting range: 0 to 1000A, positive or negative, in 1 A increments.
 - b. Time delay setting range: 0 to 60 seconds in 0.1-second increments.
 - c. Default setting: +/-15A and 50-second delay.
 2. Second stage:
 - a. Current setting range from 0 to 1000A, positive or negative, in 1 A increments.
 - b. Time delay setting range: 0 to 60 seconds in 0.1-second increments.
 - c. Default setting: +/-100A and 1-second delay.
- E. Each overcurrent stage shall trigger any one of three user-selectable responses:
 - a. Trip and reclose dc breakers (default for second stage).

- b. Trip and lockout dc breakers (default for first stage).
 - c. Trip and lockout dc breakers and transfer trip adjacent substations.
- F. The R2G shall trip and lockout the breaker on a repeat second-stage overcurrent trigger if it occurs within a user-adjustable time. The user adjustable settings are as follows:
- a. Repeat Trigger Function: Enabled, Disabled.
 - b. Time Window Setting range: 2 to 60 seconds in 1-second increments. The setting shall not be less than the Overcurrent Second Stage time delay.
 - c. Default setting: 60 seconds.
- G. If the current value measured by the R2G is lower than the current setting of the first stage, the grounding device shall open and reset after the voltage protection time duration setting of the grounding device has elapsed.
- H. R2G shall be fail-safe as described in the following two scenarios, at minimum:
- 1. A malfunction of the control component shall cause grounding device to close until control component is restored.
 - 2. An alarm signal shall be sent to alarm panel if a thyristor or control component fails.

2.03 CONNECTIONS

- A. Ground R2G enclosure and internal ground reference busbar to the structure earth using 4/0 copper cable.
- B. Connect the R2G negative reference to the negative return using 4/0 copper 2kV insulated cable.

PART 3 EXECUTION

Not Used.

END OF SECTION 34 21 33

SECTION 34 21 46

TRACTION POWER DC CONTACTOR PANEL

PART 1 GENERAL

1.01 SUMMARY

- A. Section Includes:
 - 1. Contactor panel for Operation and Maintenance Facility (OMF).
 - 2. Panel assembly includes dc contactors, fuses, relays, copper bus, control switches, and related components.
- B. Products Furnished But Not Installed Under This Section:
 - 1. Contactor panel for OMF.
- C. Related Sections:
 - 1. Section 05 05 00 – Common Work Results for Metals
 - 2. Section 26 05 19 – Low-Voltage Conductors and Cable
 - 3. Section 34 21 05 – Common Work Results for TPSS
 - 4. Section 34 21 80 – TES Spare Parts and Special Tools

1.02 REFERENCE STANDARDS

- A. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:
- B. ASTM International (ASTM)
 - 1. ASTM A653/A653M, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
 - 2. ASTM B187, Specification for Copper Bar, Bus Bar, Rod and Shapes
- C. International Electrotechnical Commission (IEC)
 - 1. IEC 60947-4-1, Low-Voltage Switchgear and Controlgear - Part 4-1: Contactors and Motor-Starters - Electromechanical Contactors and Motor-Starters

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.

B. Product Data:

1. Submit manufacturers' product data for specified equipment and materials. Include the following information for each item:
 - a. Manufacturer's model number or item identification.
 - b. UL listing and rating.
 - c. Critical dimensions and mounting arrangement.
 - d. Replacement parts list.

C. Spare Parts and Special Tools:

1. Submit a list of spare parts to be provided under this Section.
2. Submit at the same time as product data.
3. Provide part numbers for each part, including a detailed break down of each spare part assembly and set, as defined in Section 34 21 80, TES Spare Parts and Special Tools.
4. Submit a list of special tools to be provided under this Section, as defined in Section 34 21 80, TES Spare Parts and Special Tools.

D. Shop Drawings:

1. Submit shop drawings and electrical diagrams showing materials and methods of construction, door arrangement, contactors, fuses, and bus inside enclosure.

E. Operation and Maintenance Data:

1. Submit data in accordance with Section 01 78 23, Operation and Maintenance Data, including the following requirements:
 - a. Description, including part number and manufacturer, of each type of contactor, fuse, relay, control switch, and related components.
 - b. Manufacturer's operating and maintenance instructions, parts list, illustrations and diagram for components.
 - c. Recommended list of spare parts.
 - d. Wiring diagram.

F. Test Reports:

1. Submit copies of certified reports of factory and field tests performed in accordance with the applicable referenced standards and specification requirements.

1.04 SPARE PARTS

- A. Provide spare parts in accordance with Section 34 21 80, TES Spare Parts and Special Tools.
- B. List below applies to items in this Specification Section.
 - 1. Dc contactor, APS: Provide 1 spare.
 - 2. Dc contactor, OCS: Provide 1 spare.
 - 3. Dc contactor fuse: Provide 4 spare.
 - 4. Control switch: Provide 1 spare.
 - 5. Control fuse or mini-breaker: Provide 1 spare set.

1.05 QUALITY ASSURANCE

- A. Select a manufacturer who has been regularly engaged in the manufacture of similar equipment

PART 2 PRODUCTS

2.01 DC CONTACTOR PANEL

- A. General Description:
 - 1. Provide a single free-standing or wall mounted unit containing individual enclosed contactor sections connected by copper bus, as shown on Contract Drawings.
 - 2. Each contactor section includes a fuse, relays, control switches and related components for interlocking and control of Auxiliary Power Stations (APS) and future Shop OCS.
 - 3. Refer to Contract Drawings for elevation and schematic drawings.
- B. Enclosure: NEMA 1, metal enclosed, minimum 12-gage steel, welded construction, ventilated, self supporting.
 - 1. Fabricate from zinc-coated steel sheet conforming to ASTM A653/A653M, zinc coating designation G90.
 - 2. Reinforce with adequate steel framework to form a rigid structure with a smooth outer surface free from burrs, ridges and other blemishes.
 - 3. Doors: Hinged, minimum 14-gage steel.
 - a. Hinges: Stainless steel, full height.
 - b. Latches: Stainless steel, three-point.

4. Finish: Powder coat in accordance with Section 05 05 00, Common Work Results for Metals.
 5. Color: In accordance with Section 05 05 00, Common Work Results for Metals.
- C. Dc Contactor:
1. Ratings:
 - a. Voltage: 900 Vdc.
 - b. Current:
 - 1) APS Contactor: 100 A continuous.
 - 2) OCS Contactor: 400 A continuous.
 2. Control Voltage: 125 Vdc.
- D. Fuses and Fuse Holders
1. Spring-type fuse holder rated 750 Vdc.
 2. Provide current-limiting type fuse for each APS contactor and each OCS contactor.
 3. Size as shown on Contract Drawings.
- E. Bus Bars:
1. ASTM B187, 98 percent conductivity copper.
 2. Bolted bus connections, including bus taps and cable landing pads, shall be silver plated copper and joined with a minimum of two bolts and Belleville washers per joint.
 3. Each joint shall have conductivity at least equal to that of the bus bar and each joint shall be so clamped that no loss of conductivity will occur during the life of the panel.
 4. Mount bus bars on barrier-type insulation or post-type insulators of sufficient strength and braced to withstand, without damage or permanent distortion, stresses produced by the maximum available short-circuit currents.
- F. Control Switches:
1. Heavy duty, rated for dc control voltage.
 2. Mechanism for padlocking in the open position: Heavy duty, steel.

G. Control Wiring: Factory-installed.

1. Wire:
 - a. 2000 V switchboard wire complying with Section 26 05 13, Medium-Voltage Conductors and Cable.
 - b. Minimum Size: No. 14 AWG.
 - c. For wiring across hinged joints: Class D stranded wire, minimum size No. 12 AWG.
2. Wire Terminals: Tinned copper ring compression terminals with insulated sleeve installed in accordance with the manufacturer's recommendations.
3. Terminal Blocks: Provide washerhead screws suitable for ring compression terminals with insulated sleeve. Provide a minimum of ten percent spare terminals.
4. Wire Connections: Shall be made only on terminal blocks.
5. Wire Identification.
 - a. Each wire shall be provided with plastic heat shrink sleeve, attached within 6 inches of terminal connections and printed with the number indicated on the wiring diagrams.
 - b. Heat shrink sleeves after installation.
6. Provide insulated barriers to separate control wiring from power wiring.

2.02 SOURCE QUALITY CONTROL

- A. In addition to the manufacturer's standard tests, as a minimum perform the following tests at the manufacturer's plant:
 1. Electrical operation tests.
 2. Control wiring checks.
- B. Signage:
 1. Identification: Provide equipment and device nameplates on face of panel in accordance with Section 34 21 05, Common Work Results for TES. See Contract Drawings for contactor numbering.
 2. Warning Signs: Provide 'DANGER HIGH VOLTAGE' signs on each section door.

PART 3 EXECUTION

Not Used.

END OF SECTION 34 21 46

SECTION 34 21 50

DC SURGE ARRESTERS

PART 1 GENERAL

1.01 SUMMARY

- A. Section Includes: Requirements for dc surge arresters in traction power substations.
- B. Products Furnished But Not Installed Under This Section:
 - 1. Dc surge arresters for King Street TPSS, including enclosure and minimum 3 feet of extra-flexible copper ground cable for each surge arrester.
- C. Related Sections:
 - 1. Section 34 21 05 – Common Work Results for TPSS
 - 2. Section 34 21 80 – TES Spare Parts and Special Tools

1.02 REFERENCE STANDARDS

- A. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:
- B. American Society for Testing and Materials (ASTM)
 - 1. ASTM B3, Soft or Annealed Copper Wire
 - 2. ASTM B172, Rope-Lay Stranded Conductors having Bunch Stranded Members
- C. Institute of Electrical and Electronics Engineers (IEEE)
 - 1. IEEE P1627, Draft Standard for Grounding Practices for Dc Electrification Overhead Contact Systems, Including Application of Lighting Arresters for Transit Systems
- D. National Electrical Manufacturer's Association (NEMA)
 - 1. NEMA 250, Enclosures for Electrical Equipment (1000 Volts Maximum)

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Product Data: Descriptive data on the surge arresters to be provided.
- C. Shop drawings: To scale showing the surge arrester installation.

- D. Spare Parts and Special Tools:
 - 1. Submit a list of spare parts to be provided under this Section.
 - 2. Submit at the same time as product data.
 - 3. Provide part numbers for each part, including a detailed break down of each spare part assembly and set, as defined in Section 34 21 80, TES Spare Parts and Special Tools.
 - 4. Submit a list of special tools to be provided under this Section, as defined in Section 34 21 80, TES Spare Parts and Special Tools.
- E. Submit factory test reports within 30 days after conducting the following tests.
 - 1. Energy test.
 - 2. Production test.
 - 3. Test to failure.

1.04 SPARE PARTS

- A. Provide spare parts in accordance with Section 34 21 80, TES Spare Parts and Special Tools.
- B. List below applies to items in this Specification Section.
 - 1. Dc surge arrester enclosure: Provide 1 spare.
 - 2. Dc surge arrester, complete with mounting bracket and minimum 3-foot grounding conductor: Provide 10 spares.

PART 2 PRODUCTS

2.01 DC SURGE ARRESTERS

- A. Dc surge arresters shall be outdoor style, intermediate class and shall be designed, constructed, and tested in accordance with the general requirements of IEEE P1627.
- B. Surge arresters shall be of the metal oxide varistor (MOV) type.
- C. MOV elements shall be fully encapsulated in epoxy.
- D. Minimum sparkover voltage: 1000 V.
- E. Energy discharge capability: 2.6 kJ for currents 500 A or less.
- F. Line transients: 2500 Vdc withstand of either polarity to ground.

- G. Reverse voltage across rectifier silicon diodes: Arresters shall limit to a value less than 75 percent of the peak-reverse-voltage rating of the diode by limiting the rise of the transient on the positive to negative bus.
- H. Approved Manufacturer: Balfour Beatty Rail, Inc.
 - 1. Substitutions: Per 01 25 00, Substitution Procedures.

2.02 DC SURGE ARRESTER ENCLOSURE

- A. Provide enclosure such that arresters will fail in a safe manner, as demonstrated in the required Test to Failure.
- B. Enclosure shall be large enough to allow arrangement that will permit an electrical arc to clear quickly.
- C. Provide either a metallic or non-metallic enclosure, as specified below.
 - 1. Metallic Enclosure:
 - a. Stainless steel, ventilated, NEMA 250 Type 3R, 11 gage, with reinforced 1/4-inch clear Lexan water-proof cover.
 - b. Line interior of enclosure on all sides and rear with 1/4-inch glastic conforming to Section 34 21 05, Common Work Results for TES.
 - 2. Non-Metallic Enclosure:
 - a. Fire resistant material, ventilated, NEMA 250 Type 3R with reinforced 1/4-inch clear Lexan water-proof cover.
 - b. Enclosure shall pass Test to Failure without igniting.

2.03 GROUNDING CONDUCTOR

- A. Extra-flexible cable, copper, 4/0 AWG, Class I stranding, bare or stranded, ASTM B3, ASTM B172.

2.04 SOURCE QUALITY CONTROL

- A. Test to Failure:
 - 1. Perform test on one surge arrester.
 - 2. Install surge arrester in proposed enclosure complete with cables connected.
 - 3. Test to failure at two times energy rating and verify that arc clears and that enclosure does not fail catastrophically.
 - 4. If enclosure does not contain the surge arrester failure, submit a new surge arrester, new enclosure, or both, and retest.

- B. Energy Test
 - 1. Test each surge arrester and provide test report.
 - 2. Test at 80 percent of rated energy.
- C. Production Test (minimum requirement; additional tests may be performed)
 - 1. Test each surge arrester after completion of the energy test and provide test report.
 - 2. Test using a calibrated ac dielectric test set capable of reading leakage values.
 - 3. Apply 1000 Vac for 30 seconds. Maximum allowable leakage current 15 mA.
 - 4. Increase voltage to 1100 Vac for 5 seconds. Maximum allowable leakage current 30 mA.

2.05 ASSEMBLY

- A. Negative: Provide surge arresters connected between the negative bus and the ground mat. Connection to ground mat is by others.
- B. Positive: Provide surge arresters between the load side of each dc feeder breaker and the ground mat as indicated in Contract Drawings. Connection to ground mat is by others.
- C. Provide surge arresters in enclosures:
 - 1. Wall mount enclosure on exterior of TPSS.
 - 2. Mount enclosure, if metallic, on stand-off insulators.
 - 3. Mounting Height: Above 8 feet to bottom of enclosure.
- D. Install in accordance with surge arrester manufacturer's instructions.
- E. Install conductors with a minimum number of bends. Bends shall be no less than 8-inch radius.
- F. Connection of cable to surge arrester on ungrounded side shall be taped and covered with a heat-shrink insulating sleeve to provide an insulation level of 1000 V.
- G. Ground side of surge arrester: Provide grounding conductor, minimum length 3 feet.
 - 1. Provide insulating grommet or cable connector where grounding conductor penetrates metallic enclosure to prevent grounding enclosure.

PART 3 EXECUTION

Not Used.

END OF SECTION 34 21 50

SECTION 34 21 73
TE SYSTEM STUDIES

PART 1 GENERAL

1.01 SUMMARY

- A. Section Includes:
1. Requirements for the following computer-based studies and reports for ac and dc switchgear associated with traction power substations:
 - a. Short-circuit study.
 - b. Ac coordination study.
 - c. Dc coordination study.
 - d. Arc-flash hazard analysis study.

1.02 REFERENCE STANDARDS

- A. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:
- B. Institute of Electrical and Electronics Engineers (IEEE):
1. IEEE 241, Recommended Practice for Electric Power Systems in Commercial Buildings
 2. IEEE 242, Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems
 3. IEEE 399, IEEE Recommended Practice for Power Systems Analysis
 4. IEEE 1015, Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems
 5. IEEE 1584, Guide for Arc Flash Hazard Calculations
 6. IEEE C37.20.1, Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear
 7. IEEE C37.46, Standard Specifications for High Voltage (> 1000 V) Expulsion and Current-Limiting Type Power Class Fuses and Fuse Disconnecting Switches
 8. IEEE C57.96, Guide for Loading Dry-Type Distribution and Power Transformers

- C. American National Standards Institute (ANSI):
 - 1. ANSI Z535.4, Standard for Product Safety Signs and Labels
- D. Insulated Cable Engineers Association (ICEA)
 - 1. ICEA P-32-382, Short Circuit Characteristics of Insulated Cable
 - 2. ICEA P-45-482, Short-Circuit Performance of Metallic Shielding and Sheaths
- E. National Electrical Manufacturer's Association (NEMA)
 - 1. NEMA MG 1, Motors and Generators
- F. National Fire Protection Association (NFPA)
 - 1. NFPA 70, National Electrical Code (with amendments by the Authority Having Jurisdiction)

1.03 SUBMITTALS

- 1. Procedures: Section 01 33 00, Submittal Procedures.
- 2. Product Data: Computer software to be used for system simulation.
- 3. Product Certificates:
 - a. For short-circuit and overcurrent protective device coordination study, provide certification of compliance with IEEE 399.
 - b. For arc-flash hazard analysis, provide certification of compliance with IEEE 1584.
- 4. Qualifications: Submit names, contact information and qualifications including references for at least five short-circuit, coordination study and arc-flash calculations of comparable complexity within the last five years.
- 5. Provide the following reports for each substation:
 - a. Input data including completed computer program input data sheets.
 - b. Short-Circuit Study and Equipment Evaluation Reports.
 - c. Ac Coordination Study Report: Submit at the same time as Dc Coordination Study Report.
 - d. Dc Coordination Study Report.
 - e. Arc Flash Hazard Analysis Report.

1.04 QUALITY ASSURANCE

- A. Studies shall use computer programs that are distributed nationally and are in wide use.
 - 1. Software algorithms shall comply with requirements of standards and guides specified in this Section.
 - 2. Manual calculations or calculations using spreadsheet software are not acceptable.
- B. Study Specialist Qualifications:
 - 1. Analysis and reports shall be prepared by an individual experienced in the application of computer simulations to traction power systems.
 - 2. Qualifications shall be submitted for approval and shall document that the individual has at least five years experience and has prepared five studies of comparable complexity.
 - 3. Analysis and reports shall be supervised and signed by a professional electrical engineer licensed in the State of Washington.
- C. Studies, analysis, and reporting shall comply with the following standards:
 - 1. IEEE 241 and 242 for short-circuit and coordination analysis.
 - 2. IEEE 399 for general study procedures.
 - 3. IEEE 1584 and NFPA 70E for arc-flash hazard analysis.
 - 4. NFPA 70 (with Washington and Seattle amendments).

PART 2 PRODUCTS

2.01 SIMULATION SOFTWARE

- A. Acceptable Software: Subject to approval, simulation software shall be the product of one of the following developers.
 - 1. CGI CYME
 - 2. EDSA Micro Corporation
 - 3. ESA Inc.
 - 4. Operation Technology, Inc.
 - 5. SKM Systems Analysis Inc.

2.02 SOFTWARE REQUIREMENTS

- A. Computer software for short-circuit study shall include analytical features described in IEEE 399 as Mandatory, Very Desirable, and Desirable.
- B. Computer software:
 - 1. Shall be capable of plotting and diagramming time-current characteristic curves as part of the output.
 - 2. Shall report device settings and ratings of all overcurrent protective devices.
 - 3. Shall demonstrate selective coordination by computer-generated, time-current coordination plots using different colors for each protective device.

PART 3 EXECUTION

3.01 DATA COLLECTION AND COORDINATION

- A. Collect data from equipment suppliers, other contractors or subcontractors, Seattle City Light, and the Owner in order to complete the analysis.
- B. Coordinate required distribution equipment ratings and protective device settings to provide a fully-integrated distribution system that is properly coordinated and meets the requirements of NFPA 70 (with Washington and Seattle amendments).
- C. Proceed with final analysis only after relevant equipment has been finally determined and submittal information is sufficient to produce accurate simulation results.

3.02 SYSTEM DOCUMENTATION

- A. Collect and tabulate the following input data to support studies.
 - 1. Product data for overcurrent protective devices including devices furnished by others and involved in overcurrent protection.
 - 2. Resistance and reactance data and fault current data from serving utility.
 - 3. Electrical Distribution System Diagram. Provide documentation in both paper and electronic formats for the following:
 - a. Circuit breaker and fuse current ratings and types.
 - b. Relays and associated power and current transformer ratings and ratios.
 - c. Transformer ratings including kVA ratings for each cooling type, primary and secondary voltages, connection type, transformer impedance, and X/R ratios. Provide information on transformer over-temperature sensors provided.
 - d. Cable information including number in parallel, conductor material, compaction, sizes, insulation type and temperature ratings, and cable length.

- e. Busway material, ampacity, and impedance.
 - f. Motor horsepower, full-load current and code letter according to NEMA MG 1.
4. Equipment data sheets:
- a. Special load considerations including starting inrush currents and frequent starting.
 - b. Transformer characteristics, including primary protective device recommendations, inrush current, and thermal damage curve.
 - c. Motor full-load current, locked-rotor current, service factor, starting time, type of starter, and thermal damage curve.
 - d. Utility protective device types, ratings and relay settings.
 - e. Special overcurrent protective device settings or types if required by the serving utility.
 - f. Time-current characteristic curves of devices to be coordinated.
 - g. Circuit breaker manufacturer, frame size, interrupting capacity, ampere or current sensor rating, long-time adjustment range, short-time adjustment range, and instantaneous adjustment range.
 - h. Overcurrent relay manufacturer, type, ampere tap range, time-delay range, instantaneous range, and current transformer ratio.
 - i. Panelboard and switchboard, ampere rating and interrupting rating.
- B. Use equipment identification tags that are consistent with electrical distribution system diagrams, overcurrent protective device submittals, input and output data, and recommended device settings.

3.03 SHORT-CIRCUIT STUDY

- A. Calculate maximum available fault current in amperes rms symmetrical at overcurrent protective device positions throughout the electrical distribution system. Calculation shall be for current immediately after initiation of a three-phase bolted fault at each of the following:
- 1. Switchgear and switchboard bus
 - 2. Distribution panelboard
 - 3. Branch circuit panelboard
- B. Analyze the electrical distribution system from normal and alternate power sources throughout electrical distribution system. Include studies of system switching configurations and alternate operations that could result in maximum fault condition.

- C. Calculate momentary and interrupting duties on the basis of maximum available fault current.
- D. Calculations to verify interrupting ratings of overcurrent protective devices shall comply with IEEE 241 and IEEE 242.
 - 1. For transformer, comply with IEEE C57.96.
 - 2. For low-voltage circuit breakers, comply with IEEE 1015 and IEEE C37.20.1.
 - 3. For low-voltage fuses, comply with IEEE C37.46.
- E. Final Report
 - 1. Indicate calculated X/R ratios and equipment (half-cycle) fault currents on electrical one-line diagram.
- F. Equipment Evaluation Report
 - 1. 600V overcurrent protective devices: Ensure that interrupting ratings are equal to or higher than calculated available half-cycle symmetrical fault current.
 - 2. Devices and equipment rated for asymmetrical fault current: Apply multipliers listed in the Standards to half-cycle symmetrical fault current.
 - 3. Conductors:
 - a. Verify adequacy of phase conductors at maximum three-phase bolted fault currents.
 - b. Verify adequacy of equipment grounding conductors and grounding electrode conductors at maximum ground-fault currents.
 - c. Ensure that short-circuit withstand ratings are equal to or higher than calculated half-cycle symmetrical fault currents.

3.04 AC COORDINATION STUDY

- A. Perform coordination study using approved computer software. Prepare a written report using results of short-circuit study. Comply with IEEE 399.
 - 1. Calculate the maximum and minimum half-cycle short-circuit currents.
 - 2. Calculate the maximum and minimum ground-fault currents.
- B. Comply with IEEE 241 and IEEE 242 recommendations for fault currents and time intervals.

- C. Transformer Primary Overcurrent Protective Devices:
1. Devices shall not operate in response to the following:
 - a. Transformer magnetizing inrush currents.
 - b. Self-cooled, full-load current or forced-air-cooled, full-load current, as appropriate. For transformer equipped for future fan cooling option, overcurrent protective devices shall be capable of resetting to the higher forced-air-cooled rating.
 - c. Permissible transformer overloads according to IEEE C57.96 if required by expected loading or emergency conditions.
- D. Conductor Protection:
1. Protect cables against damage from fault currents according to ICEA P-32-382, ICEA P-45-482, and conductor melting curves in IEEE 242.
 2. Demonstrate that equipment withstands the maximum short-circuit current for a time equivalent to the tripping time of the primary protection or total clearing time of the fuse.
 3. To determine temperatures that damage insulation, use curves from cable manufacturers or from listed standards indicating conductor size and short-circuit current.
- E. Coordination Study Report: Prepare a written report including the following:
1. A table with settings selected for overcurrent protective devices including:
 - a. Device identification tag.
 - b. Current transformer ratios and relay curve, tap, time-dial and instantaneous pickup settings.
 - c. Circuit breaker sensor rating and long-time, short-time and instantaneous trip settings.
 - d. Fuse type and current rating.
 - e. Ground-fault relay pickup and time-delay settings.
 2. Coordination Curves:
 - a. Provide documentation of settings of overcurrent protective devices to achieve selective coordination.
 - b. Provide time-current curves to graphically illustrate that adequate time separation exists between devices installed in series, including utility upstream devices.

- c. Prepare separate sets of curves for the switching schemes and for emergency periods where the power is fed from an alternate source.
- d. Include the following information:
 - 1) Device identification tag
 - 2) Time and current multipliers for curves.
 - 3) Three-phase and line-to-ground damage points for each transformer.
 - 4) No damage, melting, and clearing curves for fuses.
 - 5) Cable damage curves
 - 6) Transformer inrush points.
 - 7) Maximum fault-current cutoff point.
- 3. Prepare and include in study completed data sheets for setting of overcurrent protective devices.
- 4. Graphs shall be plotted in both distinctive colors and line styles for each time-current characteristic and damage curve so that black-and-white copies of graphs are still understandable.
- 5. Provide both bound color copies and color electronic files in PDF format for report.

3.05 DC COORDINATION STUDY

- A. Include the following as a minimum:
 - 1. Dc bolted positive to negative and positive to ground fault calculations.
 - 2. Protective device range and setting calculations showing basis for each recommended relay setting.
 - 3. Plots of rectifier design capability with actual margin of coordination (from breaker trip to design capability) clearly indicated at each of 100, 150 and 200 percent full-load current and short-circuit current.

3.06 ARC-FLASH HAZARD ANALYSIS

- A. Perform Arc-Flash Hazard Analysis with the aid of computer software intended for this purpose.
- B. Perform analysis in conjunction with short-circuit and coordination studies.
- C. Submit the results of the analysis in a table and include device or bus identification tag, bolted fault and arcing fault current levels, flash protection boundary, distances, personal-protective equipment classes and arc-flash incident energy (AFIE) levels.

- D. Perform the analysis under worst-case fault conditions, and describe in the final report when applicable, how these conditions differ from worst-case bolted fault conditions.
- E. Provide self-adhesive equipment labels in compliance with ANSI Z535.4 to document arc flash hazard and required personal protective equipment.

END OF SECTION 34 21 73

SECTION 34 21 80

TES SPARE PARTS AND SPECIAL TOOLS

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. Requirements for providing spare parts indicated in other Sections.
- B. Requirements for providing maintenance equipment.

1.02 DEFINITIONS

- A. Assembly: A unit consisting of components or parts that have been fitted together to form a self-contained device or fixture.
- B. Set: The quantity of the stated part that is provided as part of one substation. For example, if the part is "LEDs for Dc Switchgear," and 1 substation has 2 red LEDs, 2 green LEDs, and 1 white LED for Dc Switchgear, then 4 sets consists of 8 red LEDs, 8 green LEDs, and 4 white LEDs.

1.03 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Submit all items described below a minimum of 90 days before delivery of first spare parts:
 - 1. Comprehensive list of mandatory spare parts. Include spare parts listed in each section of these Specifications that contains a spare parts requirement. List by Specification section.
 - 2. Comprehensive list of mandatory special tools for each TPSS.
 - 3. List of additional recommended spare parts, special tools, and test and maintenance equipment. List separately the recommended special tools, test, and maintenance equipment that can be shared by substations.
 - 4. Provide part numbers for each part, including a detailed break down of each spare part assembly and set.
 - 5. Provide a price for each part that can be purchased separately.

1.04 DELIVERY, STORAGE, AND HANDLING

- A. Schedule: Delivery of spare parts shall be complete a minimum of 60 days before initial energization of the first segment of OCS.

- B. Notice and Shipping List: Provide Engineer notice of delivery and a complete shipping list a minimum of 10 days before delivery. Shipping list shall include the following:
1. Quantity of each part.
 2. Manufacturer's part number.
 3. Serial number, if applicable.
 4. Description.
 5. Spaces for inserting date of delivery, signature of Contractor, and signature of Engineer.
- C. Authorization: Spare parts shall not be shipped until authorized by Engineer.
- D. Location: Deliver spare parts to a location in greater Seattle, Washington metropolitan area designated by the Engineer.
- E. Packaging: Package and label spare parts in moisture-proof containers suitable for shipment and storage. Attach copies of shipping list in the package and to the exterior of the package.
- F. Unloading: Unload spare parts in a manner that will prevent damage to the packages and the contents.
- G. Inspection:
1. Engineer will open the packages and inspect spare parts for damage. Damaged parts will be returned to Contractor and shall be replaced with undamaged parts and materials at no additional expense to the Owner.
 2. Assist Engineer in verifying quantity of parts.
 3. Sign shipping list with quantities verified, obtain Engineer's signature, and date. Engineer will retain the signed shipping list.

PART 2 PRODUCTS

2.01 REPLACEMENT PARTS

- A. Mandatory Spare Parts:
1. Provide quantity and type of spares specified in each Specification Section. Supply of a spare from one Section does not satisfy the requirement for an identical spare specified in a different Section.
 2. Spare parts shall be identical to those submitted for approval and provided in substations.
 3. Unit price: Include on the submitted mandatory and recommended spare parts lists a price for each item that can be purchased separately.

B. Spare Parts for Warranty Repairs:

1. The capital spare parts or the spare parts ordered by the Owner for support of operations are not to be used by the Contractor for warranty repairs and warranty parts replacements. Engineer will not be responsible for receiving or storing any parts for warranty support.
2. At the end of the warranty period, the Owner may consider a negotiated price for purchase of parts stocked by the Contractor for warranty support.

C. Availability of Replacement Parts

1. Guarantee parts availability for a period of 10 years from Contract award.
2. Provide detailed manufacturing drawings to the Owner at the end of the 10-year period or when the availability of parts ceases after that date.

2.02 MANDATORY SPECIAL TOOLS

- A. Special tools include but are not limited to fixtures, equipment, gages, hand tools, power tools, motors, or other tools and equipment necessary to troubleshoot, maintain, repair, overhaul, assemble, disassemble, and adjust the TPSS that are not commonly available from commercial tool suppliers.
- B. Provide one set of special tools for each TPSS.

2.03 RECOMMENDED SPARE PARTS AND SPECIAL TOOLS

- A. Provide list of recommended spare parts including description, break down, part number, recommended quantity, and unit price.
- B. Provide list of recommended special tools, test, and maintenance equipment. The Owner may or may not exercise purchase of the recommended items.

PART 3 EXECUTION

Not Used.

END OF SECTION 34 21 80

SECTION 34 21 90

TPSS TESTING

PART 1 GENERAL

1.01 SUMMARY

- A. Section Includes:
 - 1. Testing traction electrification substation and its components.
 - 2. Other test requirements may appear in other Sections.
- B. Related Sections:
 - 1. Section 34 21 23 – Transformer-Rectifier Unit
 - 2. Section 34 21 33 – Rail Voltage Monitoring and Grounding System

1.02 REFERENCE STANDARDS

- A. Section incorporates by reference the latest revisions of the following documents, or the version required by the Authority Having Jurisdiction:
- B. American National Standards Institute (ANSI)
 - 1. ANSI C39.1, Requirements for Electrical Analog Indicating Instruments
- C. Institute of Electrical and Electronics Engineers (IEEE)
 - 1. IEEE 80, IEEE Guide for Safety in Ac Substation Grounding
 - 2. IEEE 400, Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems
 - 3. IEEE 1106, Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications
 - 4. IEEE 1653.2, Standard for Uncontrolled Traction Power Rectifiers for Substation Applications Up to 1500 Vdc Nominal Output
 - 5. IEEE C37.14, Standard for Low-Voltage Dc Power Circuit Breakers Used in Enclosures
 - 6. IEEE 37.20.1, Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear
 - 7. IEEE C37.34, Standard Test Code for High-Voltage Air Switches

8. IEEE C37.41, Standard Design Tests for High-Voltage (> 1000 V) Fuses, Fuse and Disconnecting Cutouts, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories Used with These Devices
 9. IEEE C37.90, Standard for Relays and Relay Systems Associated With Electric Power Apparatus
 10. IEEE C57.12.91, Standard Test Code for Dry-Type Distribution and Power Transformers
 11. IEEE C57.13, Standard Requirements for Instrument Transformers
 12. IEEE C57.18.10, Standard Practices and Requirements for Semiconductor Power Rectifier Transformers
 13. IEEE C62.11, Standard for Metal Oxide Surge Arresters for Ac Power Circuits
- D. InterNational Electrical Testing Association (NETA)
1. NETA ATS, Acceptance Testing Specifications for Electric Power Distribution Equipment and Systems
- E. National Electrical Manufacturers Association (NEMA)
1. NEMA PE 5, Utility-Type Battery Chargers

1.03 FAILURE OF TEST

- A. If any test fails, make corrections and retest at no additional cost to the Owner.
- B. If off-site test is witnessed by Engineer or his representatives and fails, Contractor shall pay for return trip to facility or test site(s) including air fare and lodging.
- C. In the event equipment is not ready for testing by Contractor upon agreed testing date and Engineer or his representatives arrive at test site, Contractor shall pay for return air fare and lodging of Engineer or his representatives.

1.04 SUBMITTALS

- A. Procedures: Section 01 33 00, Submittal Procedures.
- B. Test program plan: Submit within 120 days after NTP and provide monthly updates.
- C. Test procedures:
 1. Submit a minimum of 60 Days before test is scheduled to be performed.
 2. Submit, for each test to be performed, under the appropriate Technical Section of these Specifications, not under this Section.

3. Tests shall not be performed and test reports will not be considered valid until procedures are approved by Engineer.
- D. Test reports:
1. Submit within 30 Days after completion of each test unless otherwise indicated.
 2. Submit, for each test performed, under the appropriate Technical Section of these Specifications, not under this Section.
 3. Factory Design Test Reports:
 - a. Submit existing test reports 90 Days prior to scheduled shipment of equipment. Equipment shall not be shipped until the report is approved by the Engineer.
 4. Factory Production Test Reports: For each test indicated in this Section.
 5. Submit Electrically Insulated Floor and Wall Test Report for each substation prior to installation of substation equipment:
 6. Wire and cable testing report: Submit prior to TPSS Field Acceptance Testing:
 7. Traction Power Substation Field Acceptance Test Reports.
 8. Integrated Testing Test Reports:
 - a. Rail Voltage Monitoring and Grounding Devices Tests.
 - 1) Initial chart recording.
 - 2) Final record chart recording.
 - b. Short Circuit Test.
 - c. Train Start Tests.

1.05 REQUIREMENTS FOR TEST PROGRAM PLAN, TEST PROCEDURES, AND TEST REPORTS

- A. Test Program Plan:
1. Identify all tests by reference to the Section, Article, and Paragraph number of the appropriate technical Section of these Specifications.
 2. Provide a detailed schedule showing the time and place of each test to be performed.
 3. Tests to be included:
 - a. Each test described in this Section and in other Contract Specification Sections, including a test for each substation equipment type or assembly.

- b. Supplier and Subcontractor tests to be completed at the suppliers' or Subcontractors' plants.
 - c. Contractor's tests to be completed at its plant or approved independent testing lab prior to delivery.
 - d. Other tests conducted by Contractor in connection with its own Quality Assurance program.
- B. Test Procedures: Develop detailed test procedures for each test containing the following:
- 1. Title of test.
 - 2. Contract Specifications Section, Article, and Paragraph number.
 - 3. Test location.
 - 4. Name of the agency performing each test (Contractor, its supplier, or an independent testing company).
 - 5. Test objective.
 - 6. Equipment and instrumentation requirements including manufacturer's name, model number, and serial number.
 - 7. Personnel requirements.
 - 8. Attached copies of applicable portions of ANSI, IEEE, or NEMA standards
 - 9. Test methodology including test setup, with circuit diagrams and test sequence.
 - 10. A step-by-step procedure for performing the test, including all steps required for each device tested, even if devices are identical. For example, if there are four circuit breakers to test, provide a separate step-by-step procedure for each breaker.
 - 11. Forms for recording test data:
 - a. May be incorporated into step-by-step procedure.
 - b. Include space for test equipment calibration data.
 - c. Include a step-by-step format for data reduction and formulas used in deriving the format.
 - d. Include criteria for acceptability and justification for the criteria set forth, including procedures for evaluating data.
 - e. Include space for signatures of test witnesses.
 - 12. Expected test results.

13. Test evaluation procedures.
14. Proposed test report form.

C. Test Reports:

1. Each test report shall have attached the related and approved test procedure.
2. Each report shall document the test results obtained and shall include the following information:
 - a. Title of test.
 - b. Contract Specifications Section and Article number.
 - c. Test objectives.
 - d. Summary and conclusions including Pass/Fail or N/A.
 - e. Test location, date, and time.
 - f. List of test equipment used, including the following for each piece of test equipment:
 - 1) Manufacturer's name.
 - 2) Model number.
 - 3) Serial number.
 - 4) Calibration certificate showing that instrument was calibrated by an independent agency within the previous 12 months.
 - g. Conditions of test, including temperature and humidity.
 - h. Raw test data from the approved test procedure forms.
 - i. Reduced test data including tables, curves, photographs and any additional test data required to support the test results.
 - j. Test results in a form that can easily be compared to these Specifications requirements.
 - k. Descriptions of equipment and material failures, and reasons for the failure.
 - l. Descriptions of all modifications to equipment or wiring performed during testing, reasons for modifications, and names of individuals approving such modifications.
 - m. Abbreviations and references.
 - n. Signatures of tester and test witnesses.

1.06 WITNESSING OF TESTS

- A. Engineer will, at his/her option, witness all tests.
- B. Testing Notification: At least 30 days before each test upon the approval of test procedure, notify Engineer in writing of the date, time, and location the test will be performed.
- C. If Engineer elects not to witness a test or tests, test reports shall nevertheless be submitted to Engineer for review and approval.
- D. Witnessing of test by Engineer shall not waive requirements in Specifications or relieve Contractor from its responsibility to produce test report in accordance with Specifications.

1.07 PERFORMANCE OF TESTING

- A. Testing shall be performed under the direct supervision of the manufacturer of the equipment, except that:
 - 1. Factory design test or production test of individual components shall be performed by the component manufacturer at the plant of manufacture or at an approved testing facility.
 - 2. Field testing of insulated power cables rated 2 kV and higher shall be performed by a NETA certified technician working for an independent testing company under the direct supervision of Contractor.
 - a. NETA technician shall have at least 5 years experience in construction acceptance testing.
 - b. Testing company shall be a NETA member and approved by Engineer.
 - 3. Field acceptance testing of each substation shall be performed under direct supervision of Traction Power Installation Supervisor representing the manufacturer of the substation equipment.

1.08 TEST CLASSIFICATIONS

- A. Factory Design Tests:
 - 1. Shall be conducted by or under supervision of the equipment manufacturer.
 - 2. Shall demonstrate compliance with specified design requirements.
 - 3. Shall be performed on production components, assemblies, subsystems and substations and shall be performed on the highest level of assembly that will allow demonstration of design compliance.
 - 4. Limited to the number of units needed to demonstrate design compliance, typically one or two.

B. Factory Production Tests:

1. Shall be conducted by or under the supervision of the equipment manufacturer.
2. Shall demonstrate that each unit to be delivered operates within specified limits and is in compliance with design requirements and industry standards.
3. Test requirements may vary from an inspection and functional demonstration for a simple component to a full system functional demonstration of an assembly.
4. Perform tests of the completed substation equipment at substation manufacturer's facility prior to shipment of the substation to the site.
5. Perform at ambient conditions unless a specific environmental or operating limit is necessary to demonstrate acceptable operation.
6. Include the following:
 - a. Substation equipment and ancillary systems including control power for each substation.
 - b. Factory installed power and control cable and wire.

C. Traction Power Substation Field Acceptance Tests:

1. Shall demonstrate that each substation is ready for energization and revenue service, both functionally and cosmetically. Include the following
 - a. Substation equipment.
 - b. Dc Protective relays.
 - c. Ancillary systems.
 - d. Power and control cable.
 - e. Internal and external wiring supplied under this Contract.

D. Integrated systems testing:

1. Perform in cooperation with other contracts to demonstrate the proper function of the traction electrification system (TES)
2. Shall demonstrate that all interfaces are correct and operable.

1.09 TESTING COMPANY QUALIFICATIONS

- A. Tests shall be performed by the manufacturer, or a company or agency employed by Contractor with all of the following qualifications:
 - 1. Approved by Engineer: Once such a company or agency is approved they shall not be discharged or otherwise replaced by Contractor without written approval of Engineer.
 - 2. Employees assigned to the project shall be personnel familiar with electrical testing procedures, electrical instrumentation, and general electrical networks.
 - 3. Personnel must be capable of modifying the specified procedures to suit actual field conditions should such modifications become necessary.

1.10 QUALITY OF TEST DATA

- A. Test Readings:
 - 1. Number of readings taken to determine an electrical/electromagnetic constant or property shall be sufficient to assure that random factors due to human error in reading the instruments and transient disturbances in electrical network have negligible influence on final results.
 - 2. Adequacy of the data can generally be established by the tester as follows:
 - a. Data shall be examined to verify that removal of either the highest or lowest value will not alter the arithmetic average of the group by more than 5 percent.
 - b. If the average would be altered by more than 5 percent, one more set of data shall be taken and results combined with the first set.
 - c. If the average of the combined data would still be altered by more than 5 percent if the highest or lowest value were removed, an unstable condition might exist then Engineer shall be advised.

PART 2 PRODUCTS

2.01 FACTORY DESIGN TESTS

- A. General:
 - 1. Factory design tests shall be run on each type of equipment specified in this Section.
 - 2. If design tests have already been performed by the manufacturer of equipment, existing test reports may be submitted to Engineer, who will determine whether the new design test may be waived.
 - 3. Existing test reports need not meet the format requirements specified in this Section. However, content of reports shall include all relevant information.

4. In the event components have not been design tested, tests shall be run on the first production unit and performed in accordance with these Specifications.
- B. Wire and Cable:
1. Multi-Conductor 600 V Type TC Control Cable: Vertical tray flame test requirements of UL 1277 for type TC power and control Tray Cable at 70,000 Btu/Hr and the ICEA T-29-520 210,000 Btu/Hr test
- C. TPSS Enclosure:
1. Coating qualification test: Perform in accordance with IEEE C37.20.1.
 2. Rain test for outdoor LV switchgear: Perform in accordance with IEEE C37.20.1. An existing design test will not be accepted; this test will not be waived.
 - a. HVAC units shall be installed and operating at full speed.
 - b. In addition to IEEE C37.20.1 requirements, all ventilation systems shall be operating at full speed.
 - c. Replace IEEE C37.20.1 satisfaction of test requirements with the following: the enclosure shall have satisfactorily met the requirements of this test if during the visible inspection no water is found.
- D. Transformer-Rectifier Unit Test:
1. Existing test reports will not be accepted in lieu of this test.
 2. Transformer-rectifier unit shall be tested as a complete assembly including interconnecting bus and/or cables and enclosures. Ac switchgear is a required part of the assembly only for the short circuit test. Dc switchgear is not required.
 3. Short circuit test:
 - a. Conduct at a certified laboratory.
 - b. Power supply shall be minimum 10 MVA.
 - c. Transformer taps on high-voltage windings shall be connected at the center position of the five available taps.
 - d. Set ac breaker for the IEEE 1653.2 short-time overload for light traction service.
 - e. Perform in accordance with IEEE C57.12.91, to fully evaluate the capability of all windings.
 - 1) Apply fault on the rectifier secondary.
 - 2) Make recommended terminal measurements.
 4. Perform rated current load tests at reduced voltage.

5. Demonstrate compliance with the requirements specified in Section 34 21 23, Transformer-Rectifier Unit.
 6. Operate transformer rectifier at 100 percent load for a minimum of 6 hours immediately before running duty cycle tests to assure temperature stabilization.
 7. Verify efficiency, voltage regulation, and power factor at loads shown in IEEE 1653.2 for Light Traction Service.
 8. Record transformer temperature rise during the rated current load tests:
 - a. Take loss measurements at specified loads.
 - b. Implant six thermocouples into secondary windings of transformer at locations approved by Engineer and mount two thermocouples on transformer frame.
 - c. Transformer temperature rise determined by any of the thermocouples shall not exceed value specified in Section 34 21 23, Transformer-Rectifier Unit.
 9. Audible sound level test:
 - a. Perform audible sound level tests in accordance with IEEE C57.12.91 except apply 3-foot distance. Maximum sound level shall not exceed level in Section 34 21 23, Transformer-Rectifier Unit.
 - b. For 12-pulse Circuit 31 rectifier transformers, include interphase transformer in transformer-rectifier assembly.
 - c. Measure sound level with rectifier-transformer in its enclosure with all panels bolted closed.
- E. Rectifier:
1. Dielectric tests: In accordance with IEEE 1653.2.
 2. Rated voltage test: Subject rectifier to 110 percent of ac rated voltage for 5 minutes with the dc circuit open.
 3. Current unbalance test:
 - a. In accordance with IEEE 1653.2.
 - b. Test may be performed during the design test for transformer-rectifier unit.
 4. Loss measurement test: Comply with IEEE 1653.2.
 5. Rated current test:
 - a. At reduced voltage.
 - b. After temperature stabilization at rated load.

- c. Include the overloads outlined in IEEE 1653.2.
- d. Perform with one diode removed from each phase arm. Engineer to select diodes to be removed for test.
- e. Shall demonstrate that the maximum safe junction temperature for each diode is not exceeded.
- f. Verify efficiency, voltage regulation, and power factor at loads shown in IEEE 1653.2 for Light Traction Service.

F. Traction Power Transformer:

- 1. Resistance measurements of all windings on rated voltage connection and on all tap settings.
- 2. Impedance and load losses at rated current on all windings on all tap settings in accordance with IEEE C57.18.10. Calculate transformer commutating reactance from these tests.
- 3. Impulse test:
 - a. Perform in accordance with IEEE C57.12.91 with exception that waveform to be used shall be 1.4 by 40 microseconds.
 - b. Perform after completion of short circuit tests.
- 4. Temperature rise tests: In accordance with IEEE C57.12.91 at 166.8 percent of rated current.
- 5. Partial discharge test: Perform after completion of all other tests.
- 6. Engineer shall be the sole judge of the serviceability of transformer after completion of design testing.

G. Dc Switchgear:

- 1. Perform on the dc switchgear assembly.
- 2. Perform the "design tests" specified in IEEE C37.20.1.
- 3. Insert and remove circuit breaker elements into connected position 200 times from disconnect position.
- 4. Drawout mechanism shall function properly showing no signs of wear.
- 5. Inspect main and auxiliary contacts for damage and weakness.
- 6. Contacts shall sustain no physical damage or wear. No wear is permissible.
- 7. Contacts shall make full contact with mating member as determined by Engineer.

- H. Dc Circuit Breaker:
 - 1. Perform in accordance with design tests in IEEE C37.14.
 - 2. Follow schedule of design tests defined in IEEE C37.14.
- I. Dc Protection Relays and Control Devices:
 - 1. Perform in accordance with design tests in IEEE C37.90.
 - 2. Frame Fault Relay (Device 64 HS and GS): Following design tests are required.
 - a. Continuous and maximum short circuit ratings: Demonstrate by test.
 - b. Response time and maximum trip time: Demonstrate by test.
 - c. Maximum trip time for this device shall not exceed 50ms.
- J. Dc Disconnect Switches:
 - 1. Conduct a complete set of design tests on one switch of each type in accordance with IEEE C37.34 and IEEE C37.41. Engineer may waive design testing and accept instead a notarized certified test report of a complete set of tests on a switch of the same design and ratings.
 - 2. Switches to be tested and certified suitable for use on dc circuits with prospective fault current capabilities of 201 kA, or more.
 - 3. Tests to be performed with switch(es) in enclosure assembled in closed, final operational configuration.
 - 4. Mechanical Test: Subject a sample switch to a maximum number of openings and closings to establish a life cycle capability.
 - 5. Acceptance criteria: Visual and mechanical performance.
 - 6. All tests shall be successfully completed to show that switches meet specification requirements before final acceptance by Engineer.
- K. Substation Alarm Panel:
 - 1. Perform with all accessories attached in accordance with design tests in IEEE C37.90.
 - 2. Demonstrate electrical operation and accuracy of all components.
 - 3. Test from alarm panel to initiating devices for proper operation.
- L. Battery: Design test for the battery shall comply with IEEE 1106.

- M. Battery Charger: Tests for the battery charger shall comply with design tests described in NEMA PE 5.

2.02 FACTORY PRODUCTION TESTS

A. Wire and Cable

- 1. Dc Feeder Cable: Standard dielectric withstand tests.

B. Traction Power Transformer:

- 1. Factory Dielectric tests in accordance with IEEE C57.12.91.
- 2. Applied-voltage and induced-voltage tests in accordance with IEEE C57.12.91.
- 3. Resistance measurements of all windings on all taps.
- 4. Ratio tests on the rated voltage connections and on all taps in accordance with IEEE C57.12.91.
- 5. Polarity and phase relation in accordance with IEEE C57.12.91.
- 6. No-load losses and excitation current in accordance with IEEE C57.12.91.
- 7. Partial discharge test:
 - a. Subject transformer to an induced voltage of 1.5 times the rated voltage at a frequency between 100 and 400 Hz.
 - b. Partial discharge extinction level shall be reached at an induced voltage of not less than 1.2 times the rated line-to-line voltage.
 - c. Partial discharge extinction level will be defined as the point when the reading at 1.9 MHz is less than 10 microvolts or 13 picocoulombs.

C. Rectifier:

- 1. Dielectric tests in accordance with IEEE 1653.2.
- 2. Continuity tests of all cables and buses.
- 3. Rated voltage test in accordance with IEEE 1653.2.

D. Dc Switchgear:

- 1. Perform in accordance with IEEE C37.20.1:
 - a. Dielectric tests.
 - b. Mechanical operation tests.

- c. Electrical operation and control wiring continuity, except that control wiring continuity shall be verified by actual electrical operation of control devices.

E. Dc Circuit Breaker:

1. Perform on each dc circuit breaker in accordance with IEEE C37.14 prior to mounting inside dc switchgear:
 - a. Calibration test.
 - b. Control, secondary wiring and device check test.
 - c. Dielectric withstand voltage test.
 - d. No-load operation test.
2. Perform on each dc circuit breaker after mounting in switchgear:
 - a. Operation test.
 - b. Position test: Disconnected, test, and connected positions.
 - c. Alignment test of primary and secondary contacts.
 - d. Interlocking test for all positions.

F. Dc Disconnect Switch:

1. Perform for each dc disconnect switch in compliance with production tests in IEEE C37.41.
2. Conduct standard production tests on all switches to check the quality and uniformity of workmanship and materials used, including the following:
 - a. Check for gaps, using a feeler gage (or other approved method) at each contact and assembly point. Gaps are grounds for rejection.
 - b. Test operation of all components.
 - c. Perform power frequency dielectric withstand test.
 - d. Test electric resistance of current path.

G. Dc Protection Relays and Control Devices: in accordance with production tests in IEEE C37.90.

H. Meters, Instruments and Instrument Transformers:

1. Check for accuracy, performance and operation in accordance with ANSI C39.1 (if analog meters are used) and IEEE C57.13.

- I. Power Meter: Test functionality.
- J. Substation Alarm Panel:
 - 1. Test all components for proper operation and function.
 - 2. Test control wiring continuity by actual electrical operation of control devices.
 - 3. Test inputs and outputs for proper operation and short circuits.
 - 4. Communications: Verify communications and SCADA information is retrievable.
 - 5. HMI: Verify that display, screens, and user interface operate in accordance with Specifications.

2.03 TESTING PRIOR TO INSTALLING EQUIPMENT IN SUBSTATION ENCLOSURE

- A. Electrically Insulated Floor and Wall Tests:
 - 1. Perform hi-potential dielectric tests on the epoxy floor and wall insulation installed in each traction power substation enclosure prior to the installation of substation equipment.
 - 2. Provide a hi-potential tester with a voltage range of 0-15,000 Vdc and a current range of 0-2000 microamperes dc to perform the tests.
 - 3. Floor: Perform a wet mop test as follows:
 - a. Provide a sponge mop with a non-metallic handle. Provide a copper plate behind the sponge with a wire terminal to attach the test lead.
 - b. Connect one lead from the tester to the copper disk and the other lead to the station ac ground bus.
 - c. Apply 4500 Vdc from the hi-potential tester, using precautions such as insulated boots and hot gloves to protect the test technician.
 - d. Saturate the mop with saline solution and mop the entire insulated floor with the room darkened. Re-saturate the mop as necessary.
 - e. Visible arcing shall be indications of inadequate dielectric strength of the epoxy coatings and additional layers of epoxy shall be applied until the leakage current is lower than 50 microamperes.
 - 4. Walls: Perform a copper disk test as follows:
 - a. Provide a copper disc 4 inches in diameter and 1/4-inch thick. The disk shall have a non-conductive handle and wire terminal to attach the test lead.
 - b. Connect one lead from the tester to the copper disk and the other lead to the station ground bus.

- c. Place the copper disc on the wall insulation at a minimum of 10 locations selected by Engineer where the laminate is fastened to the wall with mechanical fasteners.
- d. Apply 4500 Vdc for 120 seconds and record the leakage current.
- e. If leakage current is greater than 50 microamperes, epoxy insulation shall be applied to the fastener to increase the insulation and the fastener retested.

PART 3 EXECUTION

3.01 TRACTION POWER SUBSTATION TESTING PRIOR TO FIELD ACCEPTANCE TESTING

A. Wire and Cable Testing:

- 1. Continuity tests: Check continuity from point to point and check for shorts to ground with an ohmmeter.
- 2. High potential tests: In accordance with IEEE 400.
 - a. Passing criteria: No insulation breakdown or excessive leakage current.
 - b. Failures: Locate and determine the trouble, replace defective wires, cables or components, make necessary corrections to installation, and retest without additional cost to the Owner.
- 3. Test 600 V control circuit wiring for continuity and insulation.
 - a. Protect semiconductor devices against the test voltage by means of shorting jumpers or other methods accepted by Engineer, if they are not inherently protected by the circuit in which they are used.
- 4. Test 2 kV wire and cable for continuity and insulation, followed by a high potential test of 2 kV for five minutes for insulation.

3.02 TRACTION POWER SUBSTATION FIELD ACCEPTANCE TESTING

A. General Requirements:

- 1. Perform after complete installation of each traction power substation.
- 2. Verify that all equipment is properly installed in accordance with approved drawings, in operable condition and all open inspection items and NCRs have been corrected.
- 3. No equipment shall be energized or placed in operating mode until completion of Field Acceptance Testing and permission of Engineer.

B. Electrically Insulated Floor and Wall Tests:

- 1. Repeat factory tests on wall and floor areas not covered by installed switchgear.

2. Verify that insulated floor and walls have not been damaged in shipping.
- C. General Substation Operation:
1. Perform a functional test of substation operation prior to energizing the substation. Energize only circuits 600V or less for functional test.
 2. Check the interlocks on the enclosure and panels for proper functioning alarm and operation of shutdown circuitry.
 3. Use strip chart recorders or oscillographs as required to provide a permanent record of the protective functions.
 4. Perform other tests as required by substation equipment manufacturer and Engineer to determine the acceptability of the installation and equipment.
- D. Dc Switchgear:
1. High-potential tests:
 - a. Disconnect high-resistance ground relay, Device 64, for this test.
 - b. Perform test between the ac and dc switchgear, including fasteners and the isolation laminate, at 2500V dc, leakage current shall be less than 50 microamperes.
 - c. Perform test from dc switchgear enclosure to ground at 2500 Vdc. Leakage current shall be less than 50 microamperes.
 - d. Perform continuity tests on all interconnecting cables and buses.
 - e. Perform insulation test on all interconnecting feeder cables using a 2500 Vdc megohmmeter for 1 minute.
 - f. Test positive and negative feeder buses to ground using a 2500 Vdc megohmmeter for 1 minute.
 - g. Verify load measuring and reclosing functions.
 2. Verify functional tests of the emergency trip stations (ETS).
 3. Verify proper operation of all interlocks and Kirk key schemes.
- E. Dc Relays:
1. Verify proper operation and setting of all relays including rate of rise, frame fault relay and rail to earth relay.
 2. Where applicable, settings to be in accordance with approved relay coordination curves.

- F. Traction Power Transformer:
 - 1. Perform insulation tests between windings and between windings to ground and between the core to ground using a 2500 Vdc megohmmeter for 1 minute.
 - 2. Perform functional tests of temperature protective devices.
- G. Rectifiers:
 - 1. Perform insulation tests between the diode strings and rectifier enclosure using a 2500 Vdc megohmmeter for one minute.
 - 2. Perform insulation tests between the enclosure and ground using a 2500 Vdc ohmmeter for 1 minute.
 - 3. Perform a functional test of all temperature, protective, monitoring and alarm devices.
- H. Substation Alarm Panel:
 - 1. Simulate alarm and analog functions at each device at the switchgear, transformer, rectifier, and ancillary TPSS devices, and verify correct indication at HMI.
 - 2. Demonstrate downloading of event log to flash drive or laptop.
- I. SCADA: Simulate alarm functions at each device at the switchgear, transformer and rectifier and verify correct output at communications module for future SCADA.
- J. Transfer Trip: Simulate transfer trip and verify correct outputs at PLC for future transfer trip.
- K. Frame Fault (Device 64HS & GS) Tests:
 - 1. Connection: As shown in the one-line diagram.
 - 2. Test: Simulate a 750 Vdc to frame fault by passing low dc current levels through the relays.
 - 3. Approval: Provide graphical outputs, including time-current characteristics, onsite at the time of testing for review and approval.
 - 4. Criteria: Maximum total clearing time including operation of the 64HS & GS relay, the substation lock-out relay, and the tripping of the main ac and dc feeder breakers shall not exceed 300 ms.
 - 5. Field adjustments: In the event that certain test conditions do not conform to the test procedure, make necessary field adjustments, perform necessary calculations to demonstrate successful test completion, present the calculation method to Engineer for review, and include with the test report.

- L. Rail Voltage Monitoring and Grounding Devices Tests:
 - 1. Test: Demonstrate proper function of the rail-to-earth relay and rail-to-earth grounding device.
 - a. Simulate rail-to-earth voltages and currents.
 - b. Show that the substation will alarm, trip, and short circuit rail to earth when the voltage and currents exceed the alarm, trip, and short circuit points specified in Section 34 21 33, Rail Voltage Monitoring and Grounding System.

- M. Battery:
 - 1. Perform after substation equipment has been installed onsite.
 - 2. Perform acceptance tests in accordance with IEEE 1106.
 - 3. Perform load test demonstrating that batteries comply with the requirements in Section 34 21 25, TPSS Dc Control Power, by duplicating the conditions stated under Battery Duty Cycle section.

- N. Battery Charger:
 - 1. Perform after substation equipment has been installed onsite.
 - 2. Perform in accordance with NEMA PE 5.

- O. Ancillary Systems:
 - 1. Perform operational and functional tests on auxiliary and ancillary systems including auxiliary panelboards including auxiliary contacts, door interlocks, receptacles, emergency lights, HVAC, and all systems provided in this Contract which are not specifically called out in this Section.

- P. Power Meter:
 - 1. Testing shall be performed by a qualified testing agency using calibrated reference standard devices.
 - a. The test instruments shall be calibrated and traceable to the National Institute of Standards and Technology (NIST).
 - b. Calibrate analog instruments no more than 6 months prior to testing.
 - c. Calibrate digital instruments no more than 12 months prior to the test.
 - d. Provide certificates of calibration for the reference standard devices.

2. Test for accuracy of the following:
 - a. Four-quadrant energy measurement accuracy: kWh imported, kWh exported, kWh net, kVARh imported, kVARh exported, kVARh net, kVAh imported, kVAh exported, kVAh net.
 - b. Power measurement accuracy including active, reactive and apparent (kW, kVAR and kVA).
 - c. Demand Accuracy.
 - d. L-L and L-N voltage measurement accuracy of every phase.
 - e. Current measurement accuracy of every phase.
 - f. Power Factor.
 - g. Frequency.
 - h. CT accuracy test (10 percent, 20 percent, 30 percent, 40 percent, 50 percent through rated current, including ratio test), CT phase error test, PT accuracy test (including ratio test), burden test of CT circuit.
3. Verify metering transformer configuration and wiring match the power meter configuration, CT/PT polarities are correct and CT/PT ratios are correct.

3.03 TRACTION POWER SUBSTATION ENERGIZATION TESTING

- A. Obtain permission from Engineer prior to energizing substation.
- B. Traction Power Transformers
 1. Adjust transformer taps for optimum dc output voltage based on ac service voltage at each location.
- C. Transformer-Rectifier Unit:
 1. Perform audible sound test inside substation with HVAC system turned off, in accordance with requirements of Section 34 21 23, Transformer-Rectifier Unit.

3.04 INTEGRATED TESTING

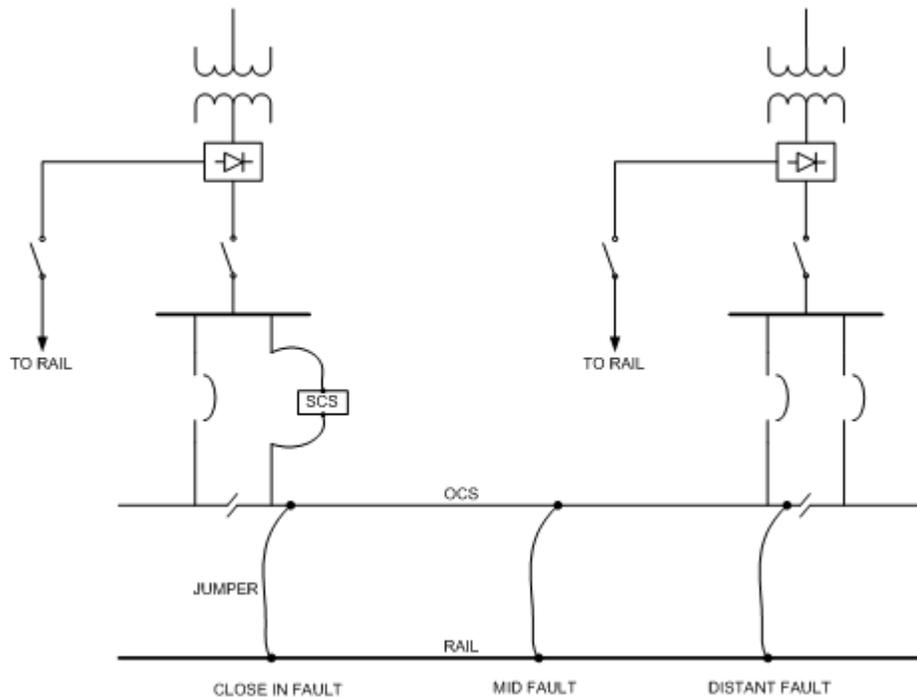
- A. Conduct the following testing that involves cooperating with the Owner and with other contracts.

B. Rail Voltage Monitoring and Grounding Devices Tests:

1. Initial Chart Recording:
 - a. For each substation, provide a 48-hour chart recording of the rail-to-earth voltages and currents measured at the terminals of the negative cubicle during simulated revenue service.
 - b. Set horizontal and vertical scale such that both time duration and magnitude of rail-to-earth voltages are clearly readable.
 - c. Resolution shall be no less than 100 ms for time and 2 V for voltage
2. Adjustment: Iteratively adjust the annunciation and trip setpoints until optimum settings have been determined to the satisfaction of Engineer. This process may require several weeks or more of monitoring and adjusting settings. Submit settings to Engineer after the following conditions are met:
 - a. The substation remains on line for 14 days without a nuisance trip (tripping under normal operation without apparent reason) including times when adjacent substations are removed from service for at least 1 hour.
 - b. The recommended settings conform to IEEE 80 for safe touch and step potential.
3. Final Record Chart Recording:
 - a. For each substation, after the rail voltage monitoring and grounding devices have been set and the settings accepted by Engineer, provide a 48-hour chart recording of the rail-to-earth voltages and currents measured at the terminals of the dc switchgear.
 - 1) Set horizontal scale so that both time duration and magnitude of rail-to-earth voltages are clearly readable.
 - 2) The recording shall be taken on a weekday, during actual or simulated revenue service and shall become a part of the as built record documentation.

C. Short Circuit Test:

Diagram for Close in, Mid, and Distant Fault Tests



1. Close in Fault Test.

- a. Purpose: This test is performed to determine system I_{max} and adjust protection relay settings.
- b. Preparation:
 - 1) Disable the automatic tripping elements of the dc breakers during this test in order to obtain data of actual fault current levels.
 - 2) Place a jumper across line and load terminals of the feeder breaker and move to the connected position.
 - 3) Energize only TPSS A. The adjacent substations are de-energized.
- c. Test: Using a short circuit switch (SCS) apply a bolted fault from line side of the dc feeder breaker to the negative bus.
- d. After Test: Verify that the dc breaker trips according to protection coordination study.

2. Mid Fault Test:

- a. Purpose: This test is performed to determine the system resistance and inductance profile and adjust protection relay settings.

- b. Preparation:
 - 1) Disable the automatic tripping elements of the dc feeder breakers.
 - 2) Energize only TPSS A. The adjacent substations are de-energized.
 - c. Test: Using a short circuit switch (SCS) apply a bolted fault from messenger wire to rail at a distance from the TPSS B to be provided by the Engineer.
 - d. After Test: Verify and apply new protective settings if necessary.
 - e. Re-test: Repeat Mid Fault Test with new settings to verify that the breaker trips according to new protection setting.
3. Distant Fault Test:
- a. Purpose: This test is to verify that the dc protection relay will detect a fault at the furthest point from the substation under test and adjust protection relay settings.
 - b. Energize only TPSS A. The adjacent substations are de-energized.
 - c. Test: Using a short circuit switch (SCS) apply a bolted fault from OCS to rail at the location furthest from the feed point of the substation under test.
 - d. After Test: Verify that the dc breaker trips according to protection coordination study.
- D. Train Start Tests:
- 1. Purpose: Verify that the traction electrification system will allow multiple trains to start under full load and adjust protection relay settings.
 - 2. Provide two chart recorders to monitor di/dt.
 - 3. Provide a technician for two days.
 - 4. Adjust protection relay settings as necessary.
 - 5. Engineer will provide the test procedure and will conduct the test.

END OF SECTION 34 21 90

SYSTEMS ABBREVIATIONS

<p>A</p> <p>A AMPERE, ANNUNCIATE, AMMETER AB ANCHOR BOLT, AC BREAKER ABUT ABUTMENT ABV ABOVE AC ALTERNATING CURRENT ACI AMERICAN CONCRETE INSTITUTE ADJ ADJACENT A/G AT GRADE AISC AMERICAN INSTITUTE OF STEEL CONSTRUCTION AM AMMETER ANC ANCHOR AP APPROACH, AUXILIARY POWER APS AUXILIARY POWER SUPPLY APT AUXILIARY POWER TRANSFORMER AREA AMERICAN RAILWAY ENGINEERING ASSOCIATION AS AMMETER SWITCH ASSY ASSEMBLY ASTM AMERICAN SOCIETY OF TESTING & MATERIALS AT CURRENT TRANSDUCER A/T AUTO TENSION (* A.T.) ATM ALONG TRACK MOVEMENT ATR ABOVE TOP RAIL AWS AMERICAN WELDING SOCIETY AUX AUXILIARY</p>	<p>D</p> <p>D DEPTH DB DIRECT BURIED DEG DEGREE DET DETAIL DGA DOWN GUY ANCHOR DIM. DIMENSION (*DIM) DISC DISCONNECT DISC SW DISCONNECT SWITCH DLGT DOME LIGHT DOC DEGRÉE OF CURVATURE DS DOOR SWITCH, DISCONNECT SWITCH</p>	<p>J</p> <p>I INTERLOCK IB IMPEDENCE BONDS IC INTERRUPTING CAPACITY IEEE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS IJ INSULATED JOINT INC INCOMING INCL INCLUDE, INCLUDING INST INSTRUMENT INSUL INSULATION I.R. IN RUNNING (RIDING CONTACT WIRE)</p>	<p>N</p> <p>N.R. NOT REGISTERED N.S. NOT SUPPORTED N.S.R. NOT SUPPORTED OR REGISTERED N-SW NEGATIVE SWITCH</p>	<p>I</p> <p>TB TAP BOX TBD TO BE DETERMINED TBR TO BE REMOVED TEMP TEMPERATURE, TEMPORARY TERM. TERMINAL, TERMINATION TES TRACTION ELECTRIFICATION SYSTEM T/F TOP OF FOUNDATION T/G TOP OF GROUND LINE TL TRACK LIGHTING T/LR TOP OF LOW RAIL TO. TURNOUT TOC TOP OF CONCRETE TORW TOP OF RETAINING WALL TPSS TRACTION POWER SUBSTATION T/R TOP OF RAIL TRAC TRACTION TRK TRACK TS TANGENT TO SPIRAL OR TEST STATION, TIE SWITCH, TEST SWITCH TTC TELEPHONE TERMINAL CABINET TWA TIE WIRE ANCHOR T/L TENSION LENGTH</p>
<p>B</p> <p>BAT BATTERY B/B BACK TO BACK BFA BY-PASS FEEDER ANCHOR BIL BASIC IMPULSE LEVEL BKR BREAKER BL BASELINE BM BEAM BR BRIDGE BRKT BRACKET B-SPAN BODY SPAN BTM BOTTOM B/W BALANCE WEIGHT BWA BALANCE WEIGHT ANCHOR BZ BRONZE</p>	<p>E</p> <p>EB EASTBOUND Eo SUPERELEVATION IN INCHES EHS EXTRA HIGH STRENGTH EQN EQUATION EQPT EQUIPMENT (*EQUIP) ES EXTRA STRENGTH ETC ET CETERA ETS EMERGENCY TRIP STATION</p>	<p>K</p> <p>K KIP KCMIL, KCM THOUSAND CIRCULAR MILS KA KILOAMPERE KVA KILOVOLT AMPERE KSF KIPS PER SQUARE FOOT KSI KIPS PER SQUARE INCH KSS KING STREET STATION KW KILOWATT KWH KILOWATT HOURS KVAR KILOVOLT AMPERES REACTANCE</p>	<p>Q</p> <p>OCS OVERHEAD CONTACT SYSTEM OHB OVERHEAD BRIDGE OMF OPERATIONS & MAINTENANCE FACILITY O/L OVERLAP O/R OUT OF RUNNING (NON-RIDING CONTACT WIRE)</p>	<p>U</p> <p>UF UNDERGROUND FEEDER UGB UNDERGRADE BRIDGE U/S UNDERSIDE UTIL UTILITY</p>
<p>C</p> <p>CAB CABINET CANT CANTILEVER CB CIRCUIT BREAKER CHAM CHAMFER CHGR CHARGER CKT CIRCUIT C TO C CENTERLINE TO CENTERLINE CISP CAST IRON SOIL PIPE COMM COMMUNICATIONS COND CONDUCTOR CONT CONTINUATION, CONTINUOUS CONTR CONTRACTOR CR CONDUIT RISER CT CURRENT TRANSFORMER CS CURVE-TO-SPIRAL OR CONTROL SWITCH CTR CENTER CU COPPER C/W CONTACT WIRE</p>	<p>F</p> <p>F1 FEEDER No.1 F FAHRENHEIT FAC FACILITY FDR FEEDER FHSC FIRST HILL STREETCAR FFJ FULL FEEDING JUMPER FIN FINISHED FJ FEEDER JUMPER FREQ FREQUENCY FOP FACE OF POLE F.O.S. FACTOR OF SAFETY FT FEET, FOOT, FEEDER TAP F TO F FACE TO FACE F/T FIXED TERMINATION (F.T.) FTA FIXED ANCHOR FUT FUTURE</p>	<p>L</p> <p>LBF POUNDS FORCE LB/FT POUNDS PER FOOT LED LIGHT EMITTING DIODE LG LONG, LENGTH LTG LIGHTING LPT LOW POINT LRT LIGHT RAIL TRANSIT LS LUMP SUM OR LINE SECTION LT LIGHT LTS LIGHT TRACTION SYSTEM/SERVICE LV LOW VOLTAGE</p>	<p>P</p> <p>P POSITIVE PAN PANTOGRAPH PB PULLBOX PF POINT OF FROG, POSITIVE FEEDER PITO POINT OF INTERSECTION OF TURNOUT PLC PROGRAMMABLE LOGIC CONTROLLER PL PROPERTY LINE PLAT. PLATFORM POS POSITIVE PS POINT OF SWITCH PSF POUNDS PER SQUARE FEET P-SW POSITIVE SWITCH PT POINT OF TANGENCY, POCKET TRACK, POTENTIAL TRANSFORMER PVC POLYVINYL CHLORIDE CONDUIT (PVCC) OR POINT OF VERTICAL CURVE PWR POWER</p>	<p>V</p> <p>V VOLT, VOLTMETER VA VOLT AMPS VM VOLTMETER V/S VERSINE VS VOLTMETER SWITCH VT VOLTAGE TRANSFORMER, VOLTAGE TRANSDUCER</p>
<p>G</p> <p>G GREEN GB GROUND BUS GFI GROUND FAULT INTERRUPTER G/L GROUND LINE GRD GROUNDING DEVICE, GROUND GRS GALVANIZED RIGID STEEL GRSC GALVANIZED RIGID STEEL CONDUIT GRX GRADE CRDSSING GTO GATE-TURN-OFF THYRISTOR</p>	<p>H</p> <p>H HEIGHT H.D. HARD DRAWN HMI HUMAN MACHINE INTERFACE HO HAND OPERATED H.R.L. HIGH RAIL LEVEL H-SPAN HEAD SPAN HSS HIGH STRENGTH STEEL HV HIGH VOLTAGE HVAC HEATING VENTILATION AIR CONDITIONING HWY HIGHWAY Hz HERTZ</p>	<p>M</p> <p>M METER M/W MESSENGER WIRE mH MILLIHENRY MH MANHOLE M/L MAIN LINE MOP MOTOR OPERATED MP MILE POST - MORE PERMISSIVE SPEED MPA MID POINT ANCHOR MPH MILES PER HOUR MTG MOUNTING MVA MEGAVOLT AMPERE mV MILLIVOLT MV MEDIUM VOLTAGE MW MEGAWATT</p>	<p>R</p> <p>R1 RECTIFIER No.1 R RADIUS OR RED, RECTIFIER RE RUNNING EDGE OF RAIL RECT RECTIFIER REV REVISION ROW RIGHT OF WAY RT RECTIFIER TRANSFORMER RTU REMOTE TERMINAL UNIT RW RETAINING WALL (R/W) RZG RAIL TO GROUND DEVICE</p>	<p>W</p> <p>W WEST, WATT, WIDTH OR WIRE WI WROUGHT IRON W/O WITHOUT WF WIDE FLANGE WWF WELDED WIRE FABRIC WB WESTBOUND</p>
<p>X</p> <p>XFMR TRANSFORMER X-ING CROSSING XOVER CROSSOVER XPASS CROSS PASSAGE X-SECT CROSS SECTION X-SPAN CROSS SPAN</p>	<p>Y</p> <p>YRD YARD YL YARD LEAD</p>	<p>S</p> <p>SA SURGE ARRESTER SAP SUBSTATION ALARM PANEL SB SOUTHBOUND, SPLICE BOX, OR SWITCHBOARD SE SPECIAL EVENTS SECT SECTION SC SPIRAL TO CURVE OR SIGNAL/COMM, SCADA SCADA SUPERVISORY CONTROL AND DATA ACQUISITION SCL SEATTLE CITY LIGHT SCWAT SINGLE CONTACT WIRE AUTO TENSION SD SMOKE DETECTOR SHP SHOP SI SECTION INSULATOR SIG SIGNAL S/N SOLID NEUTRAL SOP SET OUT POINT SPS SMALL PART STEELWORK SS SUBSTATION SPST SINGLE POLE SINGLE THROW SQ FT SQUARE FEET SQ IN SQUARE INCHES S-SPAN STEADY SPAN SST STAINLESS STEEL ST SPIRAL TO TANGENT (CONFLICT STREET) SUSP SUSPENDED SW SWITCH SWA SINGLE WIRE ANCHOR SWFT SINGLE WIRE FIXED TERMINATION SWH SWITCH HEATER SWHT SWITCH HEATER TRANSFORMER</p>		

NOTES:
 1. SEE CITY OF SEATTLE STANDARD PLANS FOR ADDITIONAL ABBREVIATIONS.

INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

JPO3 TRACTION ELECTRIFICATION SYSTEM ABBREVIATIONS

LTK Engineering Services
 505 Union Station Building
 505 5th Avenue, South
 Suite 640
 Seattle, WA 98104
 www.ltk.com

APPROVED FOR ADVERTISING
 NANCY LOCKE
 DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
 SEATTLE, WASHINGTON 20

NAME OR INITIALS AND DATE	INITIALS AND DATE
DESIGNED ALL	REVIEWED: PE CONST.
CHECKED LTK	PROJ. MGR.
DRAWN KMH	RECEIVED
CHECKED EJR	REVISED AS BUILT

ALL WORK DONE IN ACCORDANCE WITH THE CITY OF SEATTLE STANDARD PLANS AND SPECIFICATIONS AND OTHER DOCUMENTS CALLED FOR IN SECTION 01-02.3 OF THE PROJECT MANUAL.



City of Seattle
Seattle Department of Transportation
 ORDINANCE NO. APPROVED
 FUND: NA INSPECTOR'S BOOK

FIRST HILL STREETCAR TRACTION POWER SUBSTATIONS

PC	TS4580B
R/W	
CO	TS4580B
Vault Plan No.	774-721
SHEET	2 28

P:\Projects\B-Current\Projects\CAD\10_Sheets\1000X_Procurement\JPO3-TRACTION_ELEC...
 10-45am
 MADE CHKD REV'D
 NATURE REVISIONS
 35474

TRACTION ELECTRIFICATION SYMBOLS

	DISCONNECT SWITCH IS NORMALLY CLOSED, UNLESS DESIGNATED WITH (NO) NORMALLY OPEN
	FUSED DISCONNECT SWITCH
	LOW VOLTAGE CIRCUIT BREAKER
	POTENTIAL TRANSFORMER
	CABLE POTHEAD / CABLE CONNECTOR
	CURRENT TRANSFORMER
	SURGE ARRESTER
	TRACTION RECTIFIER
	FUSE
	REMOVABLE FUSE
	SHUNT OR TPSS BUS CONNECTION
	WITHDRAWABLE DC CIRCUIT BREAKER WITH SERIES TRIP UNIT
	DIRECTION OF CONTROL OR RELAY INFLUENCE LINE
	RECTIFIER TRANSFORMER, 12 PULSE
	RECTIFIER TRANSFORMER, 6 PULSE OR POWER TRANSFORMER
	DELTA, TRANSFORMER CONNECTION

	INTERPHASE TRANSFORMER
	DIODE
	CONTACTOR
	WYE, TRANSFORMER CONNECTION
	TEST SWITCH
	IMPEDANCE BOND
	OCS SECTION INSULATOR
	OCS INSULATED OVERLAP
	PAIR OF INSULATED JOINTS IN RAIL
	INSULATED KNUCKLE
	ANNUNCIATOR
	AMMETER
	VOLTMETER
	KILOWATT HOUR METER
	KILOVAR HOUR METER
	AMMETER SWITCH
	KILOWATT METER
	SCADA
	EMERGENCY TRIP STATION
	CURRENT TRANSDUCER

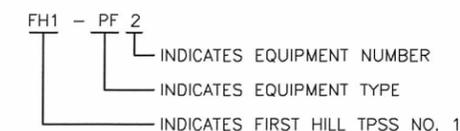
	VOLTAGE TRANSDUCER
	MECHANICAL KEY INTERLOCK
	UTILITY GROUND CONNECTION
	INTERLOCK
	SMOKE DETECTOR
	RECEPTACLE
	MH/HH/VAULT
	FLUORESCENT LIGHT
	EMERGENCY LIGHT
	ROOF VENTILATOR
	EXTERIOR LIGHT
	GROUND

52 3

RELAY OPERATING COIL. INSIDE NUMBER DESIGNATES DEVICE FUNCTION. OUTSIDE NUMBER DESIGNATES QUANTITY OF DEVICES

5	EMERGENCY STOP PUSHBUTTON
26R1	RECTIFIER OVERTEMP ALARM (1ST. STAGE)
26R2	RECTIFIER OVERTEMP TRIP (2ND. STAGE)
27	UNDERVOLTAGE RELAY
32	REVERSE CURRENT RELAY
33A	AC CIRCUIT BREAKER REAR DOOR SWITCH
33F	FEEDER BREAKER REAR DOOR SWITCH
33R	RECTIFIER DOOR SWITCH
33T	TRANSFORMER DOOR SWITCH
47	PHASE SEQUENCE
49T1	TRANSFORMER OVERTEMP ALARM (1ST STAGE)
49T2	TRANSFORMER OVERTEMP TRIP (2ND STAGE)
50/51	PHASE FAULT TIME OVERCURRENT RELAY (INST. AND TIME DELAY)
50N/51N	GROUND FAULT TIME OVERCURRENT RELAY (INST. AND TIME DELAY)
52	AC CIRCUIT BREAKER
59B	125V DC CONTROL VOLTAGE SHORTED WITH 750VDC
64GS	GROUNDING STRUCTURE
64HS	HOT STRUCTURE
64V	NEGATIVE-TO-EARTH VOLTAGE RELAY
72	DC CIRCUIT BREAKER
76	DC DIRECT ACTING OVERCURRENT TRIP DEVICE
82	LOAD MEASURING RELAY
83	RECLOSEING RELAY
85	TRANSFER TRIP RELAY
86	AC LOCKOUT RELAY
86X	AC LOCKOUT AUXILIARY RELAY
186	DC LOCKOUT RELAY
186X/H	DC LOCKOUT AUXILIARY RELAY
98R1	R1 RECTIFIER DIODE FAILURE ALARM
98R2	R2 RECTIFIER DIODE FAILURE TRIP
150	DC RATE OF RISE AND OVERCURRENT RELAY

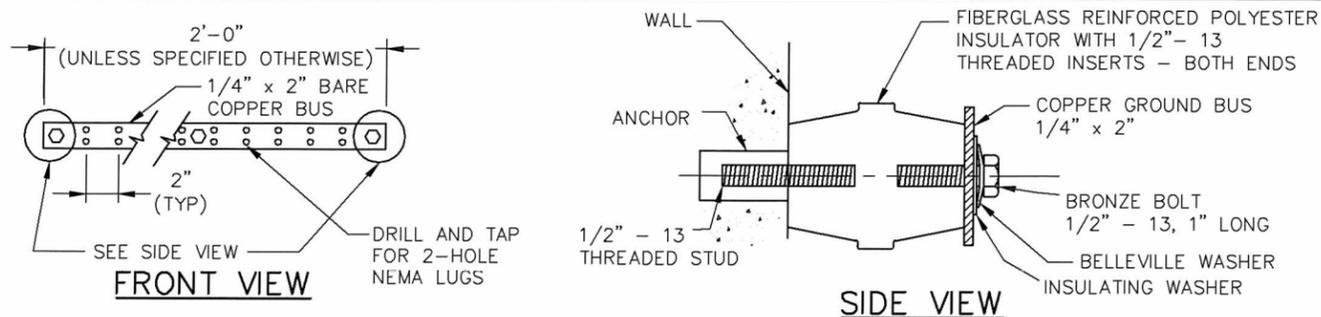
EQUIPMENT NUMBERING CONVENTION



EQUIPMENT TYPES:

DS	DISCONNECT SWITCH
NR	NEGATIVE FEEDER
PF	POSITIVE FEEDER
DR	DUCTBANK/RACEWAY
AB	AC BREAKER
VT	VAULT
DB	DC FEEDER BREAKER

TYPICAL GROUND BUS MOUNTING DETAILS



INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

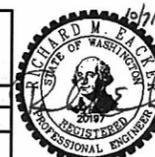
TRACTION ELECTRIFICATION SYSTEM SYMBOLS

LTK Engineering Services
 505 Union Station Building
 505 5th Avenue, South
 Suite 640
 Seattle, WA 98104
 www.ltk.com

APPROVED FOR ADVERTISING
 NANCY LOCKE
 DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
 SEATTLE, WASHINGTON 20

NAME OR INITIALS AND DATE DESIGNED ML CHECKED RME	INITIALS AND DATE REVIEWED: PE PROJ. MGR. CONST.
DRAWN KMH CHECKED EJR	RECEIVED REVISED AS BUILT

ALL WORK DONE IN ACCORDANCE WITH THE CITY OF SEATTLE STANDARD PLANS AND SPECIFICATIONS AND OTHER DOCUMENTS CALLED FOR IN SECTION 0-02.3 OF THE PROJECT MANUAL.



City of Seattle
Seattle Department of Transportation
 ORDINANCE NO. APPROVED
 FUND: NA
 INSPECTOR'S BOOK

FIRST HILL STREETCAR TRACTION POWER SUBSTATIONS

PC	TS4580B
R/W	
CO	TS4580B
VAULT PLAN NO.	774-721
SHEET	3 28

P:\Projects\B-Current\Projects\C3814_SDOT_FHSCA\010_Sheets\100%_Procurement\JP04-TRACTION_ELECTRIFICATION\NO SYSTEMS\EDEN-MARK-35474-NATURE REVISIONS

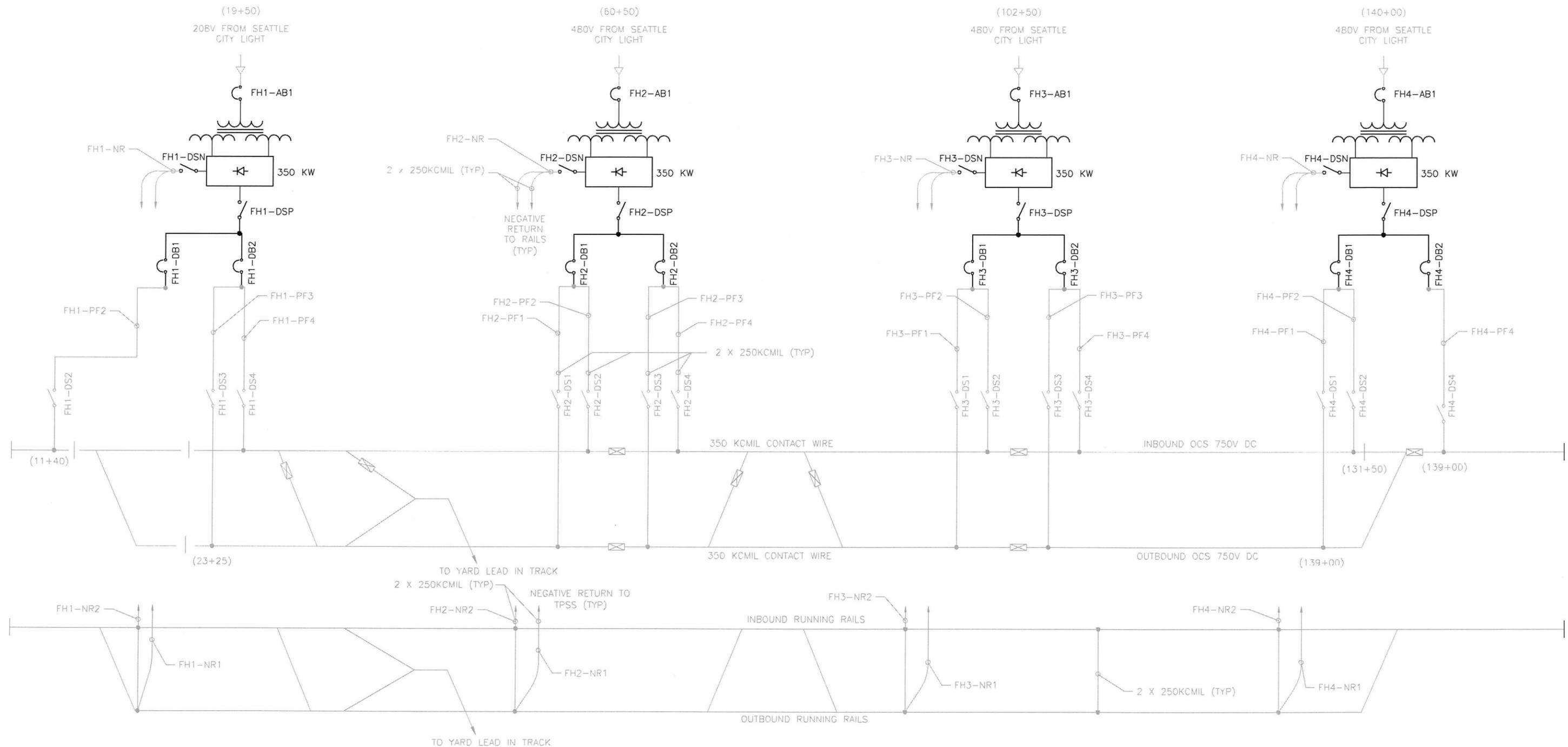
- NOTES:
1. STATIONING IS APPROXIMATE.
 2. ALL SWITCHES ARE NORMALLY CLOSED UNLESS OTHERWISE NOTED.
 3. - - - - - INDICATES WIRELESS AREAS.

KING STREET STATION TPSS FH1

S MAIN STREET TPSS FH2

E JAMES STREET TPSS FH3

E HOWELL STREET TPSS FH4



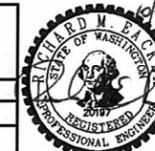
INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

SECTIONALIZING DIAGRAM MAINLINE JP06

LTK Engineering Services
 505 Union Station Building
 505 5th Avenue, South
 Suite 640
 Seattle, WA 98104
 www.ltk.com

APPROVED FOR ADVERTISING
 NANCY LOCKE
 DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
 SEATTLE, WASHINGTON 20

NAME OR INITIALS AND DATE DESIGNED ML CHECKED RME	INITIALS AND DATE REVIEWED: PE PROJ. MGR. RECEIVED REVISED AS BUILT
DRAWN KMH CHECKED EJR	



City of Seattle
Seattle Department of Transportation
 APPROVED
 ORDINANCE NO.
 FUND: NA
 INSPECTOR'S BOOK

FIRST HILL STREETCAR TRACTION POWER SUBSTATIONS

PC	TS4580B
R/W	
CO	TS4580B
VAULT PLAN NO.	774-721
SHEET	4 28

P:\Projects\B-Current Projects\CAD\10_SDOT_FHSC\CAD\10_SDOT_SECTIONALIZING\JP06_SECTIONALIZING\MADE CHKD REV'D
 NATURE REVISIONS
 DATE MARK
 35474

P:\Projects\B-Current\Projects\C3814_SDOT_FHSC\CAD\10 Sheets\1004 Procurement\JP10-TPSS_KEY_MAP\JP10-TPSS_KEY_MAP.dwg
 DATE: 10/07/2011
 MARK: 05:47:44
 MADE CHKD REVD
 NATURE REVISIONS



INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

**JP10
TPSS KEY MAP**

LTk Engineering Services
 505 Union Station Building
 505 5th Avenue, South
 Suite 640
 Seattle, WA 98104
 www.ltk.com

APPROVED FOR ADVERTISING
 NANCY LOCKE
 DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
 SEATTLE, WASHINGTON 20

BY: PURCHASING AND CONTRACTING SERVICES DIRECTOR

NAME OR INITIALS AND DATE		INITIALS AND DATE	
DESIGNED ML		REVIEWED:	
CHECKED RME		PE	CONST.
		PROJ. MGR.	
DRAWN JMM		RECEIVED	
CHECKED EUR		REVISED AS BUILT	

ALL WORK DONE IN ACCORDANCE WITH THE CITY OF SEATTLE STANDARD PLANS AND SPECIFICATIONS AND OTHER DOCUMENTS CALLED FOR IN SECTION D-02.3 OF THE PROJECT MANUAL.



City of Seattle
Seattle Department of Transportation

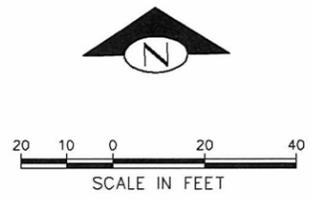
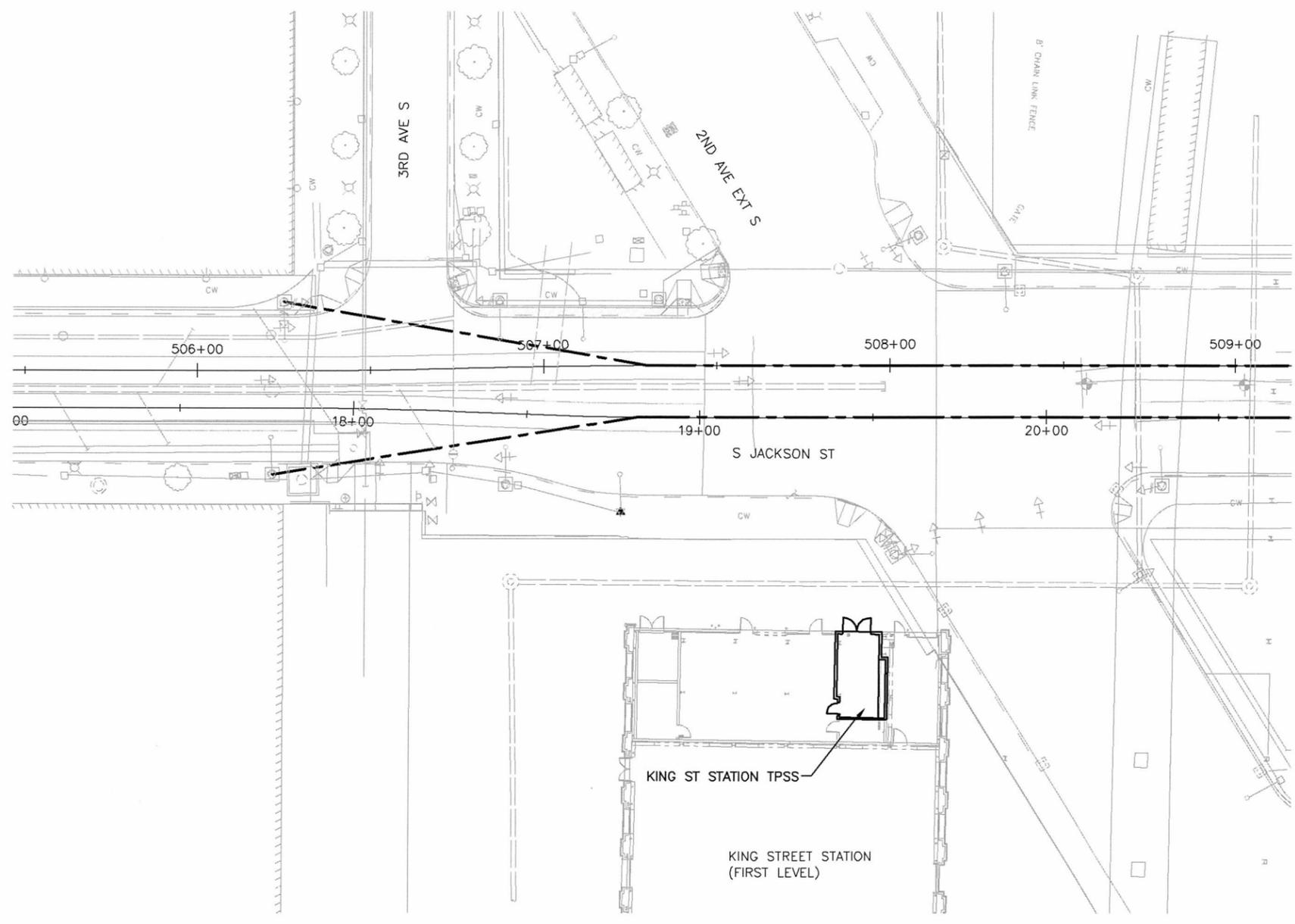
ORDINANCE NO. _____
 FUND: _____
 APPROVED

H: 1" = 300'
 INSPECTOR'S BOOK

**FIRST HILL STREETCAR
TRACTION POWER SUBSTATIONS**

CON	PC	TS4580B
JOB	R/W	
CO	CO	TS4580B
	VAULT PLAN NO.	774-721
	SHEET	5 28

P:\Projects\9-Current Projects\CAD\10_SDOT_FHSC\CAD\10_SDOT_FHSC\001-KING_STREET_L1_S1\ZANLUBER\ENGIN\AN\FIG\ATE MARK\35474
 35474
 NATURE REVISIONS
 MADE CHKD REV'D



INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

KING ST STATION TPSS SITE PLAN JP11

LTK Engineering Services
 505 Union Station Building
 505 5th Avenue, South
 Suite 640
 Seattle, WA 98104
 www.ltk.com

APPROVED FOR ADVERTISING
 NANCY LOCKE
 DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
 SEATTLE, WASHINGTON 20

BY:
 PURCHASING AND CONTRACTING SERVICES DIRECTOR

NAME OR INITIALS AND DATE	INITIALS AND DATE
DESIGNED ML	REVIEWED: PE CONST.
CHECKED RME	PROJ. MGR.
DRAWN KMH	RECEIVED
CHECKED EJR	REVISED AS BUILT

ALL WORK DONE IN ACCORDANCE WITH THE CITY OF SEATTLE STANDARD PLANS AND SPECIFICATIONS AND OTHER DOCUMENTS CALLED FOR IN SECTION 0-02.3 OF THE PROJECT MANUAL.



City of Seattle
Seattle Department of Transportation
 APPROVED

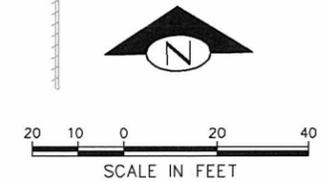
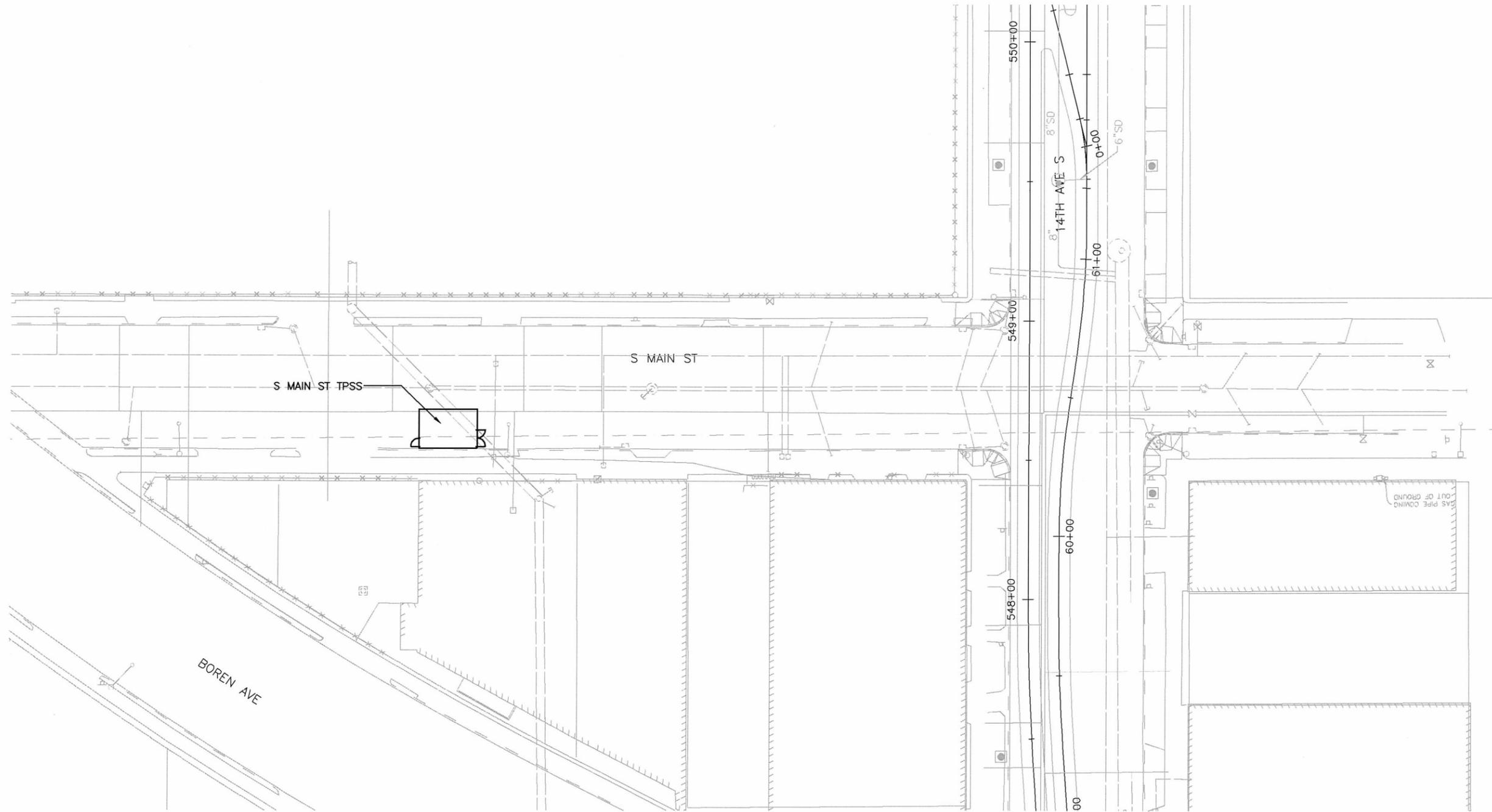
ORDINANCE NO. _____
 FUND: NA

INSPECTOR'S BOOK

FIRST HILL STREETCAR TRACTION POWER SUBSTATIONS

JOB NO.	PC	TS4580B
	R/W	
	CO	TS4580B
VAULT PLAN NO.	774-721	
SHEET	6	28

P:\Projects\B-Current\Projects\C3914_SDOT_FHSC\CAD\10 Sheets\100% Procurement\JP12-S_MAIN_STREET I WALKERMAN\09 35474.dwg DATE MARK NATURE REVISIONS MADE CHKD REV'D



INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

**JP12
S MAIN ST TPSS SITE PLAN**

LTK Engineering Services
 505 Union Station Building
 505 5th Avenue, South
 Suite 640
 Seattle, WA 98104
 www.ltk.com

APPROVED FOR ADVERTISING
NANCY LOCKE
 DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
 SEATTLE, WASHINGTON 20

By: _____
 PURCHASING AND CONTRACTING SERVICES DIRECTOR

NAME OR INITIALS AND DATE	INITIALS AND DATE
DESIGNED ML	REVIEWED: PE CONST.
CHECKED RME	PROJ. MGR.
DRAWN KMH	RECEIVED
CHECKED EJR	REVISED AS BUILT

ALL WORK DONE IN ACCORDANCE WITH THE CITY OF SEATTLE STANDARD PLANS AND SPECIFICATIONS AND OTHER DOCUMENTS CALLED FOR IN SECTION 0-02.3 OF THE PROJECT MANUAL.



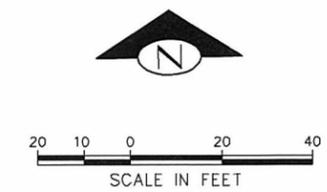
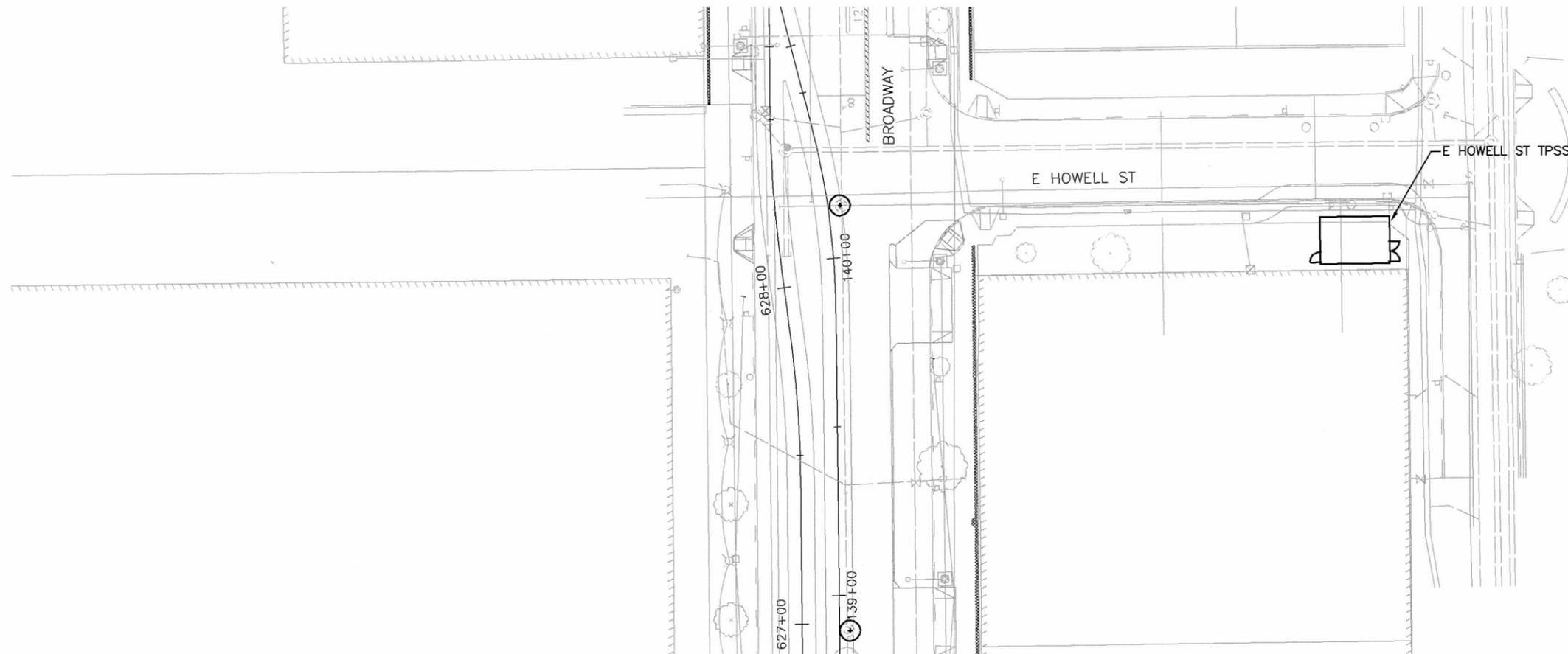
City of Seattle
Seattle Department of Transportation

ORDINANCE NO. _____ APPROVED
 FUND: NA INSPECTOR'S BOOK

**FIRST HILL STREETCAR
 TRACTION POWER SUBSTATIONS**

JOB NO.	PC	TS4580B
R/W	R/W	
CO	CO	TS4580B
VAULT PLAN NO.	774-721	
SHEET	7	28

P:\Projects\9-Current Projects\C3814_SDOT_FHSC\4010_Sheets\100% Procurement\JP14-E_HOWELL_STREQ\VAUFS_SERIAL\100% DATE MARK NATURE MADE CHKO REVD
 35474 REVISIONS



INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

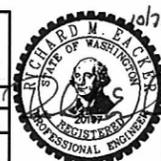
**JP14
 E HOWELL ST TPSS SITE PLAN**

LTK Engineering Services
 505 Union Station Building
 505 5th Avenue, South
 Suite 640
 Seattle, WA 98104
 www.ltk.com

APPROVED FOR ADVERTISING
 NANCY LOCKE
 DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
 SEATTLE, WASHINGTON 20

By: PURCHASING AND CONTRACTING SERVICES DIRECTOR

NAME OR INITIALS AND DATE DESIGNED ML CHECKED RME	INITIALS AND DATE REVIEWED: PE PROJ. MGR. CONST.
DRAWN KMH CHECKED EJR	RECEIVED REVISED AS BUILT



City of Seattle
Seattle Department of Transportation
 APPROVED

ORDINANCE NO. _____
 FUND: NA

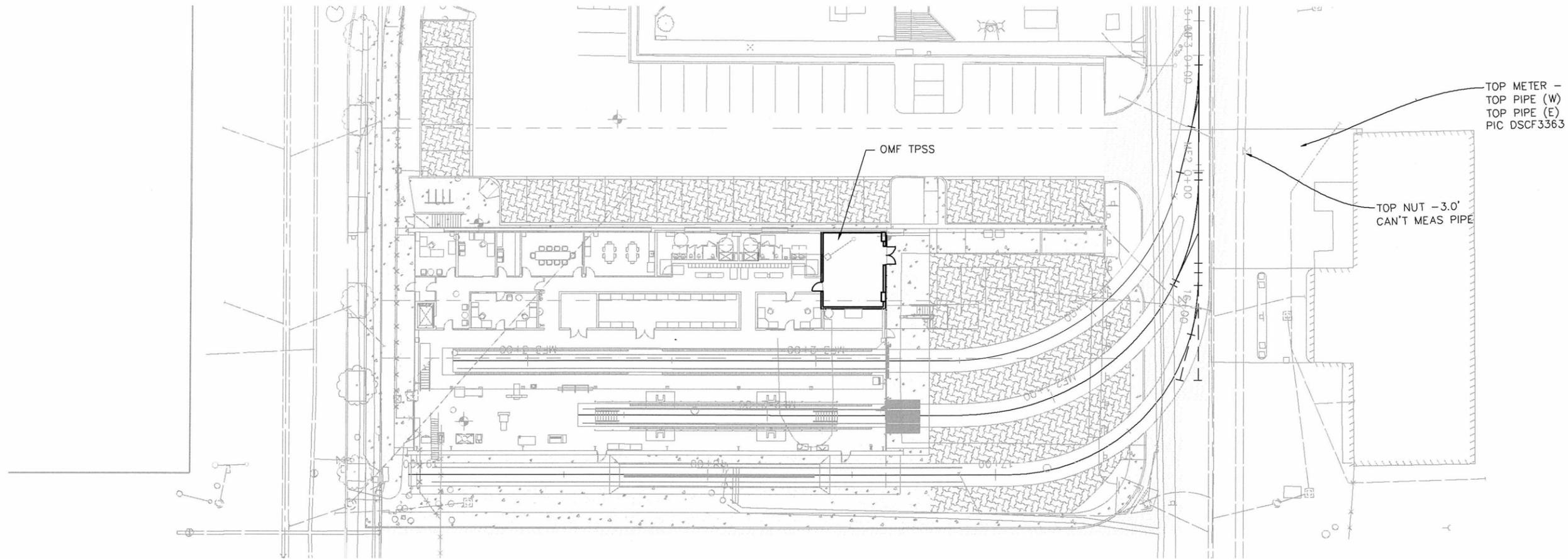
INSPECTOR'S BOOK

FIRST HILL STREETCAR TRACTION POWER SUBSTATIONS

PC	TS4580B
R/W	
CO	TS4580B
VAULT PLAN NO.	774-721
SHEET	9 28

ALL WORK DONE IN ACCORDANCE WITH THE CITY OF SEATTLE STANDARD PLANS AND SPECIFICATIONS AND OTHER DOCUMENTS CALLED FOR IN SECTION 0-02.3 OF THE PROJECT MANUAL.

P:\Projects\9-Current\Projects\C3814_SDOT_FHSC\CAD\10_Sheets\100x_Procurement\JP15-OMF_TPSS_SITE_38174.dwg
 38174
 DATE MARK
 NATURE REVISIONS
 MADE CHK'D REV'D



INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

JP15
 OMF TPSS SITE PLAN

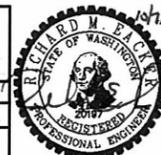
LTK
LTK Engineering Services
 505 Union Station Building
 505 5th Avenue, South
 Suite 540
 Seattle, WA 98104
 www.ltk.com

APPROVED FOR ADVERTISING
 NANCY LOCKE
 DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
 SEATTLE, WASHINGTON 20

BY:
 PURCHASING AND CONTRACTING SERVICES DIRECTOR

NAME OR INITIALS AND DATE	INITIALS AND DATE
DESIGNED ML	REVIEWED: PE CONST.
CHECKED RME	PROJ. MGR.
DRAWN KMH	RECEIVED
CHECKED EJR	REVISED AS BUILT

ALL WORK DONE IN ACCORDANCE WITH THE CITY OF SEATTLE STANDARD PLANS AND SPECIFICATIONS AND OTHER DOCUMENTS CALLED FOR IN SECTION D-02.3 OF THE PROJECT MANUAL.



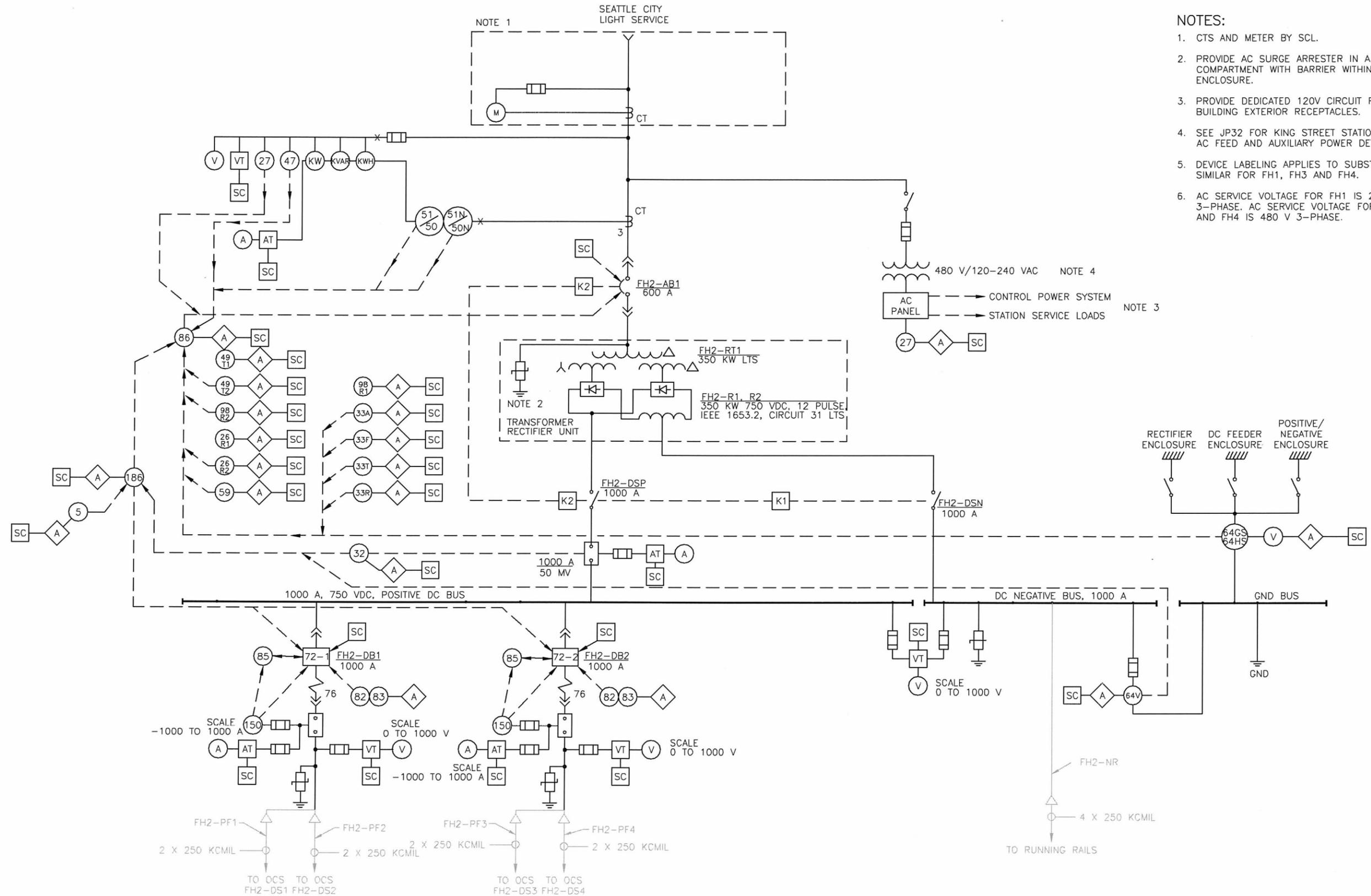
City of Seattle
Seattle Department of Transportation
 APPROVED

ORDINANCE NO.
 FUND: NA
 INSPECTOR'S BOOK

FIRST HILL STREETCAR TRACTION POWER SUBSTATIONS

NO.	PC	TS4580B
R/W		
CO		TS4580B
VAULT PLAN NO.		
774-721		
SHEET	10	28

P:\Projects\B-Current\Projects\C3814_SDOT_FHSC\CAD\10_Sheets\1000x\Procurement\JP20-TYPICAL_MAINLINE\MADE CHECK REV'D
 NATURE REVISIONS
 MAISE SERIAL NUMBER MARK
 35474



- NOTES:**
1. CTS AND METER BY SCL.
 2. PROVIDE AC SURGE ARRESTER IN A SEPARATE COMPARTMENT WITH BARRIER WITHIN TRANSFORMER ENCLOSURE.
 3. PROVIDE DEDICATED 120V CIRCUIT FOR TPSS BUILDING EXTERIOR RECEPTACLES.
 4. SEE JP32 FOR KING STREET STATION TPSS FH1 AC FEED AND AUXILIARY POWER DETAILS.
 5. DEVICE LABELING APPLIES TO SUBSTATION FH2. SIMILAR FOR FH1, FH3 AND FH4.
 6. AC SERVICE VOLTAGE FOR FH1 IS 208 V 3-PHASE. AC SERVICE VOLTAGE FOR FH2, FH3 AND FH4 IS 480 V 3-PHASE.

INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

JP20 TYPICAL MAINLINE TPSS ONE-LINE DIAGRAM

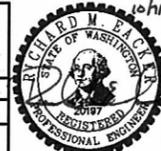
LTK Engineering Services
 505 Union Station Building
 505 5th Avenue, South
 Suite 540
 Seattle, WA 98104
 www.ltk.com

APPROVED FOR ADVERTISING
NANCY LOCKE
 DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
 SEATTLE, WASHINGTON 20

BY: PURCHASING AND CONTRACTING SERVICES DIRECTOR

NAME OR INITIALS AND DATE DESIGNED ML CHECKED RME	INITIALS AND DATE REVIEWED: PE PROJ. MGR. RECEIVED REVISED AS BUILT
DRAWN KMH CHECKED EJR	RECEIVED REVISED AS BUILT

ALL WORK DONE IN ACCORDANCE WITH THE CITY OF SEATTLE STANDARD PLANS AND SPECIFICATIONS AND OTHER DOCUMENTS CALLED FOR IN SECTION 0-02.3 OF THE PROJECT MANUAL.



City of Seattle
Seattle Department of Transportation
 APPROVED

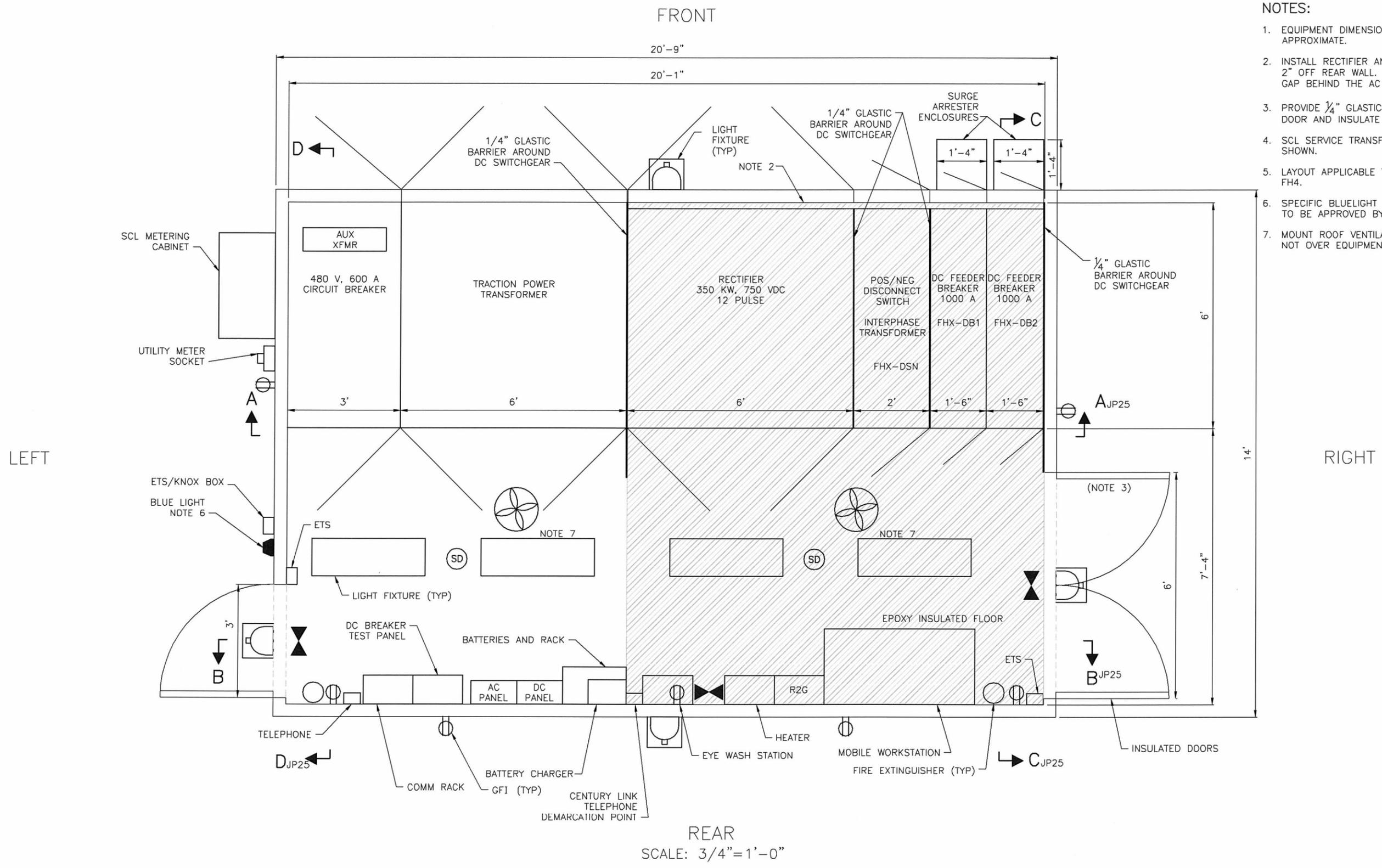
ORDINANCE NO. _____
 FUNDS: NA

INSPECTOR'S BOOK

FIRST HILL STREETCAR TRACTION POWER SUBSTATIONS

JOB NO.	PC	TS4580B
R/W		
CO		TS4580B
VAULT PLAN NO.		774-721
SHEET	11	28

P:\Projects\B-Current\Projects\CAD\10_SDOT_FHSC\CAD\10_SDOT_FHSC\CAD\10_SDOT_FHSC\JP23-TYPICAL_PREFAB_TPSSEQUIPMENT_LAYOUT.dwg 3/14/11 10:47am
 354174
 NATURE REVISIONS
 MADE BY: JCD REV'D



- NOTES:**
- EQUIPMENT DIMENSIONS ARE APPROXIMATE.
 - INSTALL RECTIFIER AND DC SWITCHGEAR 2" OFF REAR WALL. THERE SHALL BE NO GAP BEHIND THE AC SWITCHGEAR.
 - PROVIDE 1/4" GLASTIC ON INTERIOR OF DOOR AND INSULATE OVER PANIC BARS.
 - SCL SERVICE TRANSFORMER IS NOT SHOWN.
 - LAYOUT APPLICABLE TO FH2, FH3 AND FH4.
 - SPECIFIC BLUELIGHT STATION LOCATION TO BE APPROVED BY ENGINEER.
 - MOUNT ROOF VENTILATOR SO THAT IT IS NOT OVER EQUIPMENT.

INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

TYPICAL PREFABRICATED TPSS EQUIPMENT LAYOUT

LTK Engineering Services
 505 Union Station Building
 505 5th Avenue, South
 Suite 640
 Seattle, WA 98104
 www.ltk.com

APPROVED FOR ADVERTISING
 NANCY LOCKE
 DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
 SEATTLE, WASHINGTON 20

BY: PURCHASING AND CONTRACTING SERVICES DIRECTOR

NAME OR INITIALS AND DATE DESIGNED ML CHECKED RME	INITIALS AND DATE REVIEWED: PE CONST. PROJ. MGR.
DRAWN KMH CHECKED EJR	RECEIVED
ALL WORK DONE IN ACCORDANCE WITH THE CITY OF SEATTLE STANDARD PLANS AND SPECIFICATIONS AND OTHER DOCUMENTS CALLED FOR IN SECTION D-02.3 OF THE PROJECT MANUAL.	



City of Seattle
Seattle Department of Transportation
 APPROVED

ORDINANCE NO. 3/8'-1'
 FUND: INSPECTOR'S BOOK

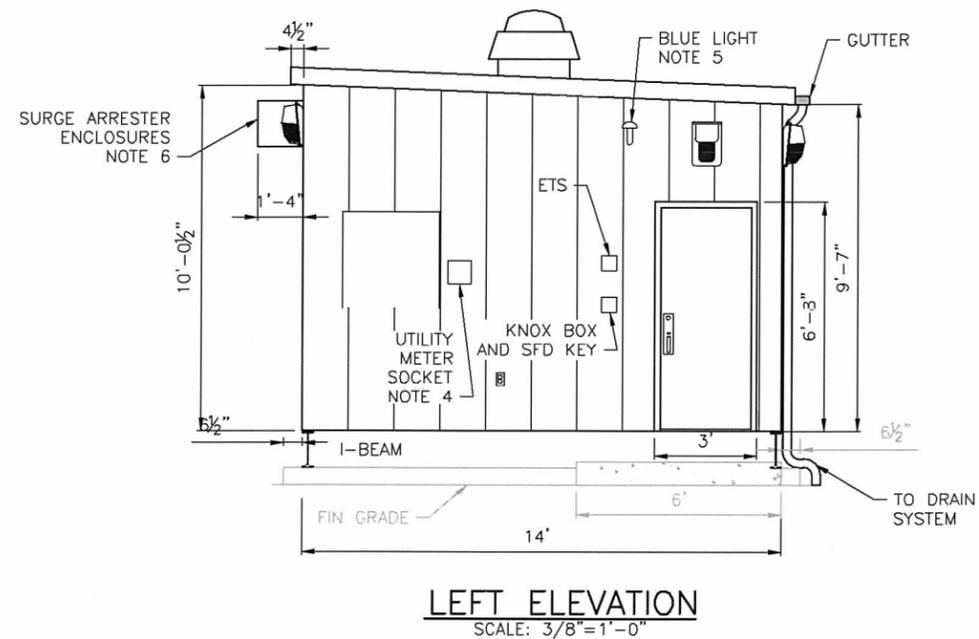
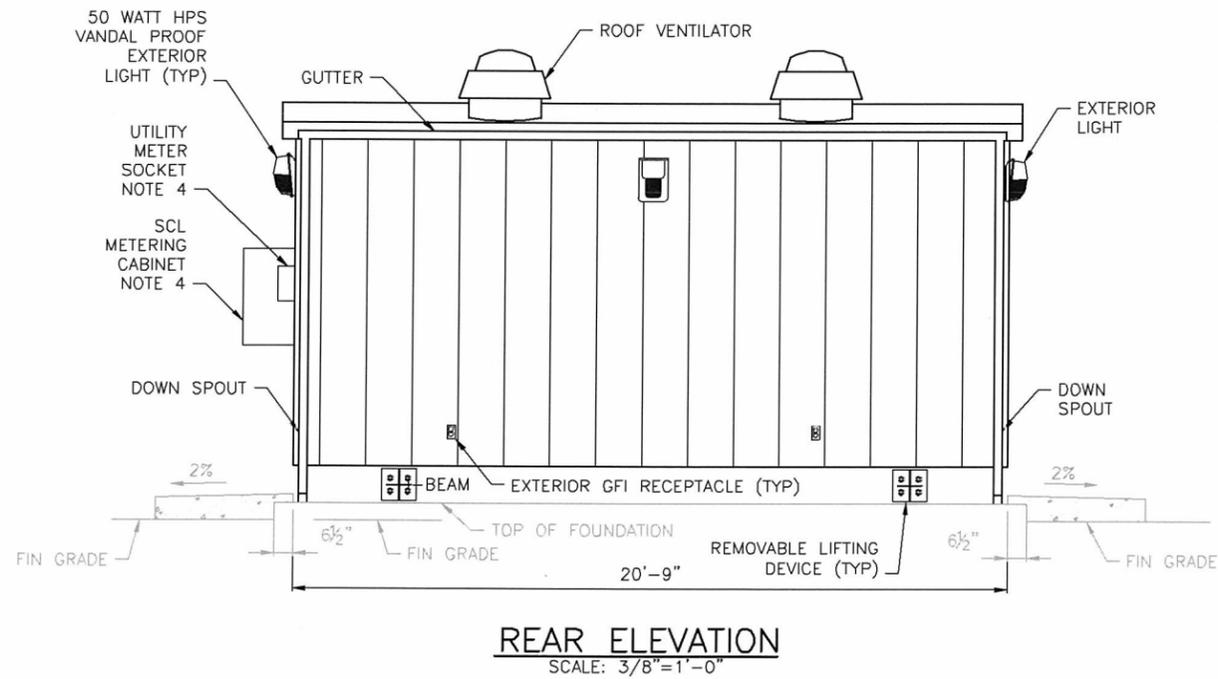
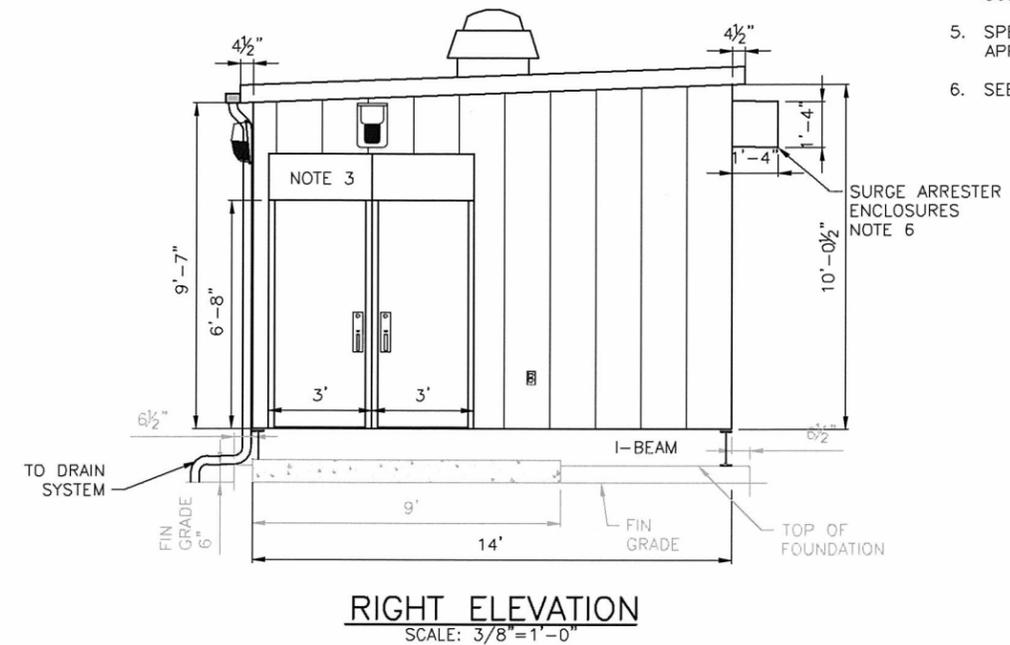
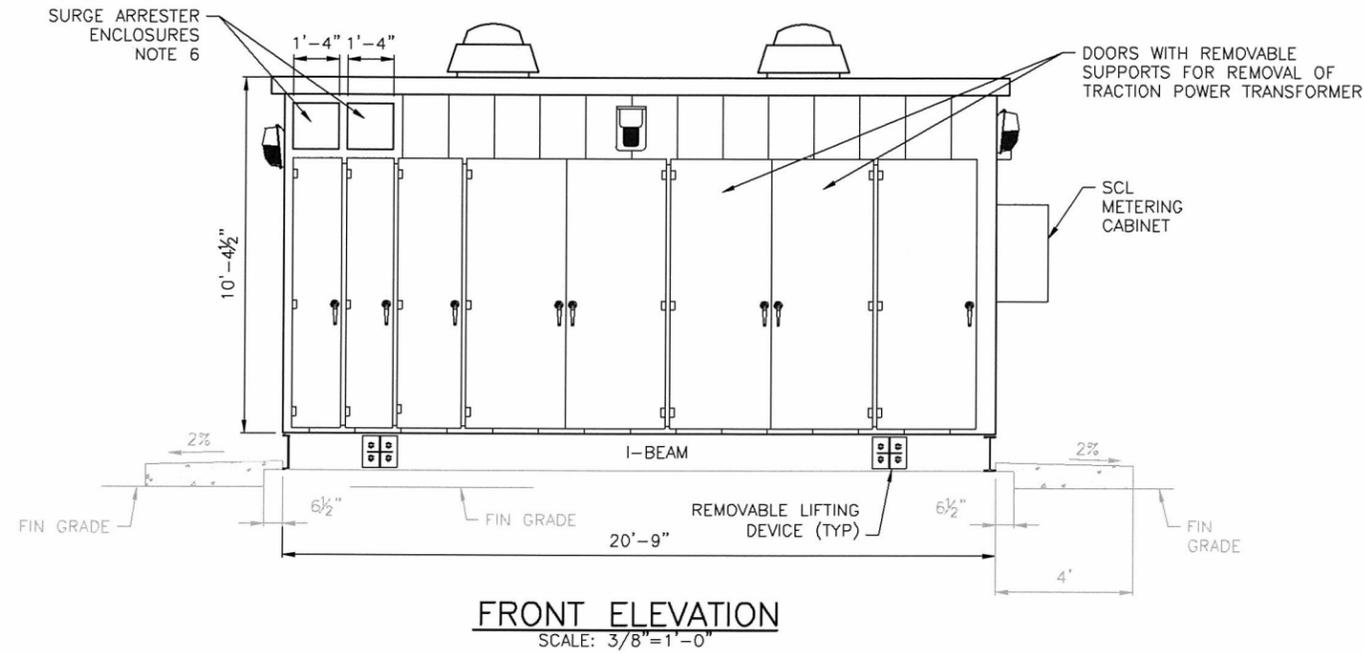
FIRST HILL STREETCAR TRACTION POWER SUBSTATIONS

PC	TS4580B
R/W	
CO	TS4580B
VAULT PLAN NO. 774-721	
SHEET	14 28

JP23

NOTES:

1. ALL DIMENSIONS ARE APPROXIMATE.
2. ELEVATIONS APPLICABLE TO TPSS FH2, FH3 AND FH4 ONLY.
3. INSTALL 1'-8" REMOVABLE TRANSOM ABOVE DOUBLE DOORS TO ALLOW FOR TOTAL OPENING OF 8'-4".
4. METERING EQUIPMENT AND SOCKET DETAILS SUBJECT TO APPROVAL OF UTILITY.
5. SPECIFIC BLUELIGHT STATION LOCATION TO BE APPROVED BY ENGINEER.
6. SEE JP29 FOR DETAILS.



INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

TYPICAL PREFABRICATED TPSS EXTERIOR ELEVATIONS

LTK Engineering Services
505 Union Station Building
505 5th Avenue, South
Suite 640
Seattle, WA 98104
www.ltk.com

APPROVED FOR ADVERTISING
NANCY LOCKE
DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
SEATTLE, WASHINGTON 20

BY: PURCHASING AND CONTRACTING SERVICES DIRECTOR

NAME OR INITIALS AND DATE		INITIALS AND DATE	
DESIGNED ML	CHECKED RME	REVIEWED: PE	CONST. CONST.
DRAWN KMH	CHECKED EUR	RECEIVED	REVISED AS BUILT
ALL WORK DONE IN ACCORDANCE WITH THE CITY OF SEATTLE STANDARD PLANS AND SPECIFICATIONS AND OTHER DOCUMENTS CALLED FOR IN SECTION 0-02.3 OF THE PROJECT MANUAL.			



City of Seattle
Seattle Department of Transportation

ORDINANCE NO. _____ APPROVED
FUND: NA INSPECTOR'S BOOK

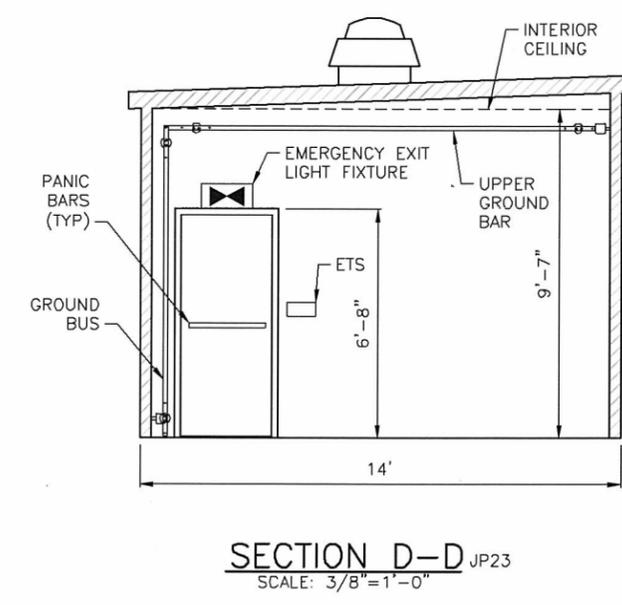
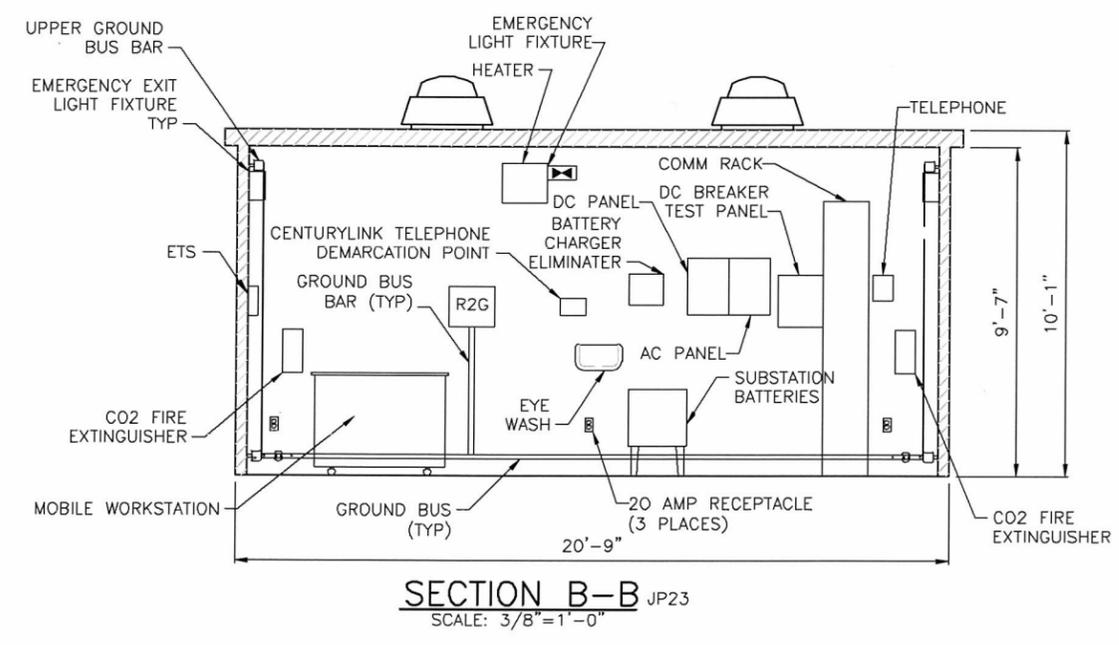
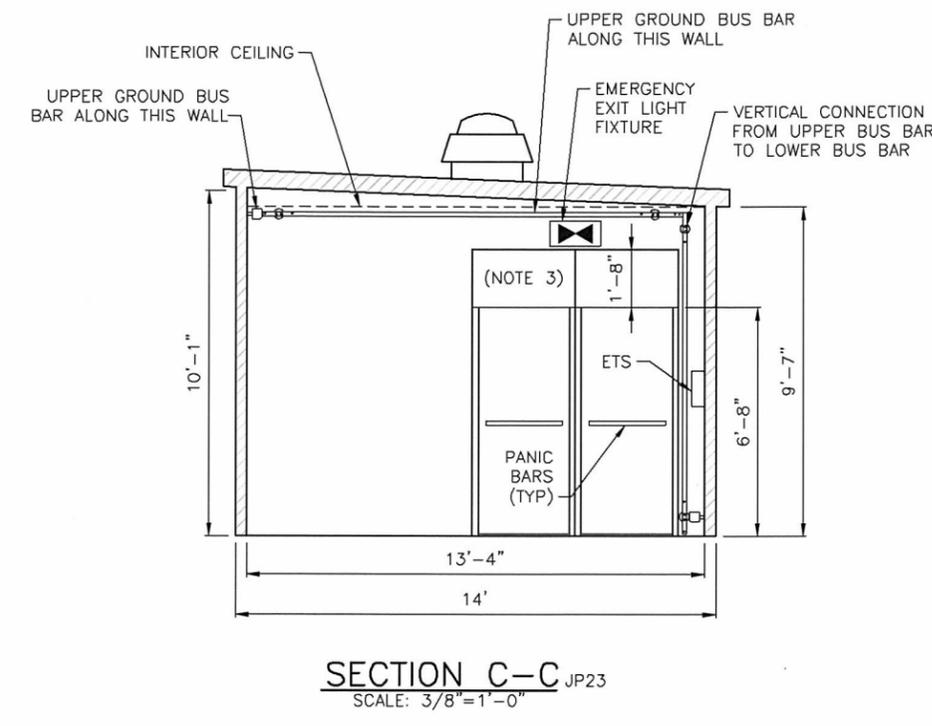
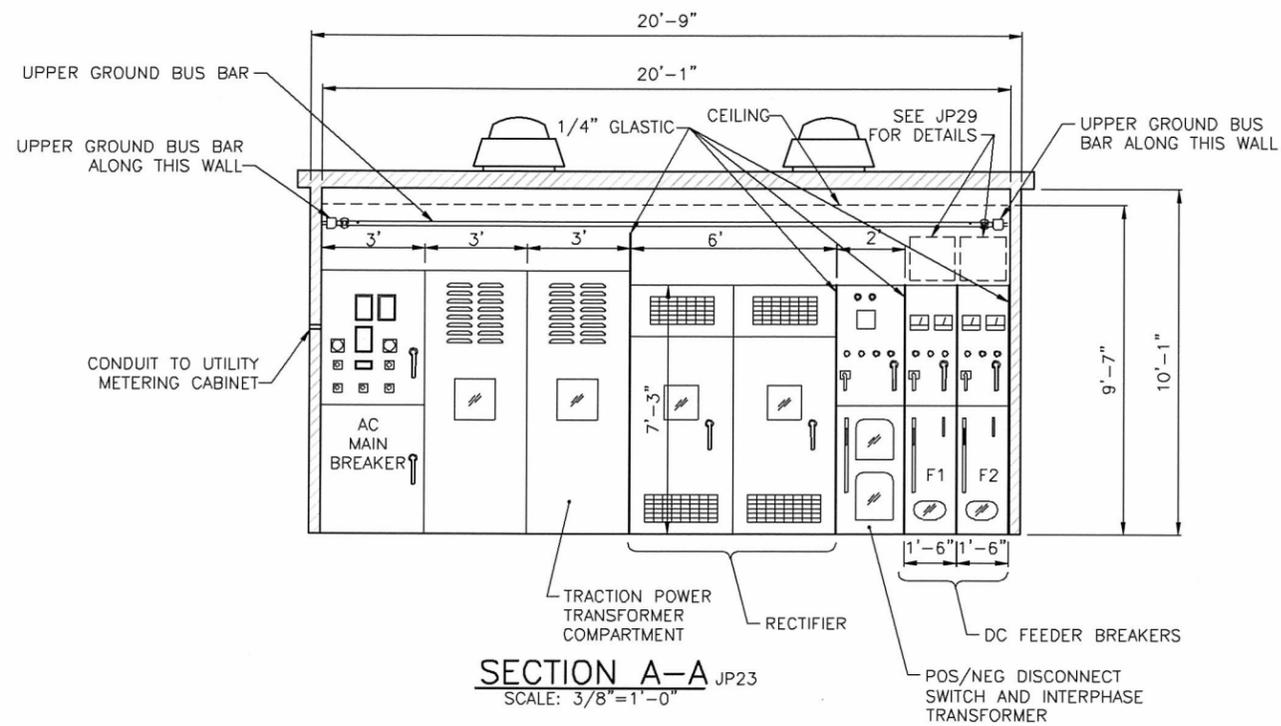
FIRST HILL STREETCAR TRACTION POWER SUBSTATIONS

PC	TS4580B
R/W	
CO	TS4580B
VAULT PLAN NO.	774-721
SHEET	15 28

JP24

P:\Projects\B-Current\Projects\3914_SDOT_FHSC\CAD\10_Sheets\0000\Procurement\JP24-TYPICAL_PREFABRICATED_TPSS_EXTERIOR_ELEVATIONS.dwg DATE: 10/07/2011 10:47am MADE CHK'D REV'D NATURE REVISIONS 35474

- NOTES:**
1. ALL DIMENSIONS ARE APPROXIMATE.
 2. SECTIONS APPLICABLE TO FH2, FH3 AND FH4.
 3. INSTALL 1'-8" REMOVABLE TRANSOM ABOVE DOUBLE DOORS TO ALLOW FOR TOTAL OPENING OF 8'-4".
 4. METERING EQUIPMENT AND SOCKET DETAILS SUBJECT TO APPROVAL OF UTILITY.
 5. CONTRACTOR TO DETERMINE SIZE AND LOCATION OF TPSS VENTILATION SYSTEM.



P:\Projects\B-Current\Projects\CAD\10 Sheets\100% Procurement\JP25-TYPICAL_PREFABRICATION\JP25-TYPICAL_PREFABRICATION.dwg
 35474
 NATURE REVISIONS
 MADE CHKD REV'D

INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

JP25 TYPICAL PREFABRICATED TPSS INTERIOR ELEVATIONS

LTK Engineering Services
 505 Union Station Building
 505 5th Avenue, South
 Suite 640
 Seattle, WA 98104
 www.ltk.com

APPROVED FOR ADVERTISING
 NANCY LOCKE
 DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
 SEATTLE, WASHINGTON 20

NAME OR INITIALS AND DATE DESIGNED ML CHECKED RME	INITIALS AND DATE REVIEWED: PE PROJ. MGR. RECEIVED REVISED AS BUILT
DRAWN KMH CHECKED EJR	

ALL WORK DONE IN ACCORDANCE WITH THE CITY OF SEATTLE STANDARD PLANS AND SPECIFICATIONS AND OTHER DOCUMENTS CALLED FOR IN SECTION 0-52.3 OF THE PROJECT MANUAL.

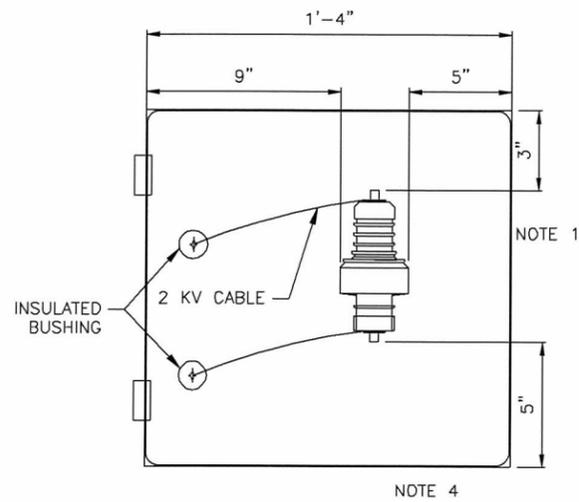


City of Seattle
Seattle Department of Transportation
 ORDINANCE NO. APPROVED
 FUND: NA INSPECTOR'S BOOK

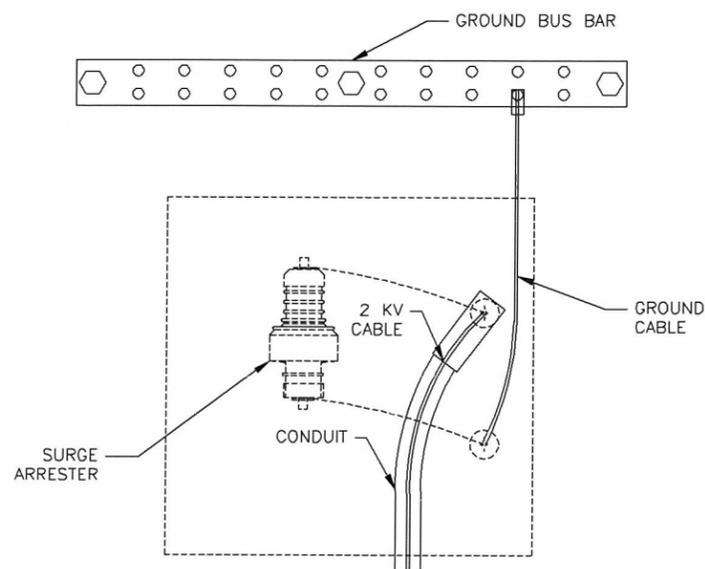
FIRST HILL STREETCAR TRACTION POWER SUBSTATIONS

CON	PC	TS4580B
R/W	CO	TS4580B
SOB	VAULT PLAN NO.	774-721
	SHEET	16 28

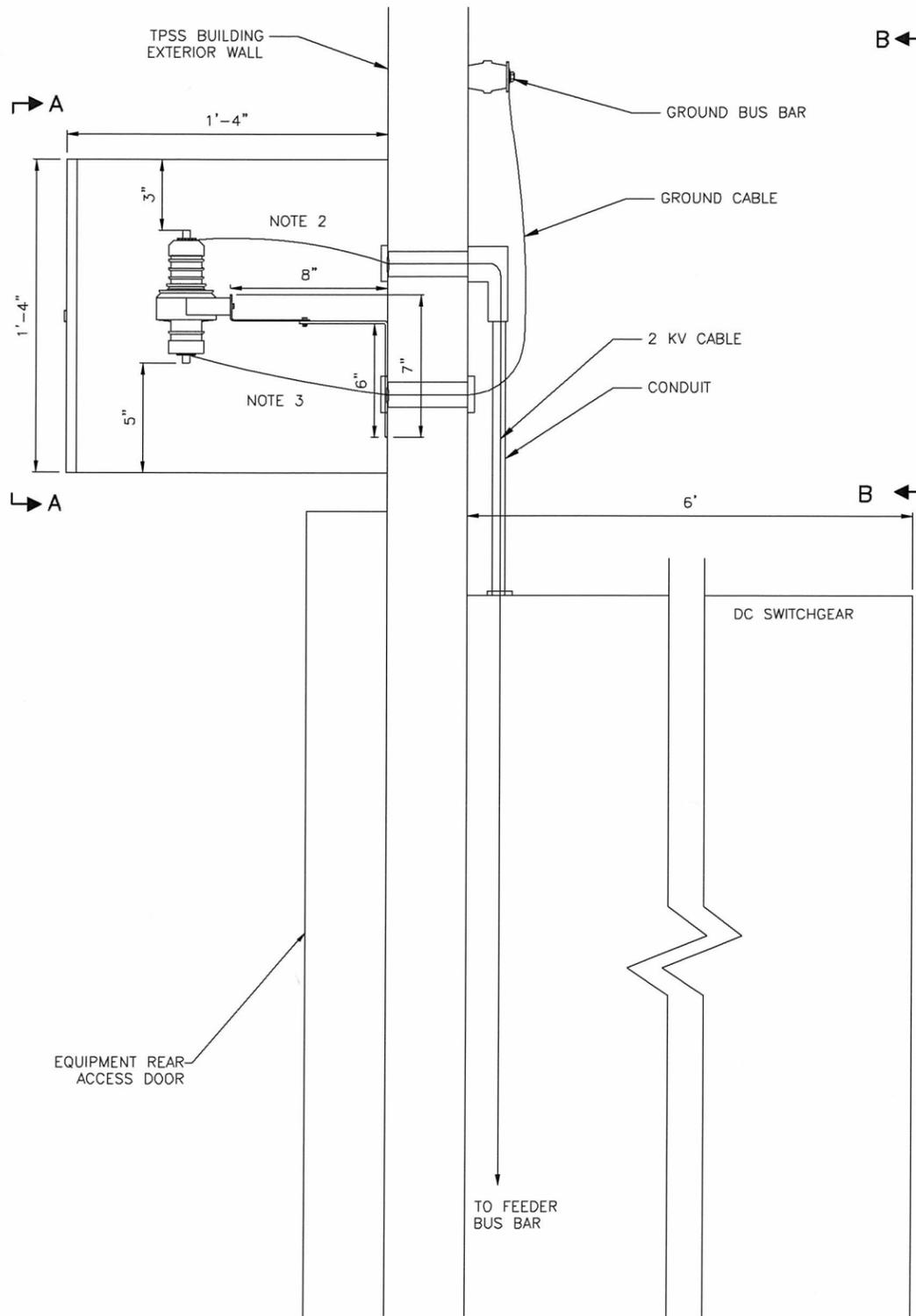
P:\Projects\B-Current\Projects\CSB14_SDOT_FHSC\CAD\10_Sheets\100%_Procurement\JP29-TYPICAL_SURGE_ARROW.dwg
 3/5/2011 10:47am
 35474
 NATURE REVISIONS
 MADE CHKD REVD



A-A EXTERIOR VIEW
SCALE: 3"=1'-0"



B-B INTERIOR VIEW
SCALE: 3"=1'-0"



SIDE VIEW
SCALE: 3"=1'-0"

NOTES:

1. PROVIDE FIBERGLASS WEATHERPROOF ENCLOSURE FOR EACH SURGE ARRESTER.
2. SECURE POSITIVE CABLE INSIDE ENCLOSURE.
3. CABLES FOR GROUND CONNECTION SHALL BE EXTRA FLEXIBLE.
4. EXTERIOR VIEW IS WITH COVER REMOVED.

INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

TYPICAL SURGE ARRESTER INSTALLATION DETAILS

OK Engineering Services
 505 Union Station Building
 505 5th Avenue, South
 Suite 640
 Seattle, WA 98104
 www.ok.com

APPROVED FOR ADVERTISING
NANCY LOCKE
 DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
 SEATTLE, WASHINGTON 20

BY: _____
 PURCHASING AND CONTRACTING SERVICES DIRECTOR

NAME OR INITIALS AND DATE	INITIALS AND DATE
DESIGNED ML	REVIEWED: PE CONST.
CHECKED RME	PROJ. MGR.
DRAWN SP	RECEIVED
CHECKED EJR	REVISED AS BUILT
ALL WORK DONE IN ACCORDANCE WITH THE CITY OF SEATTLE STANDARD PLANS AND SPECIFICATIONS AND OTHER DOCUMENTS CALLED FOR IN SECTION D-02.3 OF THE PROJECT MANUAL.	



City of Seattle
Seattle Department of Transportation

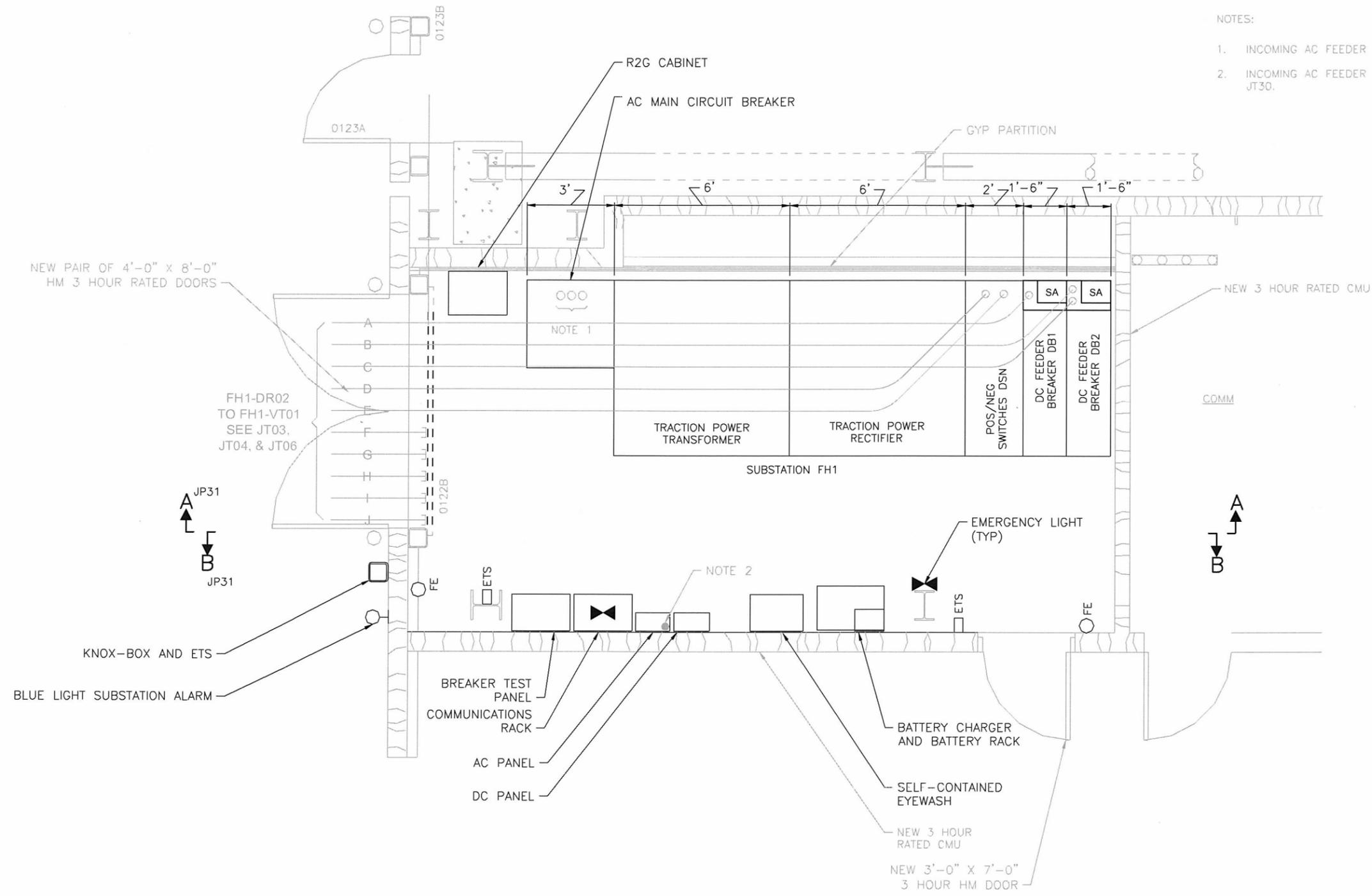
ORDINANCE NO. _____ APPROVED _____
 FUND: _____ INSPECTOR'S BOOK _____

FIRST HILL STREETCAR TRACTION POWER SUBSTATIONS

NO.	PC	TS4580B
R/W		
CO		TS4580B
VAULT PLAN NO. 774-721		
SHEET 17 28		

JP29

P:\Projects\9-Current Projects\CAD\10_Sheets\1000x_Procurement\JP30-KING-ST_IPSS_0106\REVISED\JP30-KING-ST_IPSS_0106.dwg
 DATE 10/17/2011
 REVISIONS
 35474
 MADE CHKO REVD



- NOTES:
1. INCOMING AC FEEDER FROM TPSB. SEE DRAWING JT30.
 2. INCOMING AC FEEDER FROM BUILDING SWITCHBOARD. SEE DRAWING JT30.



INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

JP30
 KING ST TPSS EQUIPMENT LAYOUT

LTK Engineering Services
 505 Union Station Building
 505 5th Avenue, South
 Suite 640
 Seattle, WA 98104
 www.ltk.com

APPROVED FOR ADVERTISING
 NANCY LOCKE
 DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
 SEATTLE, WASHINGTON 20

BY:
 PURCHASING AND CONTRACTING SERVICES DIRECTOR

NAME OR INITIALS AND DATE	INITIALS AND DATE
DESIGNED RME	REVIEWED: PE CONST.
CHECKED ML	PROJ. MGR.
DRAWN KMH	RECEIVED
CHECKED EJR	REVISED AS BUILT

ALL WORK DONE IN ACCORDANCE WITH THE CITY OF SEATTLE STANDARD PLANS AND SPECIFICATIONS AND OTHER DOCUMENTS CALLED FOR IN SECTION 0-02.3 OF THE PROJECT MANUAL.



City of Seattle
Seattle Department of Transportation
 APPROVED

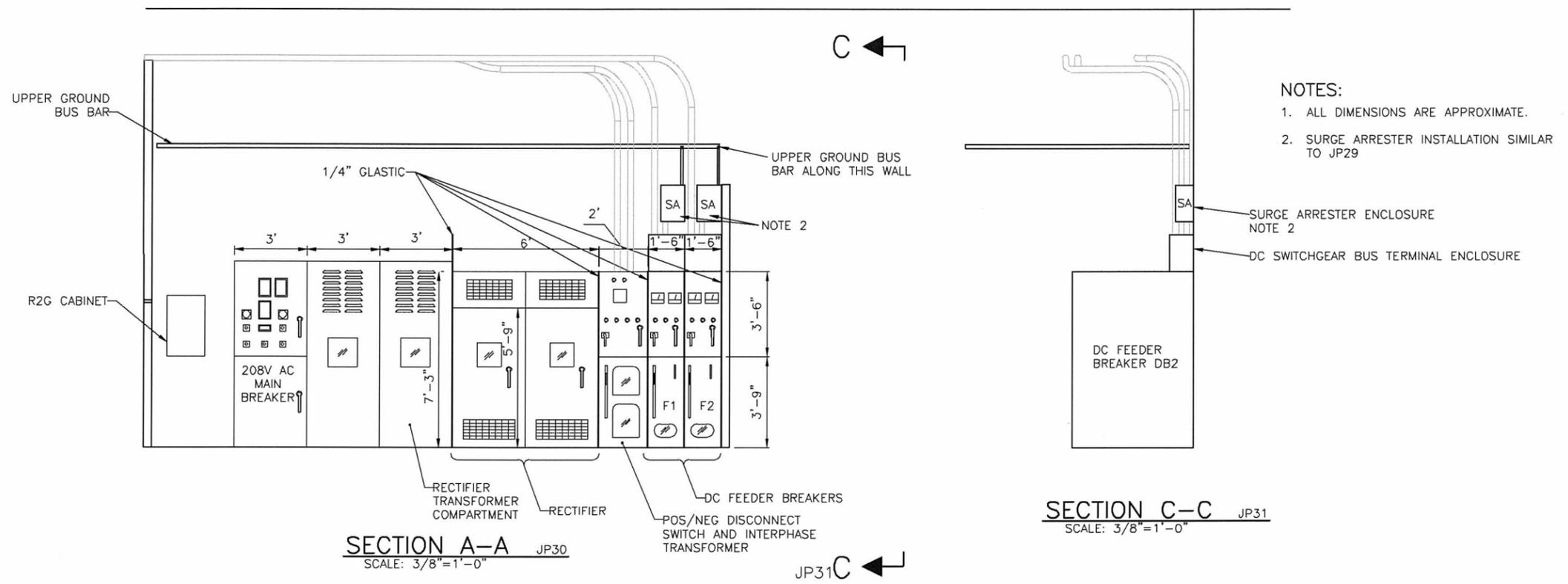
ORDINANCE NO. _____
 FUND: NTS

INSPECTOR'S BOOK

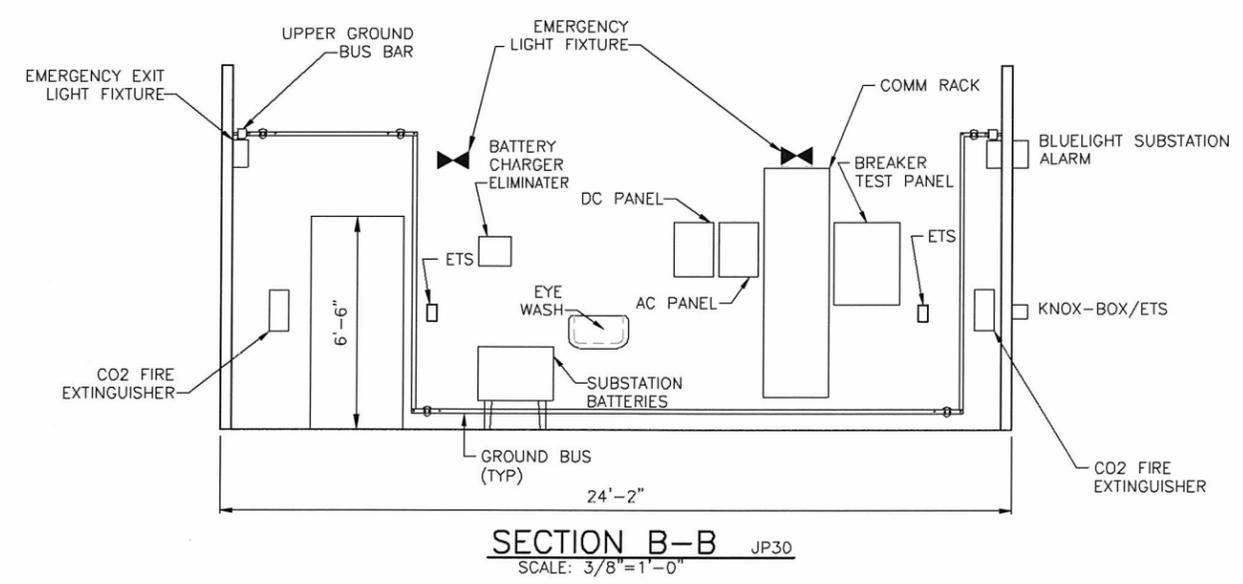
FIRST HILL STREETCAR TRACTION POWER SUBSTATIONS

NO.	PC	TS4580B
R/W		
CO		TS4580B
VAULT PLAN NO.	774-721	
SHEET	18	28

P:\Projects\B-Current\Projects\CAD\10_Sheets\100%_Procurement\JP31-KING_ST_TPSS\MARKER_SCHMIDTUNGS.cad DATE MARK NATURE REVISIONS 35474



NOTES:
 1. ALL DIMENSIONS ARE APPROXIMATE.
 2. SURGE ARRESTER INSTALLATION SIMILAR TO JP29



INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

JP31 KING ST TPSS INTERIOR ELEVATIONS

LTK Engineering Services
 505 Union Station Building
 505 5th Avenue, South
 Suite 640
 Seattle, WA 98104
 www.ltk.com

APPROVED FOR ADVERTISING
 NANCY LOCKE
 DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
 SEATTLE, WASHINGTON 20

BY: PURCHASING AND CONTRACTING SERVICES DIRECTOR

NAME OR INITIALS AND DATE	INITIALS AND DATE
DESIGNED RME	REVIEWED: PE CONST.
CHECKED ML	PROJ. MGR.
DRAWN KMH	RECEIVED
CHECKED EJR	REVISED AS BUILT

ALL WORK DONE IN ACCORDANCE WITH THE CITY OF SEATTLE STANDARD PLANS AND SPECIFICATIONS AND OTHER DOCUMENTS CALLED FOR IN SECTION 0-02.3 OF THE PROJECT MANUAL.



City of Seattle
Seattle Department of Transportation
 ORDINANCE NO. APPROVED
 FUND:

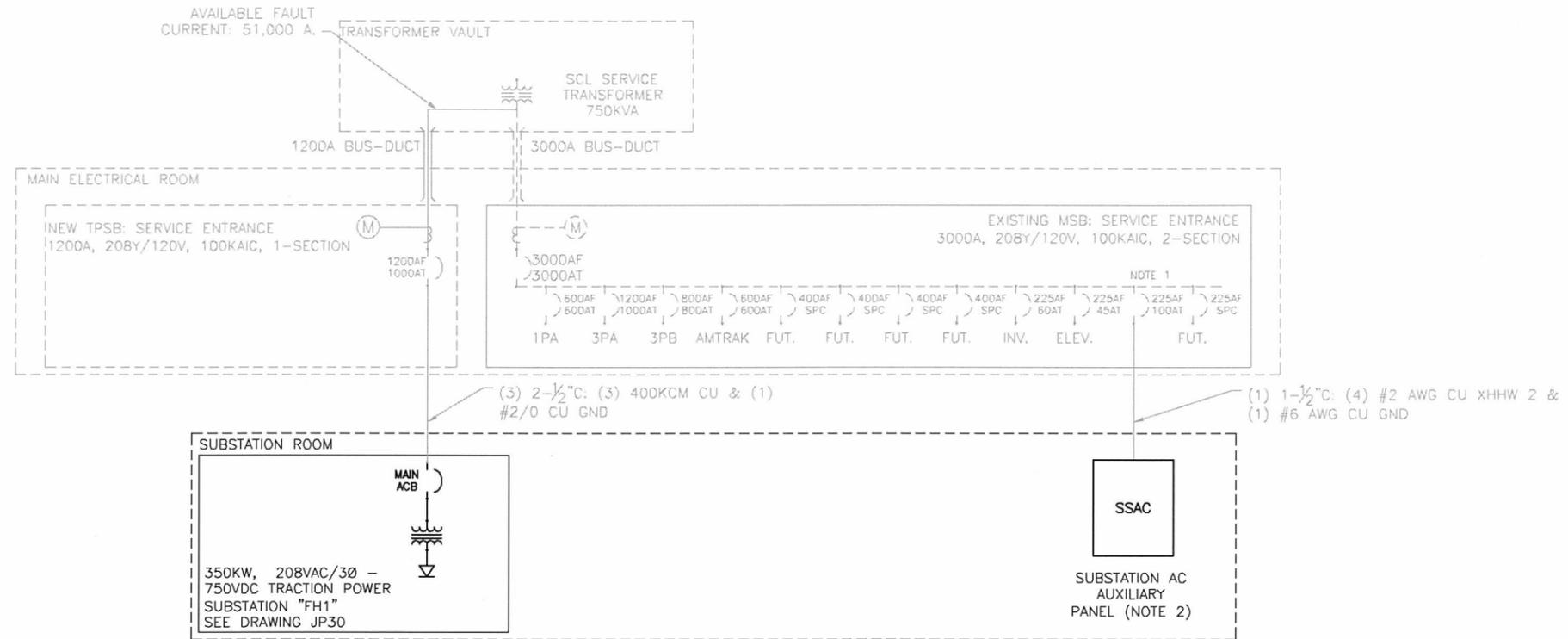
FIRST HILL STREETCAR TRACTION POWER SUBSTATIONS

JOB NO.	PC	TS4580B
R/W		
CO		TS4580B
VAULT PLAN NO.	774-721	
SHEET	19	28

H. 1"=20', V. 1"=10' INSPECTOR'S BOOK

NOTES:

1. PROVIDE NEW 100A, 3-POLE CIRCUIT BREAKER IN EXISTING 225AF SPACE IN EXISTING EATON MAIN SWITCHBOARD 'MSB.'
2. PROVIDE NEW 100A, 208Y/120V, 30-CIRCUIT PANEL 'SSAC' LOCATED IN SUBSTATION ROOM AS SHOWN ON JP30. PANEL SHALL INCLUDE (18) 20A/1Ø CIRCUIT BREAKERS AND (1) 30A/2Ø CIRCUIT BREAKER. SEE DWG JP22



ELECTRICAL ONE-LINE DIAGRAM
NOT TO SCALE

INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

JP32
KING ST BUILDING ONE-LINE DIAGRAM

LTK
LTK Engineering Services
505 Union Station Building
505 5th Avenue, South
Suite 540
Seattle, WA 98104
www.ltk.com

APPROVED FOR ADVERTISING
NANCY LOCKE
DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
SEATTLE, WASHINGTON 20

BY:
PURCHASING AND CONTRACTING SERVICES DIRECTOR

NAME OR INITIALS AND DATE	INITIALS AND DATE
DESIGNED RME	REVIEWED: PE CONST.
CHECKED ML	PROJ. MGR.
DRAWN KMH	RECEIVED
CHECKED EJR	REVISED AS BUILT

ALL WORK DONE IN ACCORDANCE WITH THE CITY OF SEATTLE STANDARD PLANS AND SPECIFICATIONS AND OTHER DOCUMENTS CALLED FOR IN SECTION 0-02.3 OF THE PROJECT MANUAL.



City of Seattle
Seattle Department of Transportation

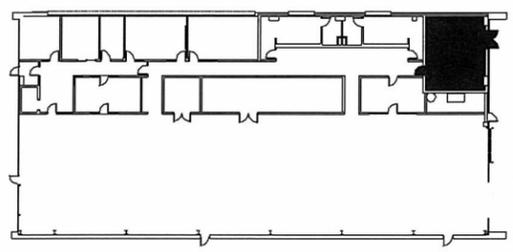
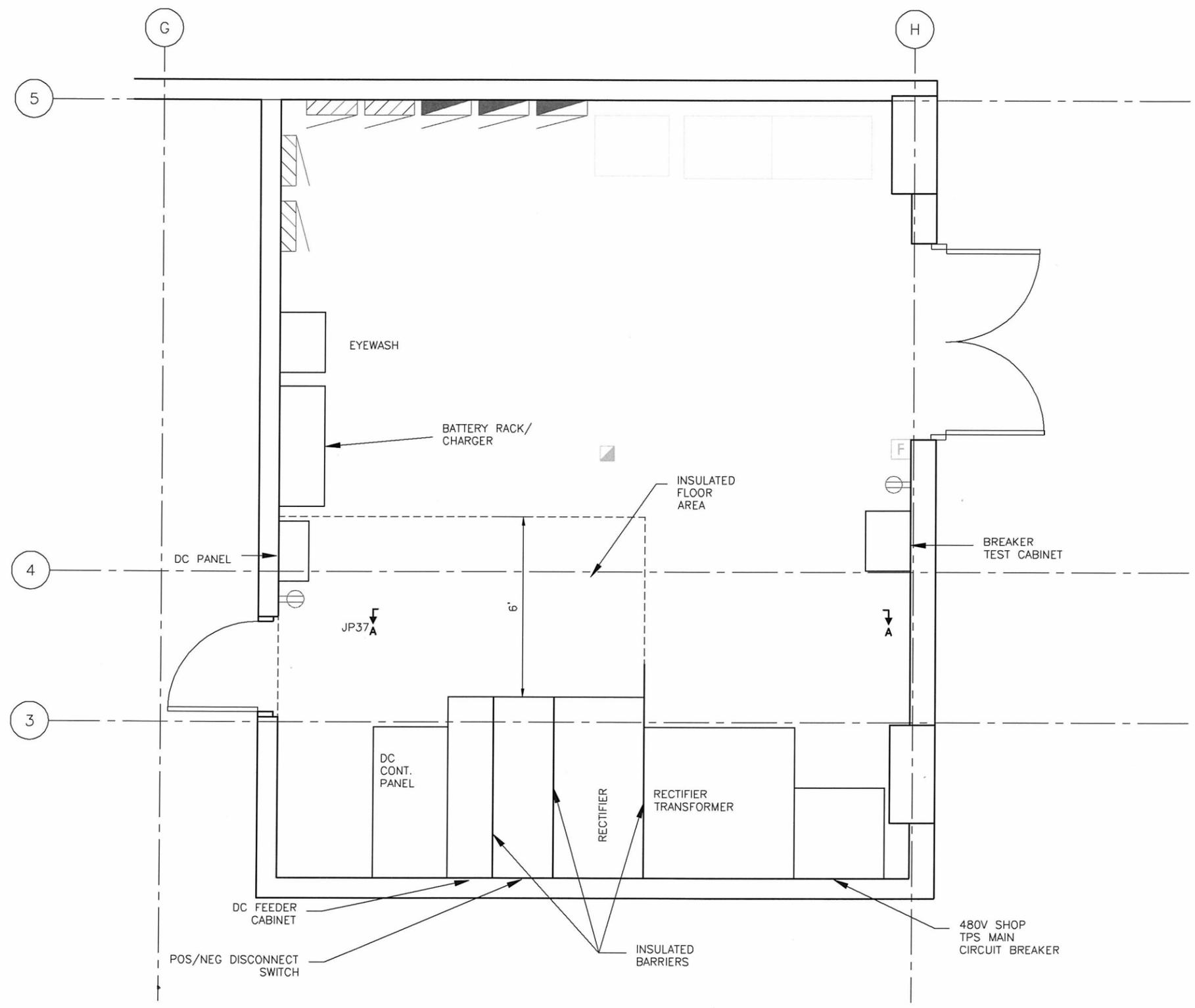
ORDINANCE NO. APPROVED

FUND: NA INSPECTOR'S BOOK

FIRST HILL STREETCAR
TRACTION POWER SUBSTATIONS

NO.	PC	TS4580B
NO.	R/W	
NO.	CO	TS4580B
VAULT PLAN NO.		
774-721		
SHEET	20	28

P:\Projects\B-Current\Projects\C3814_SDOT_FHSC\CAD\10_Sheets\1000\Procurement\JP36-OMF_IPSS_EQUIPMENT_LAYOUT_PLAN_UPDATE_DATE_35474.MXD
 NATURE REVISIONS
 MADE CHKD REVD
 35474



OMF TPSS EQUIPMENT LAYOUT PLAN
 SCALE: 1/2" = 1'-0"

INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

JP36
 OMF TPSS EQUIPMENT LAYOUT PLAN

OK Engineering Services
 525 Union Station Building
 525 5th Avenue, South
 Suite 640
 Seattle, WA 98104
 www.ok.com

APPROVED FOR ADVERTISING
 NANCY LOCKE
 DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
 SEATTLE, WASHINGTON 20

NAME OR INITIALS AND DATE	INITIALS AND DATE
DESIGNED RME	REVIEWED: PE
CHECKED ML	PROJ. MGR. CONST.
DRAWN SP	RECEIVED
CHECKED EJR	REVISED AS BUILT
ALL WORK DONE IN ACCORDANCE WITH THE CITY OF SEATTLE STANDARD PLANS AND SPECIFICATIONS AND OTHER DOCUMENTS CALLED FOR IN SECTION 0-02.3 OF THE PROJECT MANUAL.	

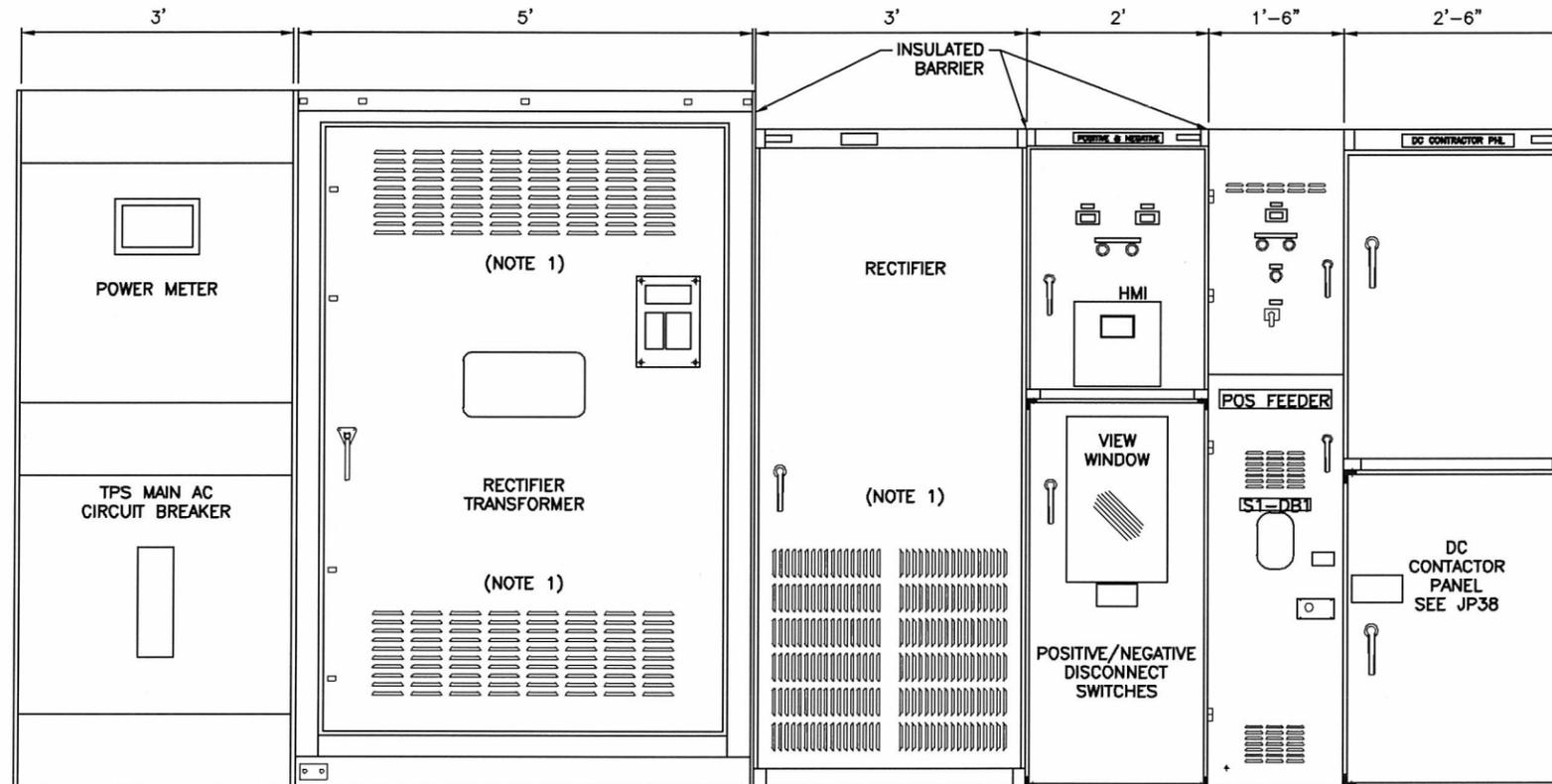


City of Seattle
Seattle Department of Transportation
 ORDINANCE NO. APPROVED
 FUND: INSPECTOR'S BOOK

FIRST HILL STREETCAR TRACTION POWER SUBSTATIONS

PC	TS4580B
R/W	
CO	TS4580B
VAULT PLAN NO. 774-721	
SHEET	22 28

- NOTES:
1. MANUFACTURER TO DETERMINE SIZE AND LOCATIONS OF VENTILATION OPENINGS FOR TRANSFORMER AND RECTIFIER COOLING.



OMF TPSS FRONT ELEVATION
SCALE: 1"=1'-0"

INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

JP37
OMF TPSS INTERIOR ELEVATION



APPROVED FOR ADVERTISING
NANCY LOCKE
DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
SEATTLE, WASHINGTON 20

BY: PURCHASING AND CONTRACTING SERVICES DIRECTOR

NAME OR INITIALS AND DATE	INITIALS AND DATE
DESIGNED RME	REVIEWED: PE CONST.
CHECKED ML	PROJ. MGR.
DRAWN SP	RECEIVED
CHECKED EJR	REVISED AS BUILT

ALL WORK DONE IN ACCORDANCE WITH THE CITY OF SEATTLE STANDARD PLANS AND SPECIFICATIONS AND OTHER DOCUMENTS CALLED FOR IN SECTION 0-02.3 OF THE PROJECT MANUAL.



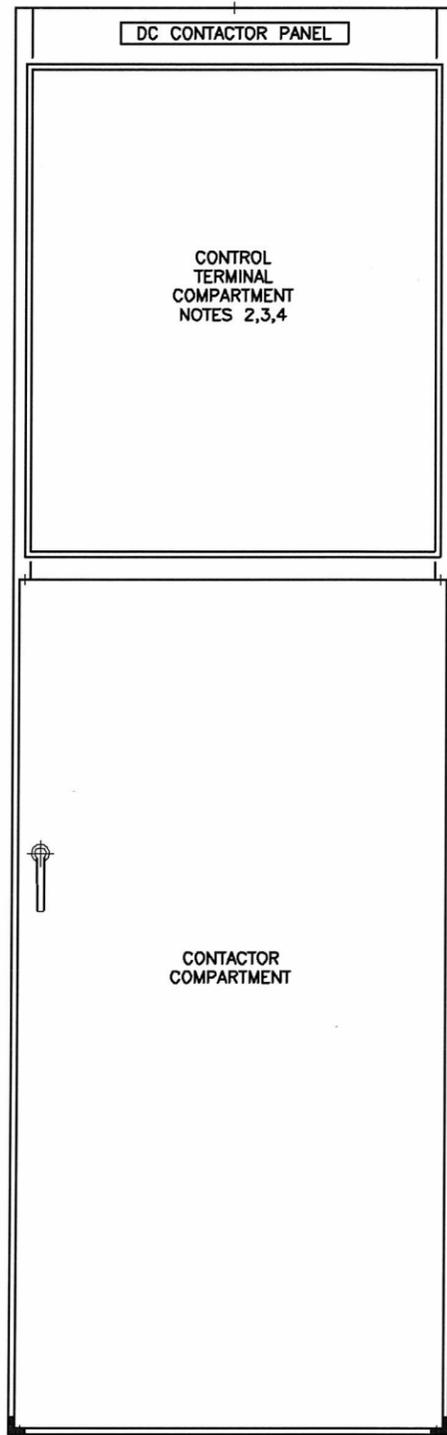
City of Seattle
Seattle Department of Transportation

ORDINANCE NO. APPROVED
FUND: INSPECTOR'S BOOK

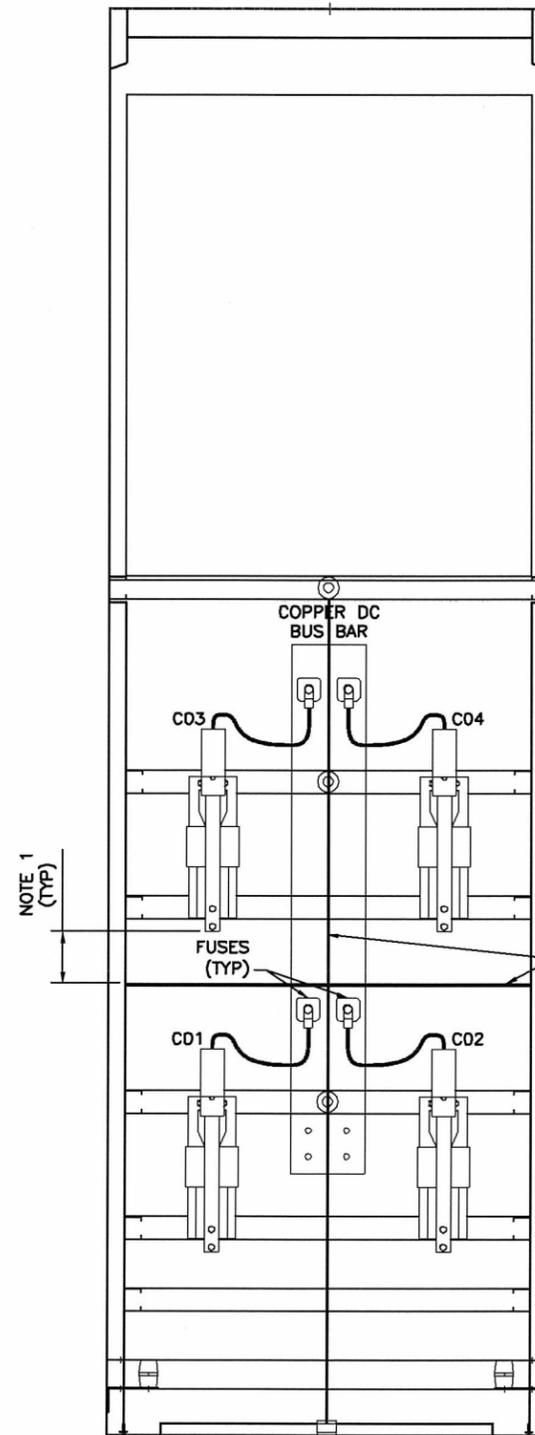
FIRST HILL STREETCAR
TRACTION POWER SUBSTATIONS

NO.	PC	TS4580B
JOB NO.	R/W	
	CO	TS4580B
	VAULT PLAN NO.	774-721
	SHEET	23 28

P:\Projects\B-Current\Projects\3814_SDOT_FHSC\CA010_Sheets\0004_Procurement\JP38-OMF_TPSS_DC_CONTACTOR_PANEL_DETAIL.dwg MARK MAKE PHKO REVD
 35474 NATURE REVISIONS



FRONT VIEW
 SCALE: 3/4"=1'-0"



FRONT VIEW
 SCALE: 3/4"=1'-0"
 (WITHOUT COVERS AND CONTROL)

- NOTES:
1. PROVIDE ADEQUATE CLEARANCE BETWEEN LOAD-SIDE TERMINALS AND BARRIER TO PERMIT TERMINATION OF 250 KCMIL FEEDERS.
 2. PROVIDE 125 VAC, 10 A, 3 PDT AUXILIARY RELAYS IN CONTROL TERMINAL COMPARTMENT FOR EACH DC CONTACTOR (FOR FIELD INTERLOCK WIRING)
 3. PROVIDE 36-TERMINAL DIN-RAIL MOUNTED TERMINAL STRIP RATED 20 A, 250 V (FOR FIELD INTERLOCK WIRING).
 4. PROVIDE REMOVABLE BACK-PANEL FOR MOUNTING OF RELAYS AND TERMINAL STRIPS.

INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

JP38
 OMF TPSS DC CONTACTOR PANEL DETAIL

OK
Engineering Services
 505 Union Station Building
 505 5th Avenue, South
 Suite 640
 Seattle, WA 98104
 www.ok.com

APPROVED FOR ADVERTISING
 NANCY LOCKE
 DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
 SEATTLE, WASHINGTON 20

BY:
 PURCHASING AND CONTRACTING SERVICES DIRECTOR

NAME OR INITIALS AND DATE	INITIALS AND DATE
DESIGNED RME	REVIEWED: PE CONST.
CHECKED ML	PROJ. MGR.
DRAWN SP	RECEIVED
CHECKED EJR	REVISED AS BUILT
ALL WORK DONE IN ACCORDANCE WITH THE CITY OF SEATTLE STANDARD PLANS AND SPECIFICATIONS AND OTHER DOCUMENTS CALLED FOR IN SECTION 0-02.3 OF THE PROJECT MANUAL.	



City of Seattle
Seattle Department of Transportation
 APPROVED

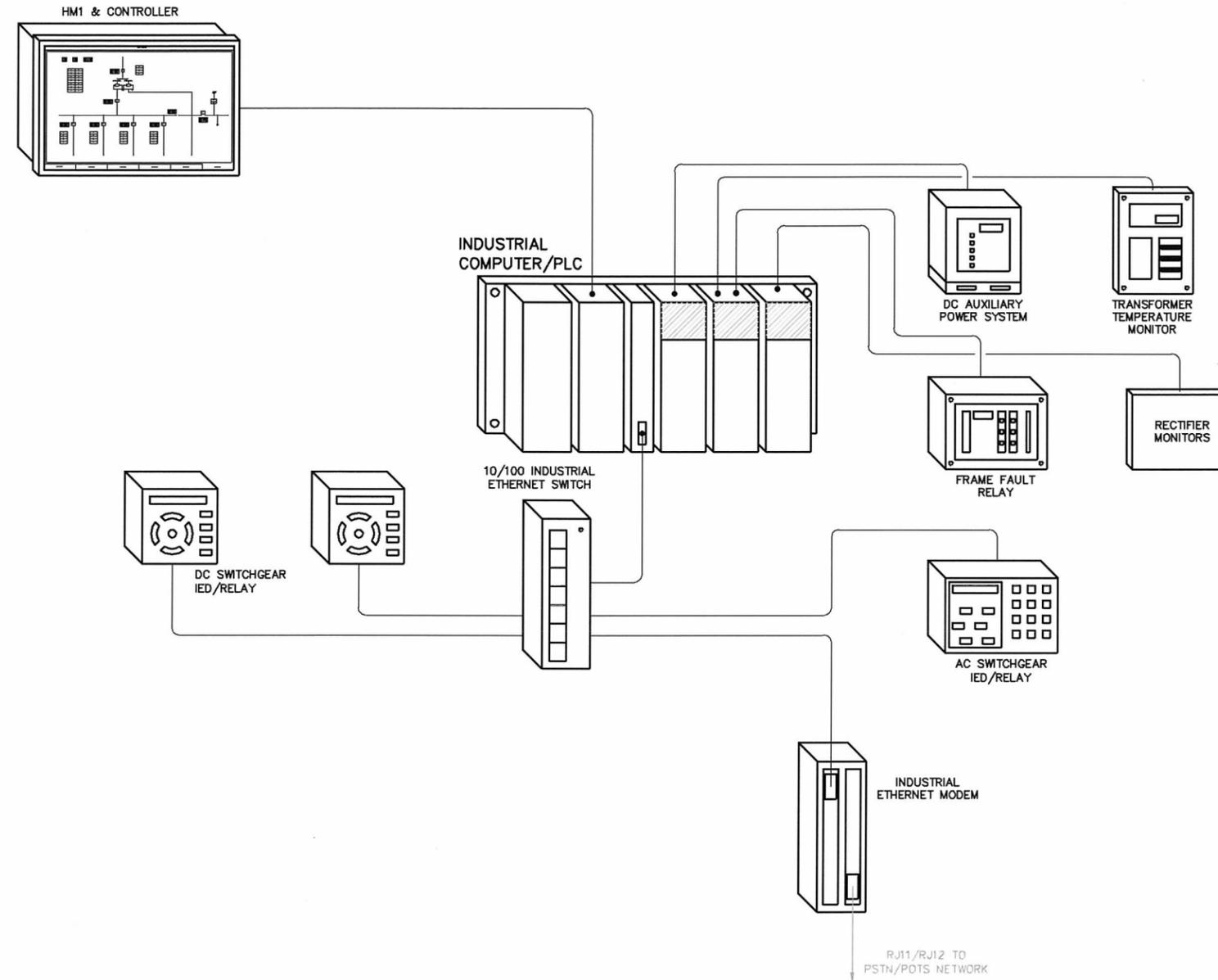
ORDINANCE NO. _____
 FUND: _____
 INSPECTOR'S BOOK

FIRST HILL STREETCAR
 TRACTION POWER SUBSTATIONS

NO	PC	TS4580B
BY	R/W	
DATE	CO	TS4580B
	VAULT PLAN NO.	774-721
	SHEET	24 28

NOTES:

1. REFER TO CONTRACT SPECIFICATIONS FOR DETAILED REQUIREMENTS.



INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

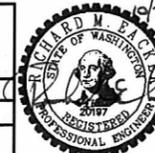
TYPICAL SUBSTATION LOCAL AREA NETWORK DIAGRAM JP40

OK
Engineering Services
 505 Union Station Building
 505 5th Avenue, South
 Suite 640
 Seattle, WA 98104
 www.ok.com

APPROVED FOR ADVERTISING
 NANCY LOCKE
 DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
 SEATTLE, WASHINGTON 20

BY:
 PURCHASING AND CONTRACTING SERVICES DIRECTOR

NAME OR INITIALS AND DATE	INITIALS AND DATE
DESIGNED ML	REVIEWED: PE CONST.
CHECKED RME	PROJ. MGR.
DRAWN SP	RECEIVED
CHECKED EJR	REVISED AS BUILT
ALL WORK DONE IN ACCORDANCE WITH THE CITY OF SEATTLE STANDARD PLANS AND SPECIFICATIONS AND OTHER DOCUMENTS CALLED FOR IN SECTION 0-02.3 OF THE PROJECT MANUAL.	

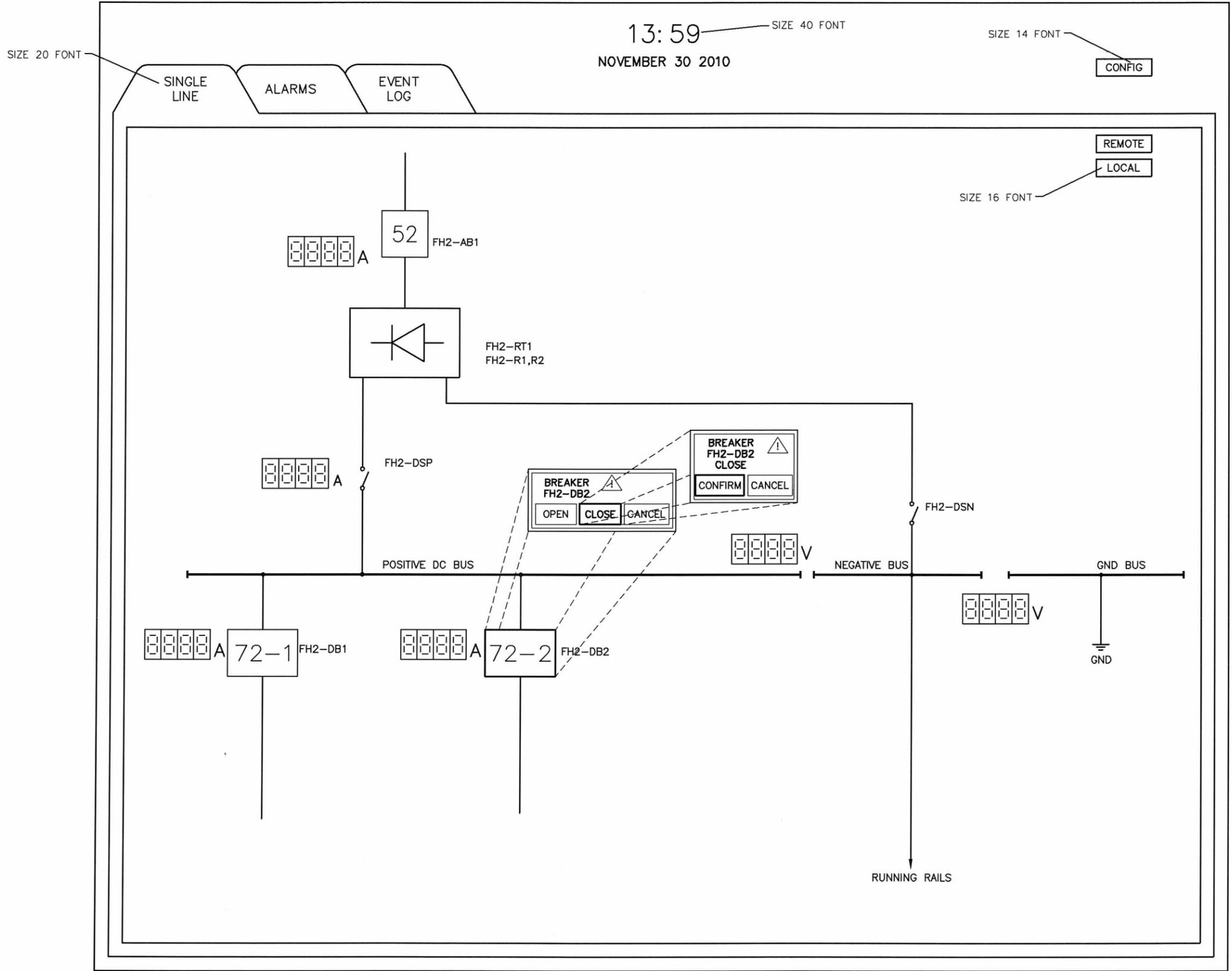


City of Seattle
Seattle Department of Transportation
 APPROVED
 ORDINANCE NO. _____
 FUND: _____
 INSPECTOR'S BOOK

FIRST HILL STREETCAR TRACTION POWER SUBSTATIONS

PC	TS4580B
R/W	
CO	TS4580B
VAULT PLAN NO. 774-721	
SHEET	25 28

P:\Projects\B-Current\Projects\3814_SDOT_FHSC\CAD\10_Sheets\1000\Procurement\JP40-TYPICAL...SUBSTRATE\10-47am
 DATE 3/24/11
 MARK REVISIONS
 MADE BY: KCD REV'D



NOTES:
 1. REFER TO CONTRACT SPECIFICATIONS FOR DETAILED REQUIREMENTS.

INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

JP41
 TYPICAL TPSS ALARM PANEL HMI
 ONE-LINE SCREEN LAYOUT

OK
Engineering Services
 305 Union Station Building
 305 5th Avenue, South
 Suite 640
 Seattle, WA 98104
 www.ok.com

APPROVED FOR ADVERTISING
 NANCY LOCKE
 DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
 SEATTLE, WASHINGTON 20

BY:
 PURCHASING AND CONTRACTING SERVICES DIRECTOR

NAME OR INITIALS AND DATE	INITIALS AND DATE
DESIGNED ML	REVIEWED: PE CONST.
CHECKED RME	PROJ. MGR.
DRAWN SP	RECEIVED
CHECKED EJR	REVISED AS BUILT

ALL WORK DONE IN ACCORDANCE WITH THE CITY OF SEATTLE STANDARD PLANS AND SPECIFICATIONS AND OTHER DOCUMENTS CALLED FOR IN SECTION 0-02.3 OF THE PROJECT MANUAL.



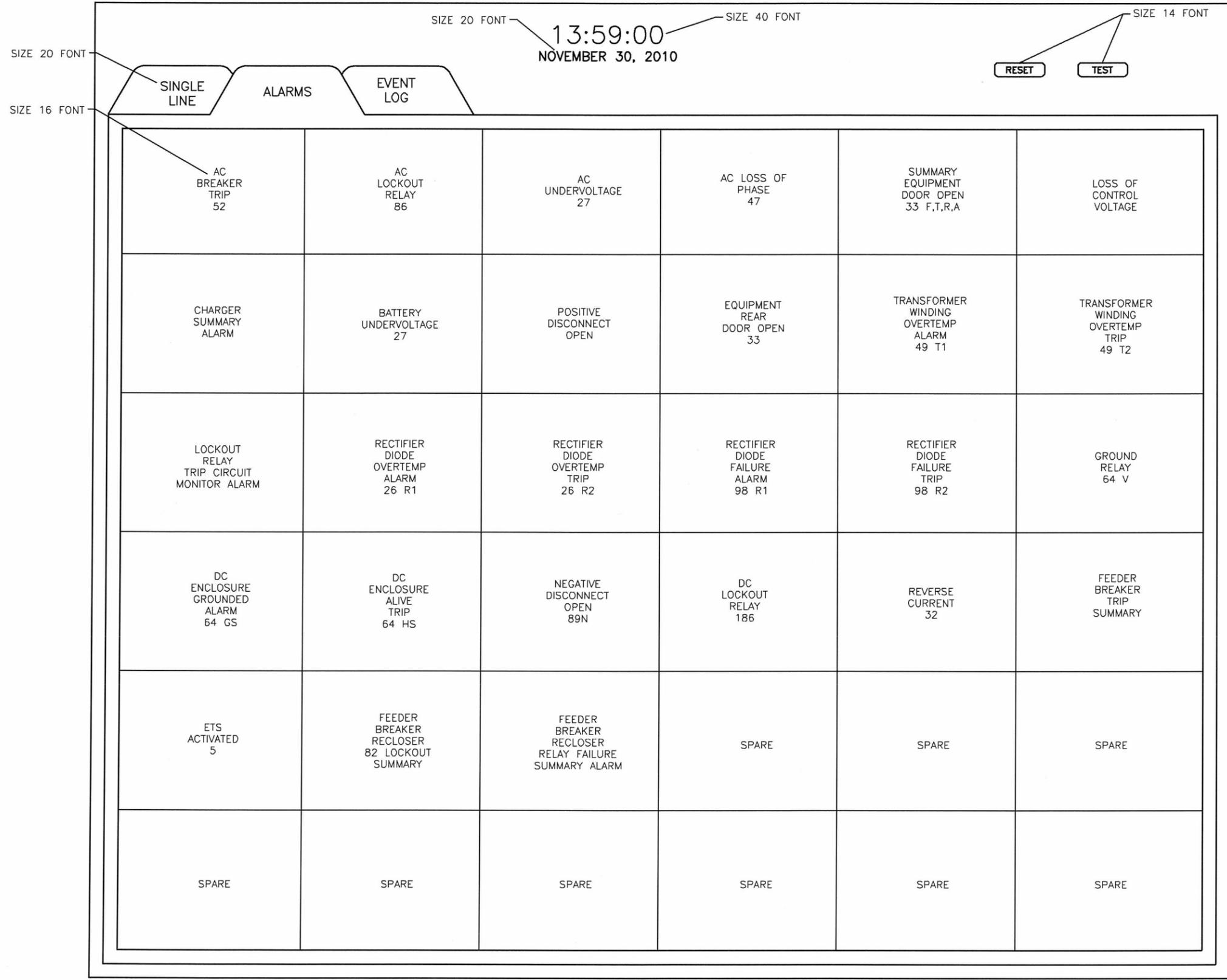
City of Seattle
Seattle Department of Transportation

ORDINANCE NO. APPROVED
 FUND: INSPECTOR'S BOOK

**FIRST HILL STREETCAR
 TRACTION POWER SUBSTATIONS**

NO.	PC	TS4580B
R/W		
CO	TS4580B	
VAULT PLAN NO. 774-721		
SHEET	26	28

P:\Projects\B-Current\Projects\C3814_SDOT_FHSC\CAD\10 Sheets\1000 Procurement\JP41-TYPICAL_TPSS_HMI\ONE_SCREEN_LAYOUT.dwg
 DATE: 10/07/2011 10:47am
 NATURE: REVISIONS
 MADE: CHK'D REVD
 35474



- NOTES:
1. REFER TO CONTRACT SPECIFICATIONS FOR DETAILED REQUIREMENTS.
 2. 36 POINTS REQUIRED.
 3. TOUCH WINDOW TO ACKNOWLEDGE ALARMS.

P:\Projects\B-Current\Projects\C3914_SDOT_FHSC\CAD\10_Sheets\100X_Procurement\JP42--TYPICAL_IPSS...
 DATE: 10/27/11
 MARK: []
 NATURE: []
 REVISIONS: []
 NO. 35474

INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

JP42
TYPICAL TPSS ALARM PANEL HMI
SCREEN LAYOUT



APPROVED FOR ADVERTISING
 NANCY LOCKE
 DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
 SEATTLE, WASHINGTON 20
 BY: PURCHASING AND CONTRACTING SERVICES DIRECTOR

NAME OR INITIALS AND DATE	INITIALS AND DATE
DESIGNED ML	REVIEWED: PE CONST.
CHECKED RME	PROJ. MGR.
DRAWN SP	RECEIVED
CHECKED EJR	REVISED AS BUILT

ALL WORK DONE IN ACCORDANCE WITH THE CITY OF SEATTLE STANDARD PLANS AND SPECIFICATIONS AND OTHER DOCUMENTS CALLED FOR IN SECTION 0-02.3 OF THE PROJECT MANUAL.



City of Seattle
Seattle Department of Transportation
 ORDINANCE NO. APPROVED
 FUND: INSPECTOR'S BOOK

FIRST HILL STREETCAR
TRACTION POWER SUBSTATIONS

JOB NO.	PC	TS4580B
R/W		
CO		TS4580B
VAULT PLAN NO.	774-721	
SHEET	27	28

P:\Projects\B-Current\Projects\3814_SDOT_FHSC\CA0\10_Sheets\1000x_Procurement\JP43-TYPICAL_TPSS_10-17-11.dwg
 10-17-11
 WAJENSEN (dmg)
 35474
 DATE MARK
 NATURE REVISIONS
 MADE CHKD REVD

SIZE 20 FONT
SIZE 20 FONT
SIZE 40 FONT
SIZE 14 FONT

13:59:00

NOVEMBER 30, 2010

SINGLE LINE
ALARMS
EVENT LOG

EXPORT
PRINT

NO.	EVENT	DESCRIPTION	TIME	STATUS
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

NOTES:
 1. REFER TO CONTRACT SPECIFICATIONS FOR DETAILED REQUIREMENTS.

INVITATION TO BID # SDOT-300 OCTOBER 10, 2011

JP43
 TYPICAL TPSS ALARM PANEL HMI EVENT LOG
 SCREEN LAYOUT



APPROVED FOR ADVERTISING
 NANCY LOCKE
 DEPARTMENT OF FINANCE & ADMINISTRATIVE SERVICES
 SEATTLE, WASHINGTON 20

BY: PURCHASING AND CONTRACTING SERVICES DIRECTOR

NAME OR INITIALS AND DATE DESIGNED ML CHECKED RME DRAWN SP CHECKED EJR	INITIALS AND DATE REVIEWED: PE CONST. PROJ. MGR. RECEIVED REVISED AS BUILT
--	--

ALL WORK DONE IN ACCORDANCE WITH THE CITY OF SEATTLE STANDARD PLANS AND SPECIFICATIONS AND OTHER DOCUMENTS CALLED FOR IN SECTION 0-02.3 OF THE PROJECT MANUAL.



City of Seattle
Seattle Department of Transportation
 APPROVED
 INSPECTOR'S BOOK

FIRST HILL STREETCAR TRACTION POWER SUBSTATIONS

NO.	PC	TS4580B
JOB NO.	R/W	
	CO	TS4580B
	VAULT PLAN NO.	774-721
SHEET	28	28