SECTION E2

SELLER FURNISHED CONTROLS, WIRING AND RACEWAY

1. GENERAL: This Specification details the requirements for Seller furnished wiring and package control systems supplied with Seller furnished equipment when specified. Typical electrical parameters for Seller supplied equipment and controls are as follows:

1.1 All critical DC electrical control devices requiring reliable power from an external DC source shall be designed for continuous operation on an ungrounded station battery at any voltage from 90 to 140 VDC. Electrical devices served from this supply shall not impose any ground connections on it.

1.2 All AC electrical control devices shall, unless otherwise specified, be designed to operate satisfactorily under the conditions listed below:

AC Control Devices Operating Conditions	
120 VAC supply voltage variation	+/- 10%
AC Frequency variation	+/- 5%
Dropout voltage for relays	< 75 V
Dropout voltage for contactors and starters	< 90 V

Alternating current electrical control devices operating at nominal voltages other than 120 V shall be designed for continuous operation over proportional voltage variations.

1.3 All devices shall be guaranteed to operate satisfactorily under voltage conditions specified in the above paragraphs and at minimum/maximum ambient temperature or minimum/maximum indoor temperature (if devices are furnished indoors), whichever is greater, as specified in Section GR-A – General Description and Scope of Work.

1.4 All electrical equipment shall be designed and manufactured to meet seismic requirements as specified in Section S1 – Structural Loading and Design.

1.5 All electrical connections and contact between dissimilar metals shall be made using only connectors and components listed and specifically intended for such use.

2. AUXILIARY POWER: Auxiliary Equipment, such as motors, transformers, panels, and rectifiers, requiring electrical power shall be designed to operate from one of the nominal electrical power sources as follows:

Volts	Phase	Hertz
13800	3	60
6900	3	60
480	3	60
208	3	60

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208	1	60
120	1	60
125	DC	DC

Terminations quantity and size shall be provided as indicated for all incoming 480V,6900V power feeds:

600V Cable Termination Requirements:

Main Disconnect Rating or Motor FLA * 125% (Amp min – Amp max)	QTY of Terminations per Phase	Cable Size per Phase	KAIC Rating
≤20A	1	#12 AWG	85kAIC – 480VAC 22kAIC – 120VAC 42kAIC – 125VDC
>20-30	1	#10 AWG	
>30 - 45A	1	#8 AWG	
>45 – 60A	1	#6 AWG	
>60 – 70A	1	#4 AWG	
>70 – 100A	1	#2 AWG	
>125 – 190A	1	#1 AWG	
>190 – 250A	1	350 kCMIL	
>250 – 300A	1	500kCMIL	
>300A	2	Subject to Buyer's approval during shop drawing reviews	

8000V Cable Termination Requirements:

Main Disconnect Rating (Amp min – Amp max)	QTY of Terminations per Phase	Cable Size per Phase	KAIC Rating
≤100	1	#2 AWG	50kAIC
>100 – 130	1	#1/0 AWG	
>130 – 150	1	#2/0 AWG	
>150 – 190	1	#4/0 AWG	
>190 – 240	1	350 kCMIL	
>240 – 290	1	500 kCMIL	
>290	2	Subject to Buyer's approval during shop drawing reviews	

15000V Cable Termination Requirements:

Main Disconnect Rating (Amp min – Amp max)	QTY of Terminations per Phase	Cable Size per Phase	KAIC Rating
≤100A	1	#2 AWG	50kAIC

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>100 – 130	1	#1/0 AWG	
>130 – 150	1	#2/0 AWG	
>150 – 190	1	#4/0 AWG	
>190 – 240	1	350 kCMIL	
>240 – 300	1	500 kCMIL	
>300	2	Subject to Buyer's approval during shop drawing reviews	

2.1 Motors shall be furnished in accordance with the requirement of Section E1 "Motors."

2.2 Emergency motors shall be designed to operate from a nominal 125 VDC supply. Direct current motors shall be capable of continuous operation at any terminal voltage from 90 to 140 VDC.

3. RACEWAY: Unless specified otherwise, all raceway provided by the Seller for interconnection between devices, panels, boxes, and fittings shall be UL listed and conform to the following requirements. All conduit connections shall be of the threaded type. Unless specified otherwise, all exposed conduit shall be galvanized rigid conduit or rigid aluminum conduit. Conduit embedded in a concrete floor shall be hot-dipped galvanized rigid steel conduit, which shall conform to ANSI C80.1, "Rigid Steel Conduit-Zinc Coated." Fittings for rigid steel conduits shall be steel or malleable iron, except for insulated bushings, and such metal fittings shall be either electro-galvanized, or cadmium plated. Fittings shall comply with the latest ANSI Standard C80.4, "Fittings for Rigid Metal Conduit and Electrical Metallic Tubing." Rigid steel conduits shall be bent to the radii in accordance with the NEC or manufacturer's recommendation.. Conduits entering enclosures shall enter either from the side or bottom where possible. All conduits entering a cable tray shall be from above and sloped downwards to prevent water intrusions. Top entries in outdoor areas are not allowed. All conduit entering outdoor enclosures shall enter through hubs or threaded openings. All conduits shall be sized in accordance with the number and total area of cables that they contain using the National Electric Code. Minimum conduit size shall be ¾" for exposed and 1" for embedded. Flexible conduit of 1/2" shall be allowed for instruments or devices requiring a 1/2" connection. Embedded conduit shall be any localized below grade conduit installed in dedicated routes from stub-up to stub-up. Vertical and horizontal conduit elbows shall have a 24" radius, though smaller radius elbows radius may be used if a pulling tension calculation is performed to ensure cable will not be damaged during pulling. Embedded conduits for use in applications other than roadway lighting applications shall consist of RGS materials throughout. Embedded conduit risers not stubbing up under a pull box shall consist of a RGS elbow, vertical section of RGS and GRC coupling or ground bushing exiting through concrete. Embedded conduit risers stubbing up under a pull box, cable tray, or electrical enclosure will terminate in an end bell. Horizontal runs of embedded conduits will not be encased withing foundation slabs, but buried beneath and parallel to the surface of the slab; horizontal portions and vertical elbows of embedded conduits will be concrete encased, and risers will be embedded within the slabs. Embedded conduits used in roadway lighting designs will be direct buried PVC conduits with direct routes from pole to pole. Conduit stub ups shall be under the Equipment intended. Conduit in hazardous areas shall be supplied with fittings and seals suitable for the hazard encountered.

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3.1 Conduit Materials: Electrical conduit and associated materials shall conform to the requirements of the articles which follow.

3.1.1 Galvanized Rigid Conduit (GRC): Steel conduit, couplings, and elbows shall be hot-dip galvanized rigid steel in accordance with ANSI C80.l and UL 6. The conduit interior and exterior surfaces shall have a continuous zinc coating with a transparent overcoat of enamel, lacquer, or zinc chromate. Fittings for rigid steel conduits shall be steel or malleable iron, except for insulated bushings, and such metal fittings shall be either electrogalvanized, or cadmium plated.

3.1.2 Rigid Aluminum Conduit (RAC): Aluminum conduit, couplings, and elbows shall be rigid aluminum in accordance with ANSI C80.5 and UL 6A.

3.1.3 Rigid Polyvinyl Chloride Conduit (PVC): Plastic conduit shall be schedule 40 (PVC40) or schedule 80 (PVC80) and shall be used with PVC fittings in accordance with NEMA TC 2 & 3 and UL 651. Each length of conduit shall be furnished with one standard bell end. Joints shall be made with solvent cement. All additional conduit couplings, factory bends, plastic-to-steel conduit adapters, solvent cement, and special fittings for the complete conduit systems shall be included. Couplings shall have a center stop to ensure proper seating. PVC conduit used outdoors shall be schedule 80 and ultraviolet resistant. No PVC installations will be allowed above grade, except PVC80 as dictated by corrosive environments and as indicated on the project drawings. Conduits in highly corrosive areas shall be PVC coated rigid steel. PVC conduits shall be Schedule 40 for use in concrete encased duct banks.

3.1.4 Liquid Tight Flexible Conduit (LFMC): All flexible conduit and fittings shall be UL (ULC) listed, plastic jacketed, galvanized steel. Sealtite Type UA shall be used for general service areas 60°C/140°F or below; for specific high temperatures locations above 60°C/140°F Sealtite Type HTUA shall be used. LFMC shall be limited to trade sizes of 1/2" through 4” and be suitable for hazardous Class 1 Division 2 and Class 2 Divisions 1 and 2 environments.

3.1.5 Connections to all motors and other Equipment subject to vibration, thermal movement, or requiring the flexibility to be moved aside during maintenance shall be made with UL listed liquid-tight flexible metallic conduit with proper end fittings. The length of liquid-tight flexible conduit will be limited to a maximum of 6 feet.

3.1.6 Seal tight flexible conduit shall be installed per the NEC with external copper ground conductor where required.

3.1.7 Conduits for structures pumping water shall be aluminum or PVC coated rigid steel.

3.1.8 All outdoor exposed conduits shall be aluminum or rigid steel, hot-dipped galvanized inside and outside.

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3.1.9 All signal level cables installed in underground duct shall be in rigid galvanized steel conduits. There shall be an independent raceway system for the telephone/communications/fiber optic systems.

3.2 Grounding type bushings shall be provided on all conduit containing power circuits and on all conduit on Equipment to be located in hazardous areas. Hazardous areas shall be as defined by the National Electrical Safety Code (NESC) and the National Electrical Code (NEC). Standard bushings shall be galvanized.

3.3 All outdoor exposed conduit shall be aluminum or rigid steel, hot-dipped galvanized inside and outside.

3.4 All outdoor exposed conduit shall have low point conduit drains.

3.5 Use of thinwall EMT conduit shall be limited to indoor concealed areas in walls and ceilings typically for lighting and convenience outlets.

3.6 Conduit fittings used on outdoor Equipment shall be sealed and gasketed. Conduit seals shall be provided as required based on the hazardous area classification of the equipment.

3.7 A run of conduit shall not contain more than the equivalent of four 90 degree bends, including those immediately at outlets and fittings. All duct banks shall have a minimum slope of 0.25 percent and arranged to drain towards manholes. Bends in conduit shall be made without reducing the internal diameter of the conduit. Duct banks shall use bends with 36” radius sweeps to minimize pulling tensions. Where conduits are larger than 4”, 48” radius sweeps may be required. Minimum of 20% of each voltage segregation type shall be incorporated into design of the main duct bank sections, which is defined as the duct bank from building to building, building to manhole/vault, or manhole/vault to manhole/vault. This design shall be reflected in the Issued for Construction (IFC) revision 0 duct bank design drawings.

3.8 All conduit runs shall be rigidly supported within the requirements of the NEC. Each conduit shall be supported within the NEC required distance of junction boxes and fittings. Piping shall not be utilized for conduit support.

3.9 Moisture pockets shall be eliminated from conduits. Conduit in wet locations shall have provisions for moisture drainage (e.g., conduit “tee” fittings with bottom breather/drains at low points and panel entries). All outdoor exposed conduit shall have low point conduit drains.

3.10 Conduit shall have the minimum separation distances listed below:

Separation between above grade conduits:

Level	400	300	200	1XX
400	0	3”	12”	12”
300	3”	0	3”	6”
200	12”	3”	0	1”
1XX	12”	6”	1”	0

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3.10.1 Circuit/Cable Level Definitions:

a. Level 400 - Instrumentation
   1. Includes circuits for analog 4-20mA devices, pulse signals, digital I/O less than 48VDC, thermocouples, and RTD's
   2. Cables will be shielded twisted pairs or shielded triad
   3. Cables will be routed in level 400 raceway or tray

b. Level 300 - Control
   1. Includes circuits for 120VAC control, >48VDC control, 120/208VAC power circuit less than 5A (may be level 200), potential and current transformer secondaries
   2. Cables will be multiconductor, and cable may be shielded if required
   3. Cable will be routed in level 300 raceway or tray

c. Level 200 - Power ≤600V
   1. Includes power circuits ≤600V (AC or DC)
   2. Cables will be routed in level 200 raceway or tray

d. Level 100 - Power > 600V and ≤ 35kV
   1. Includes medium voltage power cables ≤35kV and greater than 600V
   2. Cables will be routed in level 100 raceway or tray (105 for 5kV, 115 for 15kV, etc.)

3.11 The raceway system provided for all interconnecting wiring shall be acceptable to the Engineer.

4. ELECTRICAL ENCLOSURES: Area classifications shall be in accordance with NEC.

4.1 Electrical enclosures shall be NEMA type and shall be selected based on the installation environment as follows:

NEMA Enclosure Type	Environment/Location
NEMA 1	Indoor, conditioned locations
NEMA 12	Indoor, unconditioned locations
NEMA 3R	Indoor/Outdoor, weather protection, dripping water
NEMA 4	Indoor/Outdoor, wet locations, windblown dust, pressurized streams of water
NEMA 4X	All corrosive locations
NEMA 7	Indoor, hazardous locations Class I, Division 1, Group A, B, C or D
NEMA 8	Indoor/Outdoor, hazardous locations Class I, Division 1, Group A, B, C, or D
NEMA 9	Indoor, hazardous locations Class II, Division 1, Group E, F or G

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NEMA Z-Purge	Indoor/Outdoor, Division 2 hazardous locations

Note: Enclosures containing non-arcing devices (Hermetically sealed contacts, terminals, etc.) may be NEMA 12 or 4X in Class I, Division 2 areas.

4.2 All metal electrical enclosures with hinged doors and electrical devices mounted on the door face shall have a grounding stud provided on the enclosure door with a door bonding jumper installed.

4.3 All electrical enclosures shall be provided with a nameplate in accordance with the requirements of Section GR-A.

4.4 Access and working clearance in front of all enclosures shall be provided and maintained per NEC Article 110. All clearances provided shall be indicated on design drawings.

4.5 All conduit penetrations and connections shall be sized to accept standard conduit trade sizes per the NEC.

5. JUNCTION BOXES AND PULL BOXES: Junction boxes and pull boxes shall be in accordance with the requirements of NEC, Article 314, and shall be furnished without knockouts.

5.1 All junction boxes and pull boxes shall be provided with a nameplate in accordance with the requirements of Section GR-A.

5.2 All junction boxes or pull boxes 4” trade size or smaller in any dimension shall be galvanized malleable iron, fiberglass, aluminum, stainless steel, cast ferrous metal, or acceptable equal with gasketed cover plate.

5.3 All junction boxes and pull boxes larger than 4” trade size in all dimensions for use in indoor locations shall be sheet steel hot-dip galvanized after fabrication or fiberglass, and those for use in outdoor or damp locations shall be galvanized malleable iron, fiberglass, aluminum, stainless steel or acceptable equal cast ferrous metal, sheet steel hot-dip galvanized after fabrication, or sheet steel epoxy coated inside and outside after fabrication. Gasketed covers shall be provided.

5.4 Access and working clearance in front of all junction boxes shall be provided and maintained per NEC Article 110. All clearances provided shall be indicated on design drawings.

5.5 Junction and pull boxes shall conform to UL Standard UL 50. Galvanized coatings for steel boxes shall conform to ASTM A 525 designation G90 for dry locations and G210 for wet and outdoor locations.

6. CONTROL PANELS: This Article covers the design, fabrication, and installation of floor mounted, wall mounted, or skid mounted control panels.

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6.1 Control panels shall meet applicable requirements of NEMA as defined in this Section and shall be provided with NEMA enclosure type as specified.

6.2 Panels shall be of all welded steel construction. Exterior surfaces shall be smooth and free of defects and imperfections. All welds shall be ground smooth. Exposed edges, corners, and edges of cutouts shall be smooth and rounded.

6.3 Control panel doors taller than 36" shall be provided with full length piano type hinges and three-point latching system fasteners with stainless steel locking handles. The locks shall be keyed alike. Panel doors 36" and shorter shall use stainless steel door clamps on three sides and have padlock hasps. Control panel doors shall be the double swing half type.

6.4 Control panel doors shall be provided with a grounding bond jumper to the panel enclosure.

6.5 Braces and stiffening members shall be provided as required to prevent any panel distortion. Braces and stiffeners shall not interfere with instrument locations.

6.6 Panel tubing and wiring shall be neatly routed and supported and shall not block access to instruments or devices. Tubing and wiring shall be terminated on tubing terminal plates or terminal strips, respectively. A minimum of 20% spare terminals shall be provided. All components shall be properly marked.

6.7 All control panels shall be provided with a nameplate in accordance with the requirements of Section GR-A

6.8 Free-standing panels shall be provided with internal LED lighting fixture and door switch, and (1) 120 VAC duplex GFCIR electrical outlet. Internal lighting fixture and GFCIR shall be wired to a junction box and fed from a separate external circuit.

6.9 Ground fault circuit interrupting receptacles (GFCIR) shall be self-contained units manufactured for installation in conventional outlet boxes and installed within panel interiors. Each unit shall be designed and tested per UL 943 for a maximum 6 and a minimum 4 milliampere ground-fault trip level. Units shall have the capability of being tested and reset after tripping. Receptacles with ground-fault protection shall be UL listed with the receptacle portion conforming to UL 498. Each GFCIR shall be mounted in an outlet box of adequate size for the receptacle and wiring.

6.10 Panels shall be heated, ventilated, or air-conditioned as required to prevent overheating and moisture condensation. These devices shall be fed from a separate external power circuit.

6.11 Panels shall be designed to prevent overheating and moisture condensation. Panels located in areas subject to temperature variation shall be provided with thermostatically controlled condensation heaters.

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6.12 Control panels shall be cleaned, primed, and finish painted with the Seller's standard painting system. Interiors of the panels shall be white.

6.13 Internal swing panels are not allowed in floor standing enclosures.

6.14 Access and working clearance in front of all control panels shall be provided and maintained per NEC Article 110. All clearances provided shall be indicated on design drawings. Control panels shall be readily accessible, in accordance with the definition set forth in NEC Article 100. Seller shall coordinate with Buyer on panel height and location to support access requirements.

6.15 All panel assemblies shall be furnished completely wired. With the exception of control and ac power buses, all other control wiring for extension to remote equipment or for interconnection between compartments shall terminate at terminal blocks.

6.16 Connections between shipping sections shall be arranged to require a minimum of field wiring. Terminal blocks shall be provided on one side of a shipping break, and coiled wires, properly tagged, shall be provided on the other side to facilitate these connections.

7. CLASSIFICATION IDENTIFICATION OF ELECTRICAL EQUIPMENT IN HAZARDOUS AREAS: All electrical Equipment and devices located in areas subject to conditions classified in the National Electrical Safety Code and the National Electrical Code as hazardous shall be furnished with a nameplate stating the Equipment classification. The nameplate data shall include the class, group, division, and operating temperature and "T-Rating" designations as applicable, and the NEMA type. Classification identification nameplates and attachment pins shall be corrosion-resistant metal. Tags located outdoors shall be stainless steel.

8. WIRING: In general, all Equipment and devices furnished under these Specifications and requiring electrical connections shall be designed for wiring into electrical enclosures with terminal blocks. All Seller provided wiring shall be installed in a raceway acceptable to the Engineer. Terminal blocks shall be furnished for conductors requiring connection to circuits external to the specified Equipment, for internal circuits crossing shipping splits, and where Equipment parts replacement and maintenance will be facilitated. The Seller must comply with the terminal connectors to power the equipment as indicated in drawings reviewed by the engineer.

8.1 Splicing of cables in raceway is not allowed. No splices of any cables except for heat trace, lighting cables, and cathodic protection shall be allowed.

8.2 Internal panel wiring shall be accomplished in a neat and orderly manner. Where practicable, wiring trough or gutter with readily removable covers shall be used, and any two or more wires run together outside of trough shall be clamped or tied in straight lay bundles at approximately 15" intervals. Ties or clamps shall be nonmetallic. Wiring shall be arranged so as to be readily accessible for inspection and maintenance, and in no case shall wiring arrangement impede access to panel mounted devices or spaces for future Equipment. All cables shall be

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identified with a permanent tag securely affixed to the cable termination point. Except as otherwise proved in standard supplied packages, a maximum of 12 wires shall be in a bundle in order to facilitate tracing of wires. Wiring clamps and supports at hinge transition points shall be properly sized to prevent chafing of insulation when the cubicle door is opened and closed. Metal clamps must have insulating inserts between the clamps and wiring. Nonmetallic clamps are preferred.

8.3 Circuit/Cable tagging shall include the circuit number at minimum for all cables provided and installed by Seller. Multi-conductor control and instrumentation cables shall include a circuit number tag on the main "trunk" and individual wire tags including circuit number and wire color/number as appropriate for multiple pairs. (e.g. 3BK, 5BK, etc.) The cable tag shall be visible from cabinet or panel opening.

8.4 Hinge wiring applications shall utilize Class K, stranded tinned copper switchboard fand breaking. The hinge wire shall be protected by a spiral wrap or tape.

8.5 All switchgear assemblies shall be furnished completely wired. With the exception of control and AC power buses, all other alarm and control wiring for extension to remote Equipment or for interconnection between compartments shall terminate at terminal blocks.

8.6 Wiring shall be neatly arranged and clamped securely to panels to prevent movement. Except as otherwise proved in standard supplied packages, a maximum of 12 wires shall be in a bundle in order to facilitate tracing of wires. Wiring clamps and supports at hinge transition points shall be properly sized to prevent chafing of insulation when the cubicle door is opened and closed. Metal clamps must have insulating inserts between the clamps and wiring. Nonmetallic clamps are preferred.

8.7 All connections to panel mounted Equipment shall be made on one side of the terminal blocks, and no more than one wire plus one jumper shall be connected to any one terminal point.

8.8 All wiring leaving an enclosure shall leave from terminal blocks and not from other devices in the enclosure. Terminal blocks for external connections shall be grouped and identified for Customer use.

8.9 Terminal blocks for each of the following signal types shall be separate from one another: instrument transformer (CT and VT) circuits; 120 VAC and 125 VDC power supply circuits; analog low voltage instrument circuits; and control circuits.

8.10 All electrical cables shall be selected for the electrical and environment conditions of the installation. Oil-resistant and proper temperature application cable shall be used throughout. Except where required to be otherwise to perform satisfactorily in the service, all electrical conductors shall be Class B, stranded tinned copper switchboard wire, 16 AWG or larger with flame retardant cross link polyethylene (FRXLPE). Thermoplastic (THHN/THWN), PVC and asbestos insulations or coverings are not acceptable.

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8.11 General service wiring integral to the Equipment furnished but not part of the internal wiring of control cabinets or panels, shall be as follows.

8.11.1 Power cables shall be rated for the maximum service voltage, but not less than 600V.

8.11.2 Control cables shall be rated for the maximum service voltage, but not less than 600V.

8.11.3 Instrument cables shall be rated for the maximum service voltage, but not less than 300V.

8.11.4 All thermocouple wire shall be solid conductor with twisted and shielded conductor pairs with a minimum twist frequency of 2 inches. Insulation shall be color coded in accordance with the requirements of ASTM E230. These requirements also apply to thermocouple extension wire which is furnished internal to Seller-furnished Equipment. The shield wire for each thermocouple furnished for external connections shall be terminated on an ungrounded terminal, each being a separate terminal for each thermocouple.

8.11.5 Cable design shall be as follows:

Cable Type	Conductors	Insulation	Jacket (flame retardant)	Shield/Ground
5kV Cable	Copper, Class B stranded per ASTM B8, annealed per ASTM B3	Ethylene-propylene-rubber (EPR), 115 mils minimum 133% insulation level	Thermosetting CPE per NEC and UL listed as type MV-105 suitable for use in cable tray and suitable for wet locations. Flame and ultraviolet retardant.	Conductor/Insulation shield - Extruded semi-conducting thermosetting compound Metallic insulation shield- Uncoated copper tape, minimum 25% overlap
600V Power Cable	Copper, Class B stranded per ASTM B8, annealed per ASTM B3, minimum No. 10 AWG	Ethylene-propylene-rubber (EPR), or Cross-linked polyethylene (XLPE), 90°C	Thermosetting CPE per NEC and UL listed as type TC suitable for use in cable tray and suitable for wet locations. Flame and ultraviolet retardant.	
2kV VFD Power Cable	Copper, Class B stranded per ASTM B8, annealed per	Cross-Linked Polyethylene	Thermosetting CPE per NEC and UL listed as	Overall shield

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	ASTM B3, minimum No. 10 AWG	(XLPE) or Ethylene-propylene-rubber (EPR), 90°C	type TC and suitable for wet locations. Flame and ultraviolet retardant.	Ground – Three symmetrical insulated ground
600V Control Cable	Class B stranded bare or tinned coated soft annealed copper per ASTM B-3 or B-33 conforming to ASTM B-8, 16 AWG	Cross-Linked Polyethylene (XLPE) or Ethylene Propylene Rubber (EPR)	Chlorinated Polyethylene (CPE)	
600V Instrument Cable	Soft drawn tinned copper per Class B per ASTM B33, stranding per ASTM B3	Cross-Linked Polyethylene (XLPE) or Ethylene Propylene Rubber (EPR)	Thermosetting CPE and UL listed as Type TC	Each pair individually shielded, with overall shield of 1.5 mil aluminum or copper-mylar laminate tape for multi-pair/triad cables One Drain wire per pair or triad
Thermocouple Cable	ANSI Type E, chromel-constantan, Type K, chromel-alumel and Type T, copper-constantan, No. 18 AWG	Cross-Linked Polyethylene (XLPE)	Chlorinated Polyethylene (CPE)	Each pair individually shielded, overall shield is aluminum or copper-mylar laminate tape

8.11.6 All of the above cable shall conform to, and Equipment tests shall be conducted in accordance with, the latest applicable standards of American National Standards Institute (ANSI), Underwriters' Laboratories (UL), the Insulated Cable Engineers Association (ICEA), the Institute of Electrical and Electronics Engineers (IEEE), and the National Electrical Manufacturer's Association (NEMA), unless otherwise stated herein.

8.11.7 All cables shall meet or exceed flame test requirements of IEEE 1202.

8.11.8 All cable shall be "sunlight resistant" and for use in cable trays and wet locations.

8.11.9 Cable with PVC is not allowed in the control room or other normally occupied areas.

8.11.10 Instrumentation and thermocouple cable shall be twisted-shielded with a minimum twist frequency of 2 inches.

8.11.11 Potential transformer leads shall be 10 AWG minimum and current transformer leads

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shall be No. 8 AWG minimum.

8.11.12 All control and instrument leads for the external connections shall be brought out to terminal blocks mounted in terminal boxes, control boards, or panel in an accessible location, including all spare contacts.

8.11.13 Cable shall be identified with identification markers at both ends after cables have been permanently routed, positioned and connected.

8.12 Control conductor terminal connectors for screw type terminals shall be solid ring type connectors with solid barrel type lugs and shall be properly sized for the conductor and the terminal except for DCS I/O cabinets and PLCs, which at these devices' compression connections may be used. The connectors shall be constructed of copper and shall be tin-plated.

8.13 TERMINAL BLOCKS: Terminal blocks shall be rated 600 volt, 20 amps. A permanent marking strip, identified in accordance with Contractor's wiring diagrams, shall be furnished on each terminal block. At least 20% (two on 12-point terminal block) spare terminal points shall be furnished. Terminal blocks shall be States Type NT M-25012. If the installation requires horizontal mounting, the shall be oriented so that the link slides up to open. Terminal blocks shall be industrial duty, barriered or touch safe, and shall be furnished with white marking strips and, where permitted by the safety codes and standards, shall be without covers. Not less than 20% spare terminals shall be furnished. The number of conductors shall be well-suited to have at least 2 wires at the customer side and one at the seller side. The clamping unit inside the terminal block shall secure the wire by spring clamp or positive screwing system. The clamping force shall remain constant over the lifetime of the terminal block and shall not diminish due to expansion and contraction of the terminal or cable material caused by temperature cycle or load cycle. Wire termination and removal shall not require special tools. All terminal blocks for external control wiring shall be rated for 600V, 20A minimum and be suitable for #10 AWG and smaller 600V insulated conductors.

8.13.1 Each terminal block, terminal, conductor, relay, breaker, fuse block, and other auxiliary device shall be permanently labeled to coincide with the identification indicated on the drawings. All terminals provided for termination of external circuits shall be identified by inscribing circuit designations acceptable to the Engineer on the terminal block marking strips with indelible black ink. Terminating a conductor shall include installing cable prefabricated termination kits for shielded cable, attaching the conductor at its designated location, and insulating the entire connection where specified or required by the application. Care will be taken to extend the continuity of the cable pair shields in all field junction boxes. At points of field termination, pair shields, and drain wires will remain on the pair as close to the termination point as is practical. Shields will be permanently taped to prevent unraveling and the drain wires will have insulating sleeves installed up to the point of termination.

8.13.2 Larger Power Wiring: All terminal blocks or lugs for larger power wiring shall be rated for the maximum service voltage, but not less than 600 V.

8.13.3 Control, Instrumentation, and Small Power (20A or less) wiring: All terminal

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blocks for external control wiring rated for 600 V, 20 A minimum shall have terminals suitable for solid and standard wire size 28-10 AWG, and 600 V insulated conductors. Terminal blocks shall be Phoenix spring-cage connection type ST 4-TWIN (3031393) or engineer approved equal. Only one ground connection shall be provided for each instrument circuit. Ground connection for shield wiring shall be of the power source.

8.13.4 All power wiring internal to panels shall be 600V, No. 10 AWG minimum. Power cable #8 AWG and larger shall have copper conductors, with 90°C, heat, moisture, and flame-resistant ethylene-propylene-rubber (EPR) or FR-XLPE insulation and CPE jacket. The EPR insulation shall meet the physical and electrical requirements for Type I insulation as designated in ICEA S-68-516, Sections 3.6.1 and 3.6.2. Power cable internal to panels which is #10 AWG shall be Type SIS with copper conductors and Class D stranding. All wiring internal to panels shall be capable of passing the flame test requirements of UL 44, Section 56 or IEEE 1202. All 480V wiring shall be segregated from other control wiring and low voltage devices for personnel safety by means of an insulated barrier or other means.

8.13.5 Thermocouple Wiring: All terminal blocks shall be Phoenix screw type MTKD series fitting 4 connections, 1A current, 400V, with a 24-12 AWG maximum or engineer approved equal standard type of terminal block suitable for thermocouples.

a. Type E: MTKD-NICR/CUNI (3100075), EX (3100076)
b. Type J: MTKD-FE/CUNI (3100046), EX (3100047)
c. Type K: MTKD-NICR/NI (3100062), EX (3100063)

8.13.6 Current Transformer Wiring: All terminal blocks shall be GE EB-25/26/27 shorting type or engineer approved equal.

a. Shorting Terminal Block GE EB-25/26/27: Terminal blocks can have 4, 6, or 12 connections, fits wire sizes of 10-32 AWG maximum, and has screw connections.

8.13.7 DCS: Each terminal block, terminal, conductor, relay, breaker, fuse block, and other auxiliary device shall be permanently labeled to coincide with the identification indicated on the drawings. All terminals provided for termination of external circuits shall be identified by inscribing circuit designations acceptable to the Engineer on the terminal block marking strips with indelible black ink. Terminating a conductor shall include installing cable prefabricated termination kits for shielded cable, attaching the conductor at its designated location, and insulating the entire connection where specified or required by the application. Care will be taken to extend the continuity of the cable pair shields in all field junction boxes. All analog and digital points shall be wired to terminals for field wiring. At points of field termination, pair shields, and drain wires will remain on the pair as close to the termination point as is practical. Shields will be permanently taped to prevent unraveling and the drain wires will have insulating sleeves installed up to the point of termination. Additional shield ground terminals shall be provided to accommodate the use of multi-pair cables.

8.14 For conductors internal to Equipment, a flame-resistant conductor identification sleeve shall be provided on each end of each conductor. Each sleeve shall be marked with the opposite end destination identification. Wire sleeve shall be visible from cabinet or panel opening.

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8.15 The arrangement of connections on terminal blocks shall be acceptable to the Engineer.

9. TERMINATION OF 600 VOLT POWER CABLE: The capacities of conduit entrances, terminal enclosures, and conductor terminals for 600 V power cable terminations in Equipment furnished under these Specifications shall be as required to accommodate copper phase conductors and copper ground conductors which are sized in accordance with the requirements of this Article. An integral incoming power disconnect sized for at least 125% of the full load current shall be provided for each source of incoming power. Branch circuit breakers shall be sized in accordance with the NEC and shall provide thermal-magnetic over-current protection.

9.1 Safety-type disconnecting switches shall be type "HD", heavy duty. Switches shall be rated at 240 or 600 V as required by the voltage of the circuit on which type are utilized and shall be rated in horsepower. Each switch shall be capable of interrupting the locked rotor current of the motor for which it is to be used, which the current will be assumed as ten times the full rated load current.

9.2 Disconnects shall be of the quick-make, quick-break type, and all parts shall be mounted on insulating bases to permit replacement of any parts from the front of the switch. All current-carrying parts shall be of high-conductivity copper, designed to carry rated load without excessive heating. Switch contacts shall be silver-tungsten type or plated to prevent corrosion, pitting, and oxidation and to assure suitable conductivity. Switch operating mechanisms shall be designed to retain effectiveness with continuous use at rated capacity without the use of auxiliary springs in the current path. Switches shall be capable of withstanding the available fault current or let through current before the fuse operates, without damage or change in rating.

9.3 Fuses shall be UL listed or approved equivalent, rated for 600 V, and dual element type. Fuses shall have a thermal element that restricts the temperature rise and an element of low peak type which limits the let through fault current.

9.4 Disconnects shall be located within panel interiors with operator handles located on panel exteriors. Mechanical interlocks shall be provided to prevent opening panel door when the disconnect handle is in the "ON" position. Disconnect handles shall be provided with padlock provisions. Mechanical interlock shall have defeat mechanism to allow qualified personnel to access while energized.

9.5 If disconnects are furnished for locations remote from control panels, the disconnect enclosure shall be suitable for the environment and meet the requirements included in this Specification. Remote mounted disconnects shall have engraved nameplates.

9.6 Conduit Entrances and Terminal Enclosure. The capacities of conduit entrances and terminal enclosures for phase conductors shall be as required for conductors sized in accordance with this document.

9.7 Compression type, double indent, two-hole copper lugs will be used for all power cables. Power cables rated 600V and smaller than #6 AWG will use one-hole lugs for termination.

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Mechanical terminations require Engineer Approval prior to use. Wiring Shall be terminated using compression-type, ring-tongue terminals, which firmly grip the conductor shall be used for current transformer and potential transformer cable terminations only. Other termination types may be allowed on equipment where the manufacturer's standard design does not allow for ring tongue terminations. Connectors shall be ABB Sta-Kon or Owner approved equal. Both ends and at each terminating point of each wire shall be uniquely identified with permanent, heat shrinkable wire markers (125°C rated) (TE Connectivity Raychem Thermofit) or other Owner approved permanent marker using indelible printing, with sleeve with black lettering. Adhesive wire labels are not acceptable.

10. CONTROL PANEL EQUIPMENT AND DEVICES: As a minimum, Seller supplied control panel Equipment and devices shall conform to these requirements.

10.1 Relays: Auxiliary control relays shall be in accordance with NEMA ICS and shall be plug in, octal base type with contact ratings found herein. Relays shall have a minimum of two Form C contacts. All relays shall have 120 V, 60 hertz AC operating coils unless otherwise required by system design. Plug-in relays shall be provided with hold-down clips.

10.2 Control Switches: Control switches shall be 600 V, 20 ampere, multistage, rotary type with a minimum of 10 contacts. Control switch contacts for engineered systems shall be dual rated for AC and DC operation. See minimum contact ratings below. Each control switch shall have two (2) 12-point terminal blocks. A permanent marking strip, identified in accordance with Contractor's wiring diagrams, shall be furnished on each terminal block. At least 20 percent (two per 2-point terminal block) spare terminal points shall be furnished.

10.3 Unless otherwise stated in this specification, all auxiliary relays and control switches, shall have the following minimum contact ratings:

Contact Closing Rating:	20 A
Continuous Current Carrying Rating:	10 A continuously
Interrupting Rating:	see tables below

VDC	Non-Inductive Amps	Inductive Amps
6-24	15.0	6.0
48	8.0	3.5
125	3.0	1.0
250	1.0	0.3

VAC	Non-Inductive Amps	Inductive Amps
115	30.0	20.0
230	20.0	10.0
460	8.0	5.0

10.4 Pushbuttons, Selector Switches, Indicating Lights and Pushbutton Stations: Pushbuttons, selector switches, and indicating lights shall be heavy-duty oil-tight and shall be in accordance with NEMA ICS. Contact rating shall be 10 A continuous at 600 V, 60 hertz. Indicating

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lights shall be long-life LED type at a voltage rating appropriate for the application. Units shall be provided complete with contact blocks, legend plates, plastic caps, etc., for a complete installation. Emergency stop pushbuttons shall be of the red mushroom head type.

10.5 Indicating light lens colors shall be coordinated with indicated conditions as specified in the following table. Indicating lights shall be energized when the condition exists and shall be de-energized when the condition does not exist. Both red and green lights shall be energized for valve in intermediate position.

Lens Color	Condition
Red	Equipment in operation, such as motor running, valve open, or breaker closed
Green	Equipment not in operation, such as motor stopped, valve closed, or breaker open
Amber	Status indication, such as power monitoring, trip coil monitoring, test.
White	Equipment abnormality, such as motor trip or breaker trip

10.6 Control Power Transformers: Seller supplied control panels shall be provided with dry type control power transformers to supply all required control voltages which differ from the control panel, single point power input source. Control power transformers shall be adequately sized to supply all required control power plus 50 VA, and have both primary leads and one secondary lead fused. The other secondary side of the control power transformers shall be grounded.

10.7 Power Supplies: Seller supplied control panels requiring DC control voltage or filtered power shall be provided with all necessary power supply Equipment, rectifiers or filters.

10.8 All control wiring internal to panels shall be 600V, Type SIS, No. 14 AWG minimum. Copper conductors with Class D stranding.

11. MOTOR CONTROL: When Seller is required to supply local starters and contactors for control of Seller supplied Equipment, motor controls shall conform to the following minimum requirements:

11.1 Starters and contactors supplied with Seller furnished controls shall be located within Seller's control panels. Magnetic starters and contactors shall have 120 VAC operating coils. Coil power shall be supplied from Seller panel control power transformers provided in accordance with above requirements. Each magnetic starter or contactor shall be provided with line side short circuit protection consisting of a UL approved molded case thermal magnetic circuit breaker or motor circuit protector (MCP). Magnetic starters shall be provided with manual reset electronic solid state overload relays, sized to match motors furnished. Overload relay manual reset shall be operable from panel door. Magnetic starters shall be NEMA rated and selected to match

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the horsepower nameplate of the motors provided. Control transformer leads, starter overload relay contacts, contactor operating coils, and starter auxiliary contacts shall be wired to marked unit terminal blocks.

11.2 Auxiliary contacts shall be provided as required by the Seller's design, plus a minimum of two normally open and two normally closed spare contacts for Buyer's use. Each contactor or starter provided in this Section for motor or Equipment operation shall be provided with the following hard wired functions.

11.2.1 Equipment "running" or "on" indication available for connection to plant DCS.

11.2.2 Ready signal to indicate power is available and the HAND-OFF-AUTO switch is in AUTO for connection to plant DCS.

11.2.3 Overload tripped indication for connection to plant DCS.

11.2.4 When local manual controls are provided as part of an OEM standard, e.g., actuators, drives, self-contained skids, the status of the control selection (local, or remote) shall be transmitted via the BOP DCS to the Control Room in order to inform the operator and to inhibit the automatic control and sequence programs, where appropriate.

11.3 All AC and DC motor starters shall have red and green indicating lights and a HAND-OFF-AUTO switch on its motor control panel door.

11.4 If a motor heater is required by Section E1 or by the drawings, it shall be controlled by an auxiliary contact of the motor starter or low voltage switchgear breaker and shall be energized when the motor is not running. This circuit shall be wired to be fed from an external source separate from the motor starter feeder circuit. Where Seller provides a control panel with motor starter(s), a separate local disconnect shall be provided at the panel for this circuit along with an NEC compliant warning label describing multiple sources of power.

11.5 Variable Frequency Drives: The following describes basic design parameters and criteria for consideration in selection of low voltage variable frequency drive units. VFDs supplied with Seller furnished controls shall be located within Seller's control panels.

11.5.1 Type: Variable Frequency Drives (VFDs) shall be of the ac voltage source, pulse-width modulated (PWM) type. Output devices shall be insulated gate bipolar transistors (IGBT).

11.5.2 Coordination: The design of each VFD shall be coordinated with the design of the driven equipment. The manufacturer of the driven equipment shall be responsible for furnishing the VFD, matching the motor and the drive, and coordinating the collection of data and the design effort to limit harmonics and to assure no problems with mechanical resonant vibrations.

11.5.2.1 VFDs shall be factory pre-wired, assembled, and tested as a complete package by the supplier. Customer specific drive, motor, and application data shall be pre-loaded into the local operator interface, if provided and tested prior to shipment.

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11.5.2.2 VFDs shall be provided with a local HMI for Buyer interface, including digital display, keypad, and port for Buyer's laptop connection. The keypad shall be suitable for local control (start/stop, forward/reverse, speed adjust) and for stepping through displays and menus.

11.5.2.3 Motors shall be specifically selected for service with a variable frequency type speed controller and shall be derated if required to compensate for harmonic heating effects and reduced self-cooling capacity at low-speed operation. Each motor shall be designed to be continuously pulsed at the motor terminal. Motor life expectancy shall not be compromised in any way by operation with a VFD system.

11.5.2.4 Physical Requirements: Each VFD system shall be capable of continuous operation in the specified environmental conditions and shall be air-cooled. Each VFD enclosure shall be provided with a thermostatically controlled space heater or installed in a climate-controlled building.

11.5.3 Design and Performance Parameters: Each VFD shall produce an adjustable ac voltage/frequency output and shall be equipped with an output voltage regulator to maintain correct output volts/hertz, regardless of incoming voltage variations.

11.5.3.1 Each VFD shall produce a quality output waveform for stepless motor control from 10 to 100 percent of base speed.

11.5.3.2 VFDs shall be suitable for either constant torque (CT) or variable torque (VT) loads as required by the driven equipment.

11.5.3.3 VFDs shall be rated to power the motor continuously at the motor's nameplate horsepower multiplied by the service factor. For motors with no service factor showing on the nameplate, VFDs shall be rated at the motor's nameplate horsepower multiplied by 1.15 or as specified by the material contract. Each VFD shall comply with the latest edition of IEEE 519 for total harmonic voltage and current distortion calculation and measurement. IEEE 519 requirements shall be met regardless of motor loading and speed.

11.5.3.4 The system design shall not have any inherent output harmonic resonance in the operating speed range. The VFD/motor/cable system shall be designed to produce no standing waves or over-voltage conditions based on a cable length of 1000 from the VFD to the motor. If the VFD requires an output filter to meet this requirement, it shall be an integral part of the VFD system and included within the VFD enclosure. In addition, the filter shall eliminate any potential harmonic resonance in the operating speed range.

11.5.3.5 The design of the VFDs and associated power circuits shall include provisions for protection against fault conditions including input, internal, and output protection.

11.5.3.6 VFD speed regulation shall be +/- 0.5 percent. The speed accuracy within the specified speed range, expressed as a percent of top speed, shall be within 0.05% of base speed without encoder or pulse tachometer feedback and 0.005% with encoder or pulse tachometer

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feedback.

11.5.3.7 Acceleration/deceleration time shall be adjustable over a range that meets the requirements of the driven equipment.

11.5.3.8 Each VFD shall be controlled from the DCS and shall be provided with communication capability to facilitate control, monitoring, and alarm functions in the DCS, including providing status of key parameters to the DCS for operator monitoring, logging, and trending and other applicable requirements of these specifications.

11.5.4 Low Voltage VFDs. Each low voltage VFD shall meet the following requirements, ratings, and parameters:

Input voltage and frequency	Nominal volts (+/- 10 percent); 3-phase; nominal Hz vccv ch(+/- 2 Hz); unbalance (2 percent maximum).
Minimum VFD efficiency	Guaranteed minimum total isolation transformer/VFD system efficiency (nsys) shall be a minimum 95% at 100% speed & 100% load and minimum 92% at 80% speed & 50% load. Efficiency evaluation shall include harmonic filter and power factor correction (if applicable), VFD converter, and output filter. Auxiliary controls, such as internal VFD control boards, cooling fans, etc., shall be included in all loss calculations
Displacement power factor	VFD shall be capable of maintain a 0.98 minimum true power factor, adjustable between 0.90 lagging to 0.90 leading, from 10% to 100% speed
Controller continuous output current rating	100 percent of motor nameplate current.
Overload capacity	The overload rating of the drive shall be minimum 110% of its normal duty current rating for 1 minute every 10 minutes, 130% overload for 2 second.
Output frequency stability	0.5 percent of nominal.
Total harmonic distortion	Not more than 5% rms under any operation condition.

12. ELECTRICAL DRAWING REQUIREMENTS: Seller supplied control systems shall be provided with detailed control schematics, wiring diagrams, wire list, loop diagrams, and termination information. Drawings shall meet the requirements specified in Section GR-B – Engineering Data and Submittal Schedule. Field wiring by others shall be clearly indicated on Seller schematics and shown using dashed lines. Dedicated terminal blocks for field wire terminations shall be arranged for field wiring to be landed at a common location. Interconnection drawings showing the physical arrangement and function of the terminals shall be provided as part

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of the drawing submittals for approval. Seller shall be responsible for engineering costs incurred if Seller revises this drawing after being approved. If the motor has Multispeed and Multi-winding, the seller should share motor connection diagram on starter schematic.

13. ALARM INDICATION: Discrete alarm indication shall be provided on the front of Seller furnished control panels. Each discrete alarm shall be annunciated by a dedicated pilot lamp with nameplate or by other means such as LED readout or flashing annunciator plates. A "common alarm" relay shall be provided for each panel and shall activate for any of the discrete panel alarms. A dedicated N.O. auxiliary contact from each common alarm relay shall be provided for status output to the plant distributed control system.

14. EQUIPMENT SAFETY GROUNDING: All electrical Equipment that is part of a skid, integral shipping unit or assembly shall be furnished with a bare copper or stainless-steel welded, grounding pads drilled and tapped for connection to a NEMA 2-hole ground lug. The ground pads shall be located at opposing ends/corners of the skid and shall be suitable for field connection to the station ground grid. Minimum pad thickness shall be one (1) inch.

14.1 Isolated logic system or single-point ground connections required for proper operation of electronic Equipment shall be insulated from the Equipment safety ground. Such connections will be extended, using insulated cable, to a single termination point suitable for field connections to the appropriate ground system.

14.2 Electrical Equipment shall include all enclosures containing electrical connections or bare conductors with the exceptions of control devices, such as solenoids, pressure switches, and limit switches, unless such devices require grounding for proper operation.

14.3 Any skid mounted raceway system shall not be considered to be a ground conductor except for itself. All conduits containing power circuits shall be connected to the enclosure or Equipment grounding pad or grounding bus with bare copper conductor. Grounding bushing ground conductors shall be not less than #10 AWG bare copper conductor.

14.4 Ground conductors shall be Class B copper, concentric-lay stranded, annealed copper conductor per ASTM B8. All clamps, conductors, bolts, washers, and nuts used with the grounding system shall be silicon bronze if required.

14.5 All panels shall be equipped with a 1/4 - in. x 1-in., solid copper ground bus extending the entire length of each panel.

15. INSTRUMENTATION: See Section I2 – General Instrumentation Requirements for additional requirements for skid-mounted and Seller-engineered systems.

END OF SECTION

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