Motor Control (AMPGARD) —Medium Voltage

Contents

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Specifications

See Eaton's *Product Specification Guide*, available on CD or on the Web.

CSI Format:	1995	2010
AMPGARD Motor Starters	**Section 16349**	**Section 26 18 39**
AMPGARD Starters Arc Resistant	**Section 16349C**	**Section 26 18 39.01**
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SC9000 EP Arc Resistant	**Section 16349D**	**Section 26 18 39.03**

AMPGARD Motor Control Assembly

AMPGARD Motor Control Assembly

General Description

Eaton's AMPGARD® medium-voltage metal-enclosed control family provides control and protection of medium-voltage motors and equipment rated 2300–13,800 V nominal/15,000 V maximum.

Application Description

AMPGARD control has a complete metal-enclosed offering:

- Full and reduced voltage starting of medium-voltage motors up to 8000 hp
- Main breaker metal-enclosed switchgear, a smaller footprint, single integrated assembly direct coupled to the AMPGARD control
- Integral LBS loadbreak switches available as main, tie or feeder. The LBS can be supplied as fused or un-fused
- Adjustable frequency drives (SC9000 EP™) up to 4160 V, 6000 hp

Features, Benefits and Functions

Personnel safety: Positive mechanical isolating switch with visible disconnect completely grounds and isolates the starter from the line connectors with a mechanically driven isolating shutter, leaving no exposed high voltage. Medium-voltage door is mechanically locked closed with interlocking mechanism; low-voltage section has separate door and is segregated from the medium-voltage section.

Ease of installation: Current limiting fuses, contactor assembly and isolating switch assembly are easily removed from the enclosure; line and load terminals are completely accessible from the front.

Ease of maintenance: All components are front accessible, facilitating routine inspection and/or parts replacement.

The low-voltage compartment is painted white as standard to maximize serviceability.

Simplicity of design: Component-to-component design eliminates half of the electrical connections.

Time-proven contactor technology: Three vacuum contactor ratings are used, 400 A and 800 A 7.2 kV and 300 A 15 kV. 400 A 7.2 kV contactors are available as stab-in or bolt-in design. 800 A 7.2 kV and 300 A 15 kV contactors are available as stab-in design only.

High degree of isolation: Main bus is located in separate compartment on top of lineup. Vertical bus is barriered in rear of starter. Load cables are isolated from adjacent starter in two-high sections. A vertical low-voltage wireway is provided for isolation of customer control wiring. The low-voltage control compartment is isolated from medium voltage by grounded steel barriers.

Starter catalog types are available for the following applications:

- Squirrel cage, full voltage (reversing and non-reversing)
- Squirrel cage, primary reactor
- Squirrel cage, autotransformer
- Reduced voltage solid-state
- Synchronous full voltage
- Synchronous primary reactor
- Synchronous auto-transformer (reversing and non-reversing)
- Two-speed, two winding
- Two-speed, one winding

Enclosures

AMPGARD products are available in NEMA® 1 general purpose enclosures as standard. NEMA 12 (dust tight), NEMA 3R (outdoor) and arc-resistant enclosures are available options for most products. Contact Eaton for exceptions. Enclosure type affects the maximum continuous current rating of the starters in the enclosure.

Refer to **Table 10.1-5** on **Page 10.1-19** for specific ratings for each enclosure type.

Arc-Resistant AMPGARD

When specified, AMPGARD is available in special arc-resistant construction. AMPGARD AR is available with a 50 kA, 0.5 sec rating. The design has been tested and verified to meet the requirements of IEEE C37.20.7 for Type 2B construction. Type 2B construction is defined as arc-resistant at front, back and sides of the enclosure with the low-voltage compartment door open. Most types of 400 A and 800 A starters, as well as 24-inch (610 mm) wide incoming cable sections are available in arc-resistant construction. A common plenum design to close couple to Eaton arc-resistant switchgear is also available. Consult Eaton for ratings on this design. Main Breaker AMPGARD, LBS load break switches and 15 kV starters are not available in arc-resistant construction. Due to the specific nature of arc-resistant testing, no modifications may be made to the enclosure while maintaining the arc-resistant rating. Consult Eaton for more details.

Personnel Safety Features

One of the most important considerations in designing the AMPGARD starter was personnel safety. The result is an extensive system of interlocks and other safety features.

Interlocks

Interlocking on AMPGARD starters includes:

- Isolating switch mechanism locks the medium-voltage door closed when the switch is in the ON position
- Provision for optional key interlocks
- When door is open, interlock prevents operating handle from being moved inadvertently to ON position
- When contactor is energized, isolating switch cannot be opened or closed

AMPGARD Main Breaker *SC 9000 4160 V, 2500 hp AFD* *MV4S RVSS* *2-High FVNR*

Other Safety Features

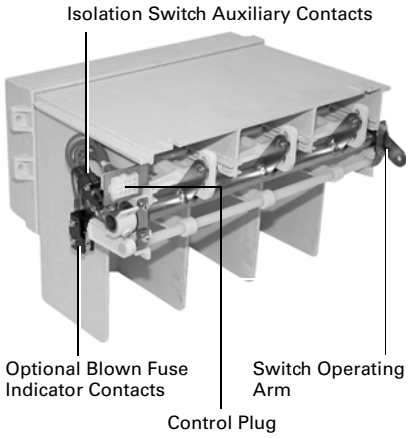
AMPGARD starters include many additional features designed to protect operating personnel. These features include:

- Provision for a padlock on the isolating switch handle in OFF position
- Shutter barrier between line terminals and isolation switch stabs is mechanically driven
- Distinctive marking on switch assembly appears when shutter barrier is in position and starter is completely isolated from the line
- Grounding clips provide a positive grounding of the starter and main fuses when the isolating switch is opened
- High- and low-voltage circuits are compartmentalized and isolated from each other
- The drawout isolation switch is easily removed by loosening two bolts in the back of the switch. The shutter remains in place when the switch is withdrawn

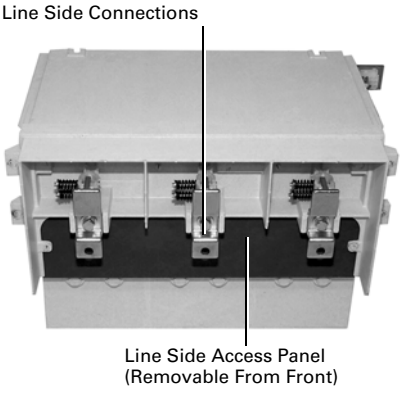
A remote operator for the starter isolation switch is an available option. The AMPGARD Remote Operator (ARO) enables users to open or close the switch through the use of a pushbutton station operated up to 30 feet away from the starter. Users can mount the ARO on the front of the starter, plug it into any available 120 Vac source, then easily operate the isolation switch from outside the starter arc flash boundary.

AMPGARD Remote Operator

Mechanical Non-Loadbreak Isolating Switch



JMT-400/800 A Isolation Switch Front View



JMT-400/800 A Isolation Switch Rear View

Isolation Switch

Eaton's Type JMT-4/8 and JMT-15 are each a drawout, lightweight, three-pole, manually operated isolating switch mounted in the top of the starter enclosure. They may be easily removed by loosening two bolts in the rear of the switch. The JMT-4 is rated 400 A continuous while the JMT-8 is rated 720 A continuous. The JMT-15 is rated 300 A continuous at 15 kV. All isolation switches have a mechanical life rating of 10,000 operations.

The component-to-component circuitry concept includes the mountings for the current limiting fuses as part of the isolating switch.

Features

A positive mechanical interlock between the isolating switch handle mechanism and contactor prevents the isolating switch from being opened when the contactor is closed or from being closed if the contactor is closed.

An operating lever in the isolating switch handle mechanism is designed to shear off if the operator uses too much force in trying to open the non-loadbreak isolating switch when the contactor is closed. This feature ensures that the operator cannot open the switch with the main contactor closed, even if excessive force is used on the operating handle.

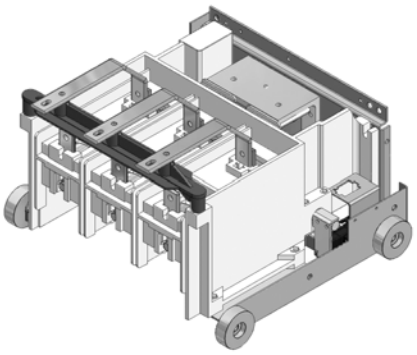
To operate the isolating switch, the operating handle is moved through a 180° vertical swing from the ON to the OFF position. In the ON position, a plunger on the back of the handle housing extends through a bracket on the rear of the starter high-voltage door, preventing the door from being opened with the switch closed. When the high-voltage door is open, a door interlock prevents the handle from being inadvertently returned to the ON position.

When the operating handle is moved from ON to OFF, copper stabs are withdrawn from incoming line fingers. As the stabs withdraw, they are visible above the top of the fuses when viewed from the front, and simultaneously grounded. As the fingers are withdrawn, a spring-driven isolating shutter moves across the back barrier to prevent front access to the line connections. As the shutter slides into position, distinctive markings appear on the back barrier, making it easier to check the position of the shutter.

Switch Handle Closed

Switch Handle Open

400 A, 7.2 kV Vacuum Contactor, Type SL



400 A Bolt-in Contactor
7200 Volt Maximum

General Description

Eaton's Type SL Vacuum Contactors were designed and engineered specifically for use in AMPGARD starters. 7.2 kV SL 400 A Vacuum Contactors are self-supporting, compact, drawout, three-pole, dc magnet closed contactors. To permit application matching of the starter to the motor rating, the SL Contactor is available in 400 A standard and high interrupting ratings.

SL Contactors are available in the standard bolt-in configuration and optional stab-in design. Either bolt-in or stab-in designs can be supplied in a two-high configuration, with a starter maximum of 400 full load amperes. The total NEMA 1 structure rating cannot exceed 720 A for a combination of two starters. Refer to **Table 10.1-5** on **Page 10.1-19** for other ratings.

Design

Eaton Vacuum Contactors are highly versatile, low-chop contactors that have been designed to meet all applicable NEMA standards and are UL® recognized components. The contactors accommodate mechanical interlocks that function with the starter isolation switch and with other contactors. These interlocks provide unmatched safety and service protection.

The contactors consist of a molded frame with moving armature, magnet and vacuum interrupters. The contactor is easily positioned into the starter, and vacuum interrupters provide long life with a minimal maintenance program. The SL operating coils are energized by a control board that provides a pulse-width-modulated dc output. Control voltages and contactor dropout times are programmed using a DIP switch located on the control board. The control board is mounted in a protected cavity in the molded contactor frame to prevent inadvertent access to the voltage and dropout DIP switch. Four auxiliary contacts (2NO, 2NC) are supplied with each contactor and are wired to terminal blocks on the starter control panel.

The vacuum interrupters employ special main contact materials that exhibit a low chop current plus other specially engineered characteristics that minimize switching surges. Surge protection is therefore not required due to the use of the vacuum contactor. Surge protection may be required for other reasons such as the high probability of lightning strike, etc.

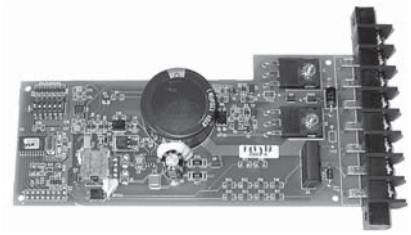
Supplemental Devices

A lift device is available to assist in withdrawal, removal and installation of medium-voltage breaker or contactor.

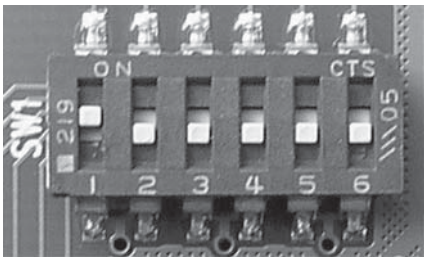
Maintenance

Reduced maintenance is one of the outstanding features of Eaton's Vacuum Contactor line. The special contact material in the vacuum interrupters provides long life even under severe operating conditions. The main coils operate with a very low temperature rise to maximize insulation life. Steel bearings on the main shaft provide long, trouble-free operation.

An included simple go/no-go gauge is used for checking contact wear. Wear can be checked without removing the contactor from the starter. The vacuum contactor at 60 lb is much lighter than previous generation airbreak or vacuum contactors, which allows for easier insertion and removal from the starter structure.



Contactor Control Board



DIP Switch on Contactor Control Board

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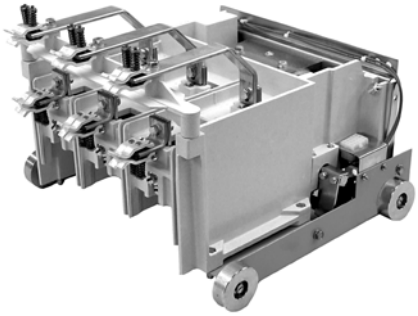


400 A Stab-in Contactor 7200 V Maximum

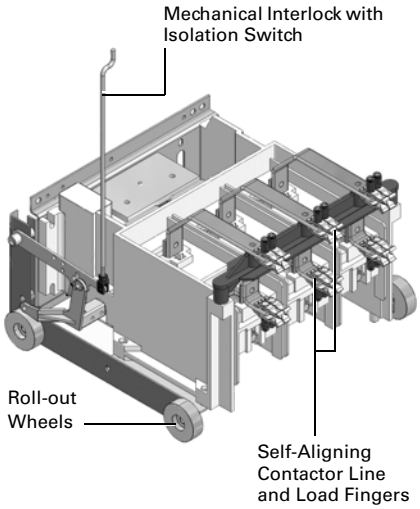
400 A, 7.2 kV Bolt-in

The bolt-in version of the SL Contactor is supplied as standard for those applications requiring a 400 A contactor. The contactor is mounted on wheels and rolls into the AMPGARD structure on steel rails. Bolted bus bars connect the contactor line and load terminals to the power components in the starter cell. A three-phase current transformer, three-phase potential transformer and ground fault current transformer are mounted in the cell when required. A plug on the side of the contactor connects the contactor to the low-voltage control panel.

The contactor is easily withdrawn from the structure by removing the six bolts securing the contactor line and load terminals, and the pin connecting the isolating switch interlock arm. The contactor can be removed from the starter without disconnecting any medium-voltage cables.

400 A, 7.2 kV Stab-in

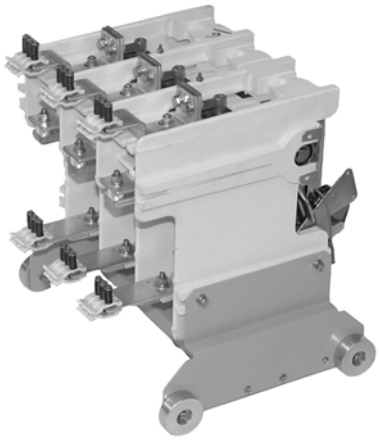
A stab-in version of the SL Contactor is an available option. The stab-in contactor is mounted on wheels and rolls into the AMPGARD structure. Contactor line and load fingers engage cell-mounted stabs as the contactor is inserted into the starter cell. The contactor is held in position by a bolt and bracket combination. It can be easily withdrawn from the starter cell by removing the bolt holding the contactor against the bracket and disconnecting the isolation switch interlock. The contactor can be removed from the starter without disconnecting any medium-voltage cables.



400 A Stab-in Contactor 7200 V Maximum with Mechanical Interlock

800 A, 7.2 kV Vacuum Contactors

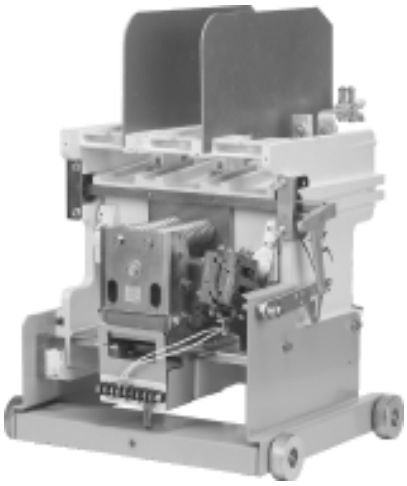
The 800 A SL Contactor is available in a one-high configuration and is rated at 600/650/750 A enclosed. The 800 A contactor is available with a stab-in or bolt-in type connection. The 800 A contactor is mounted on wheels and has similar features to the stab-in 400 A contactor.



800 A Vacuum Break Contactor 7200 V Maximum Stab-in with Wheels, and Line and Load Fingers

300 A, 15 kV Stab-in Contactor

The 300 A 15 kV SL Contactor is available in a one-high configuration and is rated at 300 A enclosed. The 300 A contactor is available with a stab-in type connection only. The 15 kV contactor is mounted on wheels and has similar features to the 800 A 7.2 kV contactor. The maximum starter current is 300 full load amperes when supplied with 15 kV 400 ampere CLS fuses.



300 A Stab-in Contactor 15 kV Maximum

Current Limiting Fuses

AMPGARD starters use Eaton's Type CLS power fuses with special time/current characteristics for motor service. Type CLE or Type HLE power fuses are applied when the starter is used to feed a transformer. The fuse is coordinated with the contactor and overload relay characteristics to provide maximum motor/transformer utilization and protection. The standard mounting method for power fuses is bolted with an option for fuse clips in the 400 A starter. 800 A 7.2 kV and 300 A 15 kV fuses are supplied as bolted only.

Interruption is accomplished without expulsion of gases, noise or moving parts. Type CLS/CLE/HLE fuses are mounted in a vertical position to ensure maximum rating reliability, proper operation and to eliminate the possibility of dust and dirt collecting, resulting in a deterioration of dielectric properties. When a fault has been cleared, a plastic indicator in the top of the fuse, normally depressed, pops up to give visible blown fuse indication. This indicator also operates the optional blown fuse mechanism (available with bolted 7.2 kV fuses only) on the isolation switch that gives a contact closure to allow use in the starter control circuit.

Blown fuses may be removed and replaced without removing or drawing out the contactor. The control circuit primary fuses are also current limiting.

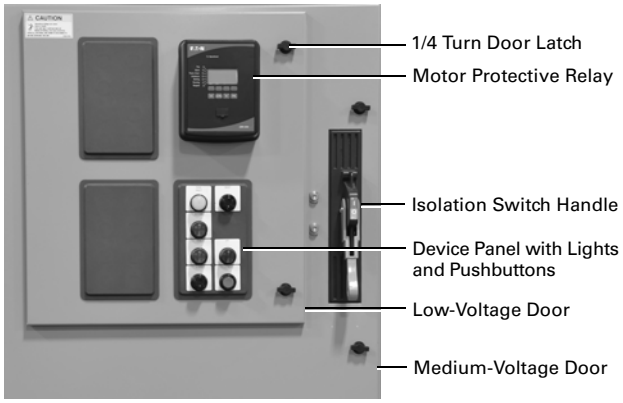
CLS Clip Fuse CLS Bolted Fuse

Standard Fuse Mounting is Bolted with Optional Clip Mounting

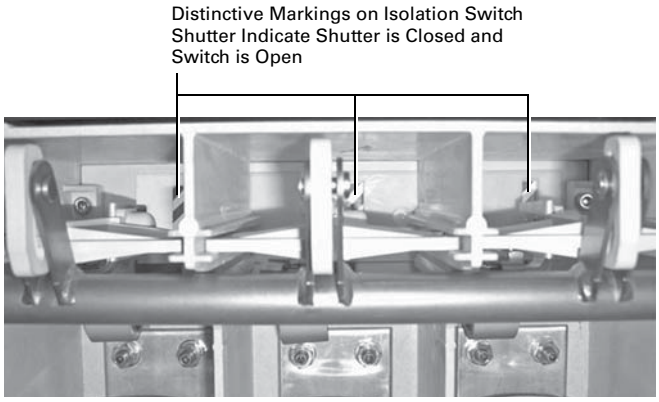
Blown Fuse Indicating Device

Isolated Low-Voltage Control

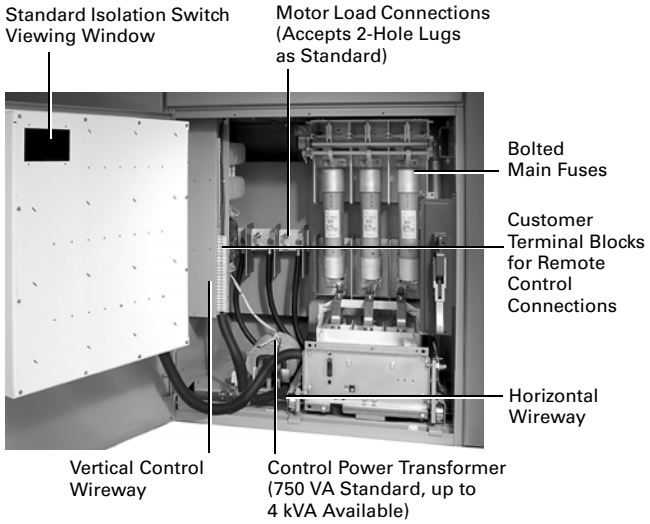
The low-voltage door has four cutouts as standard.



AMPGARD 400 A Starter Door Closed

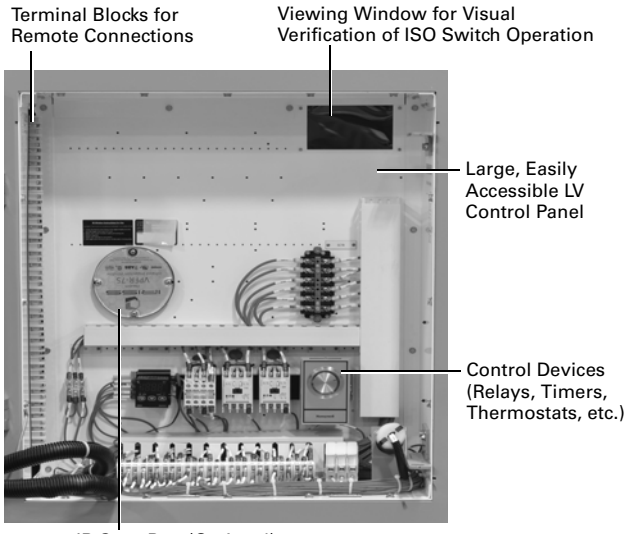


View of Isolation Switch Through Viewing Window



AMPGARD 400 A Starter—Medium-Voltage Door Open

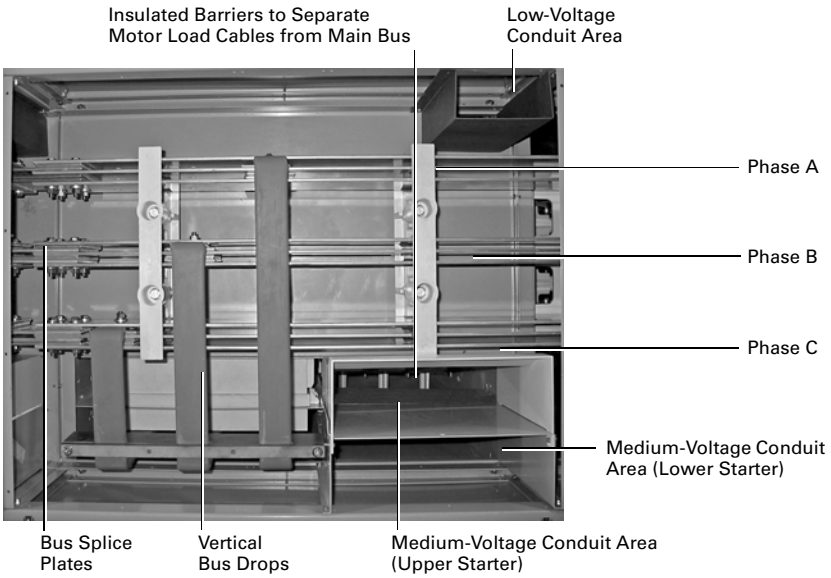
Device panels are provided on the low-voltage door to simplify the mounting of pilot devices. The low-voltage control panel is behind the low-voltage door and is completely isolated from the medium-voltage compartment. A standard viewing window allows visual verification of the isolation switch status before attempting to open the medium-voltage door. The medium-voltage door is locked closed whenever the isolation switch is closed.



AMPGARD 400 A Starter—Low-Voltage Compartment

Estimated low-voltage compartment dimensions 22 inches W x 25 inches H x 8 inches D.

Bus and Optional Features



Bus Compartment Top View 3000 A Main Horizontal Bus

Vertical Bus, Rear View (2-High 400 A)

Main Bus

When starters are grouped together in a lineup, a typical option is the main bus. The AMPGARD main bus is mounted in its own 12-inch (305 mm) high top-mounted enclosure, which isolates it from the starter. The connection from the main bus to the starter is done with rigid vertical bus. Insulated barriers are provided for separate top entry of power and control cables. The main bus is top, side and front accessible, which allows for ease of maintenance or extension of lineup without disassembling the starters.

Main bus is available for 1000, 1200, 2000 and 3000 A. Main bus is uninsulated as standard on 7.2 kV and below. Fully insulated bus is an available option for up to 7.2 kV starters and is standard on 15 kV and starters. Bus may be supplied with either tin or silver plating. Crossover bus available in 1000, 1200, 2000 and 3000 A. Busway entry and pull boxes for 3000 A require an additional 24-inch section or main bus without vertical bus drops (3000 A bus duct provisions are available with the main breaker AMPGARD, see **Page 10.1-13**).

The standard bus short circuit rating is 50 kA for 10 cycles per NEMA and UL standards. An optional 50 kA, 2-second bus rating is available for customers that require a higher rating for the main bus.

Vertical Bus

Vertical bus is located behind a fixed barrier in the rear of the enclosure. It is fully insulated as standard, with plating to match that of the main bus.

Other Optional Features

AMPGARD starters are available with a variety of accessories and modifications to satisfy a wide range of application requirements. Some of the broad areas covered include:

- Bus and cable entrance enclosures
- Transformers
- Power factor correction capacitors
- Operators and pilot devices
- Instruments and meters
- Control relays and timers
- Solid-state or selected electro-mechanical protection devices

Standards and Certifications

UL, CSA and IEC Certification

AMPGARD starters are designed, assembled and tested to meet all applicable standards:

- NEMA/ANSI ICS3
- UL 347
- CSA® C22.2 No. 14

The major components, i.e., contactor, isolating switch, fuses, EMR-3000 and EMR-4000 are UL recognized.

UL or CSA labeling of a specific starter requires review to ensure that all requested modifications and auxiliary devices meet the appropriate standards. Refer to factory when specified. AMPGARD starters meet the requirements of IEC standards 60694, 60298 and 60470.

Seismic Qualification

Refer to **Tab 1** for information on seismic qualification for this and other Eaton products.

Reduced Voltage Starters

General Description

Eaton offers traditional electro-mechanical reduced voltage starters in addition to reduced voltage solid-state (RVSS) starters. Unless otherwise specified, reactors and autotransformers are NEMA medium duty rated. They are designed for three 30-second starts per hour. Heavy-duty reactors and transformers can be supplied when specified. Locked rotor current must be specified when ordering reduced voltage starters to ensure that the reactors or autotransformers are properly sized.

Reduced Voltage Reactor Starter

Reactor Starter

Table 10.1-1. Type 502 Reactor Starting Characteristics

Starter Type	% Motor Voltage	% Motor Current	% Line Current	% Torque
80% tap	80	80	80	64
65% tap ①	65	65	65	42
50% tap	50	50	50	25

① Factory set on 65% tap.

Advantages

- Reduces starting currents
- Least costly reduced voltage starting method

Disadvantages

- Large footprint: 1-1/2 structures at 400 A
- "Bump" on transition to full voltage
- Not as efficient as autotransformer
- Due to reduced torque during starting, motor must typically be unloaded during the start sequence

Sequence of Operation

- Main contactor (M) closes
- Current flows through reactor reducing voltage to motor (based on tap setting)
- When motor current reaches ~125%, the run contactor (R) closes providing full voltage to the motor

Reduced Voltage Autotransformer Starter

Auto Transformer Starter

Table 10.1-2. Type 602 Auto-transformer Starting Characteristics

Starter Type	% Motor Voltage	% Motor Current	% Line Current	% Torque
80% tap	80	80	67	64
65% tap ②	65	65	45	42
50% tap	50	50	28	25

② Factory set on 65% tap.

Advantages

- Produces the most torque per incoming line ampere of any reduced voltage starting method
- Less costly than RVSS

Disadvantages

- Large footprint: 1-1/2 structures at 400 A
- More costly than reactor
- "Bump" on transition to full voltage
- Due to reduced torque during starting, motor must typically be unloaded during the start sequence

Notes: Care should be taken when selecting the motor for reduced voltage starting to ensure that there is sufficient torque to accelerate the load at reduced voltage. Motors that do not fully accelerate at reduced voltage will generate high voltages at transition that can damage the autotransformer and void the factory warranty.

Sequence of Operation

- Shorting contactor (S) closes
- Main contactor (M) closes
- Current flows through autotransformer reducing voltage to motor (based on tap setting)
- When motor current reaches ~125%, the shorting contactor (S) opens and the run contactor (R) closes providing full voltage to the motor

Notes: Because the motor is never disconnected from the supply voltage, the starting is closed transition.

Solid-State Reduced Voltage AMPGARD MV4S

Eaton offers reduced voltage solid-state soft starters in 400 A and 720 A configurations. Horsepower ratings are available through 5000 hp. The 400 A AMPGARD soft starter requires one full height structure with a full voltage starter in the upper compartment bus connected to a soft start truck assembly in the lower compartment. The 720 A soft starter requires two full height structures (total 72 inches (1829 mm) wide). The soft start components are fixed mounted in the 720 A starter. Both soft starters include internal fault protection and built-in basic motor protection. The assembly includes an EMR-3000 relay or other optional motor protective device.

Why is Solid-State Reduced Voltage "Soft" Starting Desirable?

- Eliminate shock to your mechanical components
- Avoid coupling and shaft damage
- Prevent rotor and winding failure
- Stop drive belt squeal and breakage
- Prevent water hammer in pipes
- Soft stop the pump motors
- Reduce pressure so valves close gently
- Avoid the surge wave
- Reduce peak starting currents
- Reduce voltage drop on motor start

Ratings

- 2300–4160 Vac
- 60 kV BIL impulse rating
- Horsepower: to 5000 hp or 720 A

Refer to **Table 10.1-26** on **Page 10.1-35** for more detailed ratings information.

Industry Standards

The AMPGARD solid-state starter is designed and built to meet all applicable industry standards. The 400 A starter is available as a UL listed assembly.

- NEMA ICS3
- UL 347
- CSA
- Manufactured in an ISO® 9001 and ISO 14001 certified facility

Starting Characteristics

The soft start controller provides a number of selectable starting characteristics as standard:

Kick Start

Provides an initial boost of current to overcome motor and system inertia. Range 0.1 to 2 seconds at 10–100% voltage.

Ramp Start

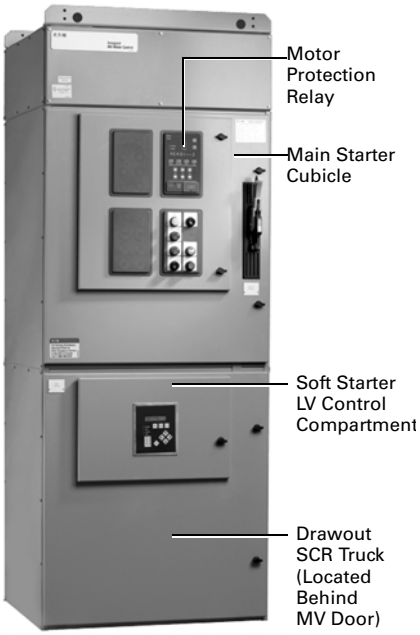
Operator sets the initial starting voltage and ramp time. Factory setting for starting voltage is 20%. Range is 0 to 100%. Factory setting for starting time is 10 seconds. Range is 1 to 120 seconds.

Current Limit

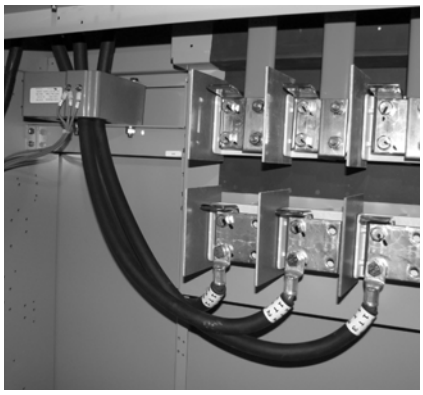
Limits the maximum starting current. Used in long start time applications and motor protection applications. Factory setting is 350% of motor FLA. Range is 200 to 600%.

Solid-State Soft Stop

Provides a slow decrease in output voltage. Extends the stopping time of the motor. Typically used with pumps.



AMPGARD 400 A Soft Starter



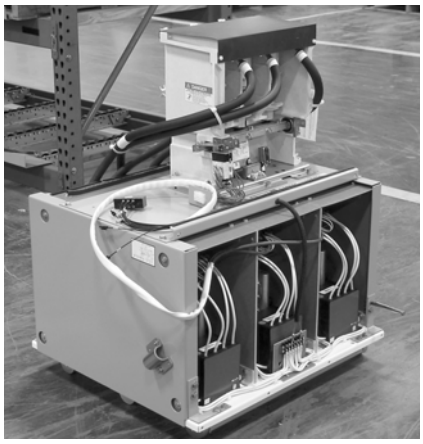
Load Cables—Normal

Load Cables—Moved for Full Voltage Start

Table 10.1-3. MV4S Specifications

Description	Specification	
Type of load	Three-phase medium-voltage ac induction or synchronous motors	
ac supply voltage	2300, 3300, 4160 Vac +10% to –15%, 50/60 Hz line voltages	
hp ratings	Up to 5000 hp at 4160 V (720 A)	
Overload rating	AC-53b (600-30-60m) (500% 60 sec; 600% 30 sec)	
Power circuit	Highest rated series SCRs available	
SCR peak inverse voltage	**Line voltage**	**PIV rating**
	2300	6500
	3300	9000
	4160	13,000
BIL rating	2300–4160 V: 60 kV; corona free design	
Transient voltage protection	Standard on all models	
Vacuum Bypass Contactor	In-line and bypass standard on all models	
Ambient operating conditions	0–50 °C (82 °F to 122 °F) (optional –20 °C to +50 °C with heaters) 5–95% relative humidity 0–3300 ft (1000 m above sea level without derating)	
Operator interface panel (HMI)	Programmable keypad/operator with 2 lines x 20 character backlit LCD Plain text display Status/Alarm LEDs (indicate: Power, Run, Alarm, Trip, Aux 1–8)	
Available I/0	Dedicated E-Stop circuit Multiple Form C contacts rated 5 A at 250 Vac maximum 8 fully programmable Relays (4 customer definable) Fail safe operation 5 dedicated relays (fault, at-speed, etc.) 2 analog outputs	
Acceleration control	Voltage ramp, voltage ramp with current limit, power (kW) ramp, current ramp, current limit, or custom ramp, tach feedback closed loop speed ramp optional, dual ramp, kick start, jog	
Deceleration control	Pump-flex decel control standard on all models	
Motor and starter protection	Electronic overload (49) Instantaneous overcurrent (50) ac time overcurrent (51) Undercurrent (37) Current imbalance (46) Phase loss (46) Overvoltage (59) Undervoltage (27) Phase rotation (47) Starter over-temp Starts per hour lockout (66) Lockout/Start inhibit (86)	Time between starts (66) shorted SCR Bearing RTD protection (38) optional Stator RTD protection (49) optional Mechanical condition (39) optional Instantaneous overcurrent (50) ac time overcurrent (51) Ground fault (option) incomplete sequence (48) Power factor trip (55) Differential (87 M) optional Ground fault (50N/51N, 50G/51G) Rate of rise “di/dt” (7)
Statistical data	Fault log up to 60 events (data includes date and time) Elapsed run time, last start time, average starting current Time-to-trip, remaining inhibit time and starts/hour values	
Metering (voltage and current)	Percent of FLA, phase currents, kVAR, kVA, kW, power factor, demand, avg. start current, remaining thermal register, thermal capacity to start, measured capacity to start, time since last start, line frequency, phase order, RTD values (optional)	
Commissioning software	Free MV4SLink-based programming software	
Communications	RS-485 with Modbus® RTU protocol or RS-232 with Windows® interface Optional DeviceNet™, PROFIBUS®, Ethernet Modbus/TCP, EtherNet/IP Optional Web Server Remote Monitoring Optional EZ-SCADA communications	

MV4S Keypad and Display



400 A MV4S Roll-out Truck

Application with Capacitors

Capacitors of any kind may not be connected to the load of the solid-state starter. When power factor correction capacitors are required, the capacitors are connected ahead of the RVSS truck and are switched with a separate capacitor contactor. If multiple starters with capacitors are supplied in the same lineup, capacitors are prevented from switching while solid-state starter ramps. Long cable runs may create enough capacitance to be of concern. Capacitance connected to the starter motor connections must not exceed 0.3 uF, typically 750 feet or 350 feet of two cable runs per phase. Power factor capacitors or surge capacitors must not be connected at the motor.

Note: Contact Eaton for output capacitance or cable lengths that exceed the recommended values.

Design

Soft start components and bypass contactor are mounted in a easy-to-remove roll-out truck assembly. Maintenance can be performed with the truck on a bench away from the starter cubicle.

The internal bypass contactor can be manually closed for emergency full voltage start operation.

How It Works

1. At the time of start, the bypass contactor is open and all current passes through the SCRs that ramp the voltage per the pre-programmed starter settings.
2. After start is complete, the bypass contactor closes, taking the SCRs out of the circuit.
3. The SCRs are on for only a short time therefore no MCC venting or cooling is required.
4. When a stop command is received, the SCRs can be programmed to ramp down, providing a soft stop.

AMPGARD 720 A Soft Starter

720 A MV4S with Doors Open

Synchronous Motor Control, Brush-type or Brushless

AMPGARD synchronous starters are available for Brush-type and Brushless Motors. The Brush-type design features the AMPGARD exclusive "Soft-sync" that minimizes mechanical shock as the motor is synchronized.

Eaton Factory Authorized Start-up Service is recommended with all Synchronous Starters.

Brush-type

The Brush-type starter includes a three-phase exciter to generate dc rotor current up to 200 A plus a control board that determines the proper time to apply the dc field. Output voltage is available at 125 Vdc or 250 Vdc. Basic protections include:

- Locked rotor protection
- Incomplete sequence
- Failure to synchronize
- Blown fuse protection
- Pullout protection
- Field loss protection
- Power factor regulation/ var regulation (option)

The protective features are displayed on an Eaton GP02 interface module. Stator protection is provided by an EMR-3000 or other solid-state motor protection relay.

AMPGARD Synchronous Starter

Brush-type Display with Trip Indication

Brushless

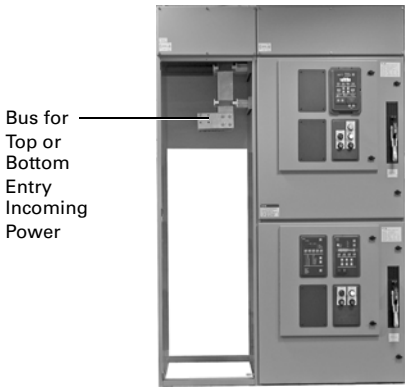
The Basic Brushless starter includes a three-phase dc power supply to generate exciter field current up to 10 A plus a control board that provides basic protection. A solid-state motor protective relay is supplied for pullout protection. Output voltage is adjustable from 62–125 Vdc.

Stator protection is provided by an EMR-3000 or other solid-state motor protection relay.

Incoming Line

Depending on the size and number of incoming cables, an incoming line enclosure may be necessary. Different designs are available for incoming power for top or bottom entry.

When incoming line metering is specified, an additional 24-inch (610 mm) wide metering structure is typically supplied.



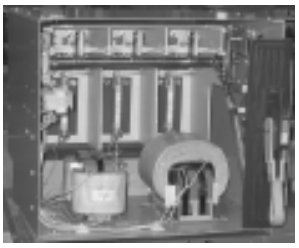
Typical 24-Inch (610 mm) Wide Incoming Line Structure

Incoming Line Connection Options

- **Cable:** Maximum of six per phase, 750 kcmil maximum, top or bottom entry
- **Bus Duct:** Top only, 1200 A, 2000 A. Standard Eaton three-wire designs only
- **Transformer Throat:** Must be the standard design used by Eaton

Potential Transformers, Control Power Transformer Disconnect and Fuses

Bus connected (7.2 kV max.) potential transformers and/or control power transformers are mounted in a 20-inch (508 mm) high assembly that includes a disconnect and primary fuses. The assembly can be mounted in a 24-inch (610 mm) or 36-inch (914 mm) wide structure.

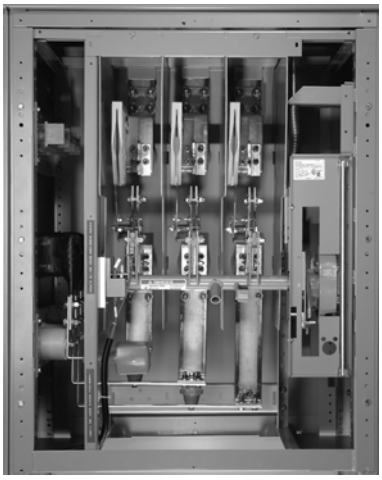


Potential Transformers, Control Power Transformer and Fuses Mounted in a Disconnect Assembly, Height 20 Inches (508 mm)

Type LBS Loadbreak Switch

For application needs with loads rated 600 or 1200 A at 2300–6600 V, AMPGARD is available with the Type LBS loadbreak switch. The LBS is fixed mounted and will fit in one-half of a standard 80-inch (2032 mm) high, 36-inch (914 mm) wide vertical structure. Power fuses up to 450E amperes can be mounted within the half-high structure. 600E or 750E fuses require an additional half-structure, 1100E or 1350E fuses require an additional full structure. Lineups supplied with unfused LBS switches or with switches that use fuses greater than 450 A cannot be rated for 50 kAIC. Refer to **Table 10.1-6** on **Page 10.1-19** for additional ratings information. Mechanical interlocks are incorporated so that the door cannot be opened when the switch is on, and when the door is open the switch cannot be closed. A safety screen is supplied behind the switch door. The Type LBS switch can be supplied with two Form C electrical interlocks. LBS switches have a mechanical life rating of 500 operations.

Type LBS Loadbreak Switch Shown in Upper or Lower Half of 36-Inch (914 mm) Wide Structure, Height 40 Inches (1016 mm)



Type LBS Loadbreak Switch Shown with Safety Screen Removed

10

Main Breaker AMPGARD

Main Breaker AMPGARD

General Description

Eaton's Main Breaker AMPGARD (MBA) is a fully integrated metal-enclosed medium-voltage Type VCP-W drawout vacuum circuit breaker that is bus connected (close-coupled) to AMPGARD medium-voltage starters in a single integrated assembly.

Notes: MBA sections are 100 inches (2540 mm) high.

Main Breaker AMPGARD (7.2 kV max.) is suitable for service entrance. Utility metering sections are not available. Main Breaker AMPGARD is designed and built to meet the following standards where applicable:

- NEMA ICS-1 and NEMA ICS-3, Part 2
- ANSI/IEEE C37.20.3
- UL 347
- CSA C22.2, No. 31 and No.14

Integral Racking

The MBA is available with Eaton's MR2 integral motorized remote racking option. The MR2 provides a means of remotely racking the main breaker, helping mitigate arc flash exposure for the user.

Listing/Certification

UL listing and CSA certification is available, depending on the specific bill of material.

Ratings

- 2300–6600 Vac systems (7200 Vac maximum), three-phase
- 60 kV BIL impulse withstand rating
- ANSI interrupting ratings—50 kA, K=1 breaker is standard
- Continuous current—1200 A, 2000 A, and 3000 A

Main Breaker AMPGARD—Doors Open

Requires Less Floor Space

- Only 60 inches (1524 mm) deep, the integrated MBA design provides a bus system that directly connects to AMPGARD motor starters, eliminating space-consuming transition sections. The reduced floor space requirements yield significant cost savings, particularly when installation in a prefabricated electrical house is required
- Back-to-back starters provide for an increase in the number of starters without an increase in floor space

Front/Side Accessible Connections

- All connections requiring maintenance are front or side accessible
- Rear access space is not required
- An MBA (excluding back-to-back design) can be installed flush against the wall
- Incoming line terminal can accept up to 6 cables per phase, 500 kcmil

Circuit Breaker Rating Chart

Table 10.1-4. ANSI Standards—Type VCP-W Circuit Breakers Rated on Symmetrical Current Rating Basis

ANSI Interrupting Rating	Nominal Voltage	Impulse Withstand Rating	Short-Circuit Current	Continuous Current at 60 Hz
kA	kV	kV Peak	kA rms	Amperes
50	4.16	60 kV BIL	50	1200 2000 3000
50	6.9	60 kV BIL	50	1200 2000 3000

Notes: See **Page 10.1-22** for complete ratings.

10

Microprocessor-Based Relays

Eaton's protective relays provide programmable circuit protection, information and operator conducted testing. Refer to **Tab 4** for more information.

Metering

Power Xpert® meters are available for multi-function metering. Refer to **Tab 3**.

Communications

Eaton's Power Xpert Architecture communications provides for monitoring and controlling complete electrical distribution systems of those parts of a system selected by the operator. Refer to **Tab 2**.

Enclosures

The MBA is available in NEMA/EEMAC 1, NEMA/EEMAC 1G/1 A, and NEMA/EEMAC 12 enclosures.

AMPGARD 2-High Structure Bus Connected to Main Breaker Section

Low-Voltage Equipment Cell Compartment for Metering and Protection Devices

Side Panel Removed to Show Incoming Cable Connections

Technical Data

Typical Wiring Diagram for Full Voltage FVNR Starter

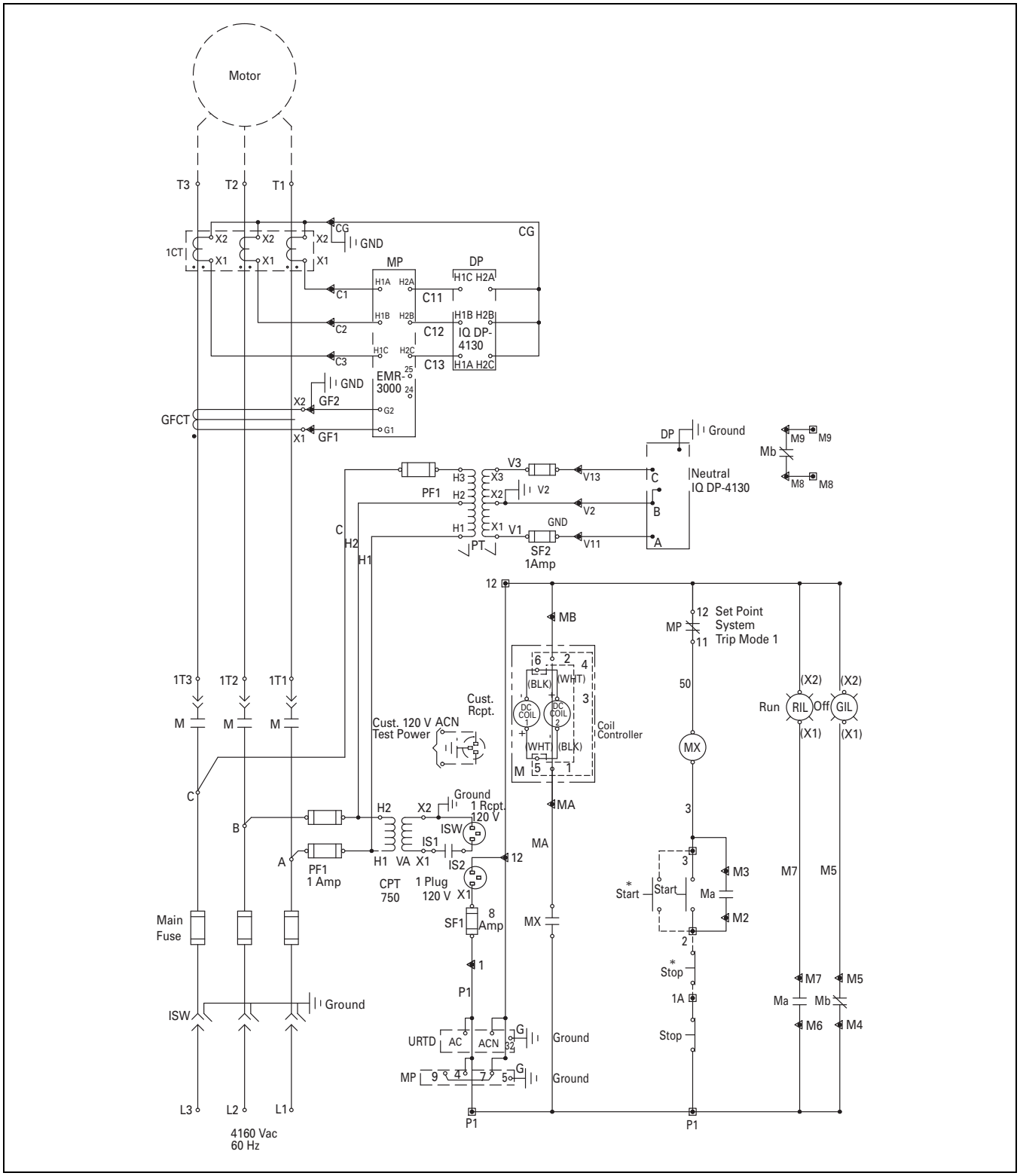


Figure 10.1-1. Induction Motor Across-the-Line Starter, Vacuum Contactor with Optional EMR-3000 Motor Protection and IQ Metering, Start-Stop Pushbuttons, and Red and Green Indicating Lights

Typical Wiring Diagram for Reduced Voltage Autotransformer RVAT Starter

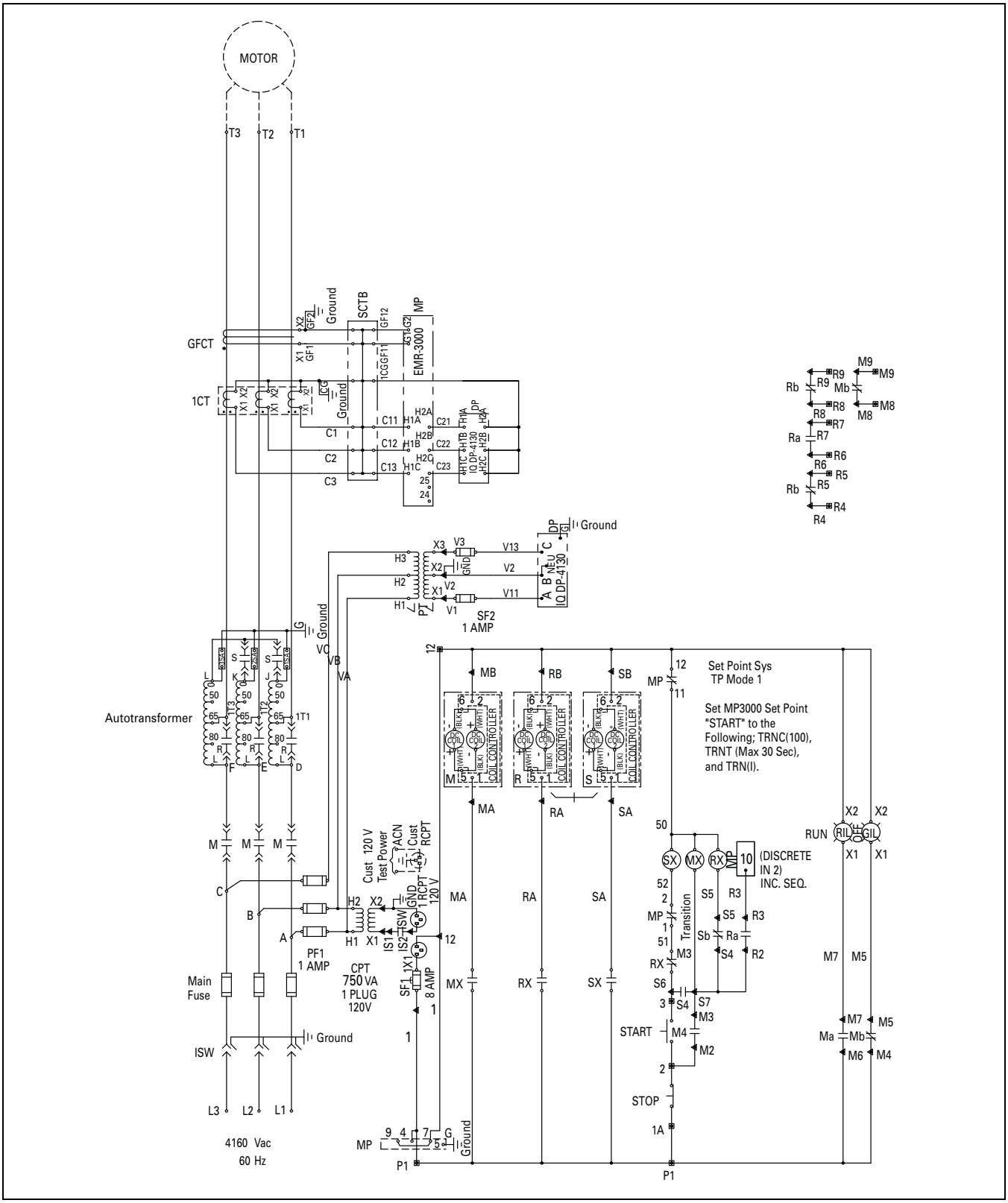


Figure 10.1-2. Induction Motor Reduced Voltage Autotransformer Starter, Vacuum Contactor with Optional EMR-3000 Motor Protection and IQ Metering, Start-Stop Pushbuttons, and Red and Green Indicating Lights

Typical Wiring Diagram for Solid-State Reduced Voltage Starter

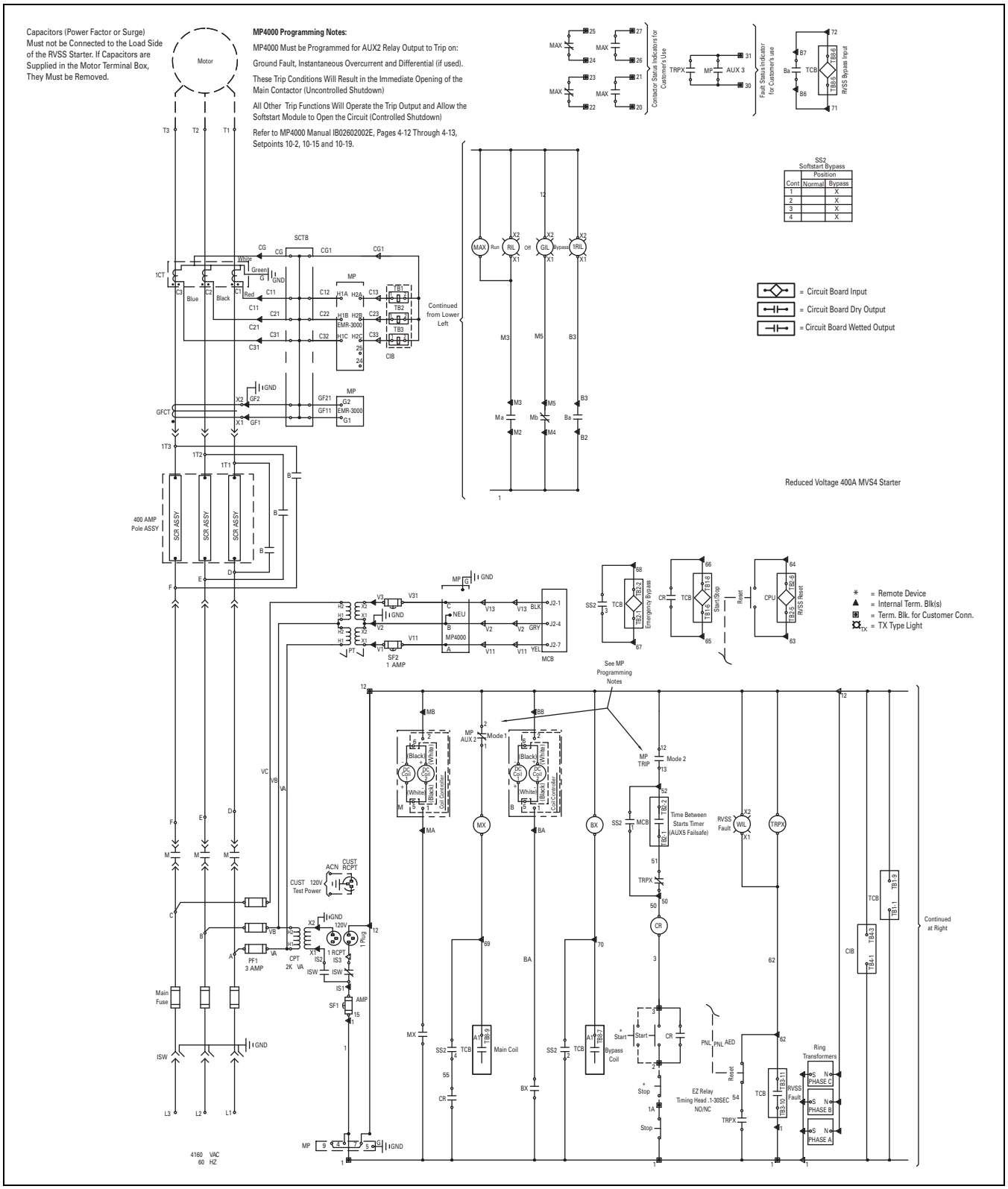


Figure 10.1-3. Induction Motor Reduced Voltage Solid-State Starter, Vacuum Contactor with EMR-3000 Motor Protection, Local and Remote Start-Stop Pushbuttons, and Local and Remote Red and Green Indicating Lights

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Typical Wiring Diagram for Main Breaker Ampgard

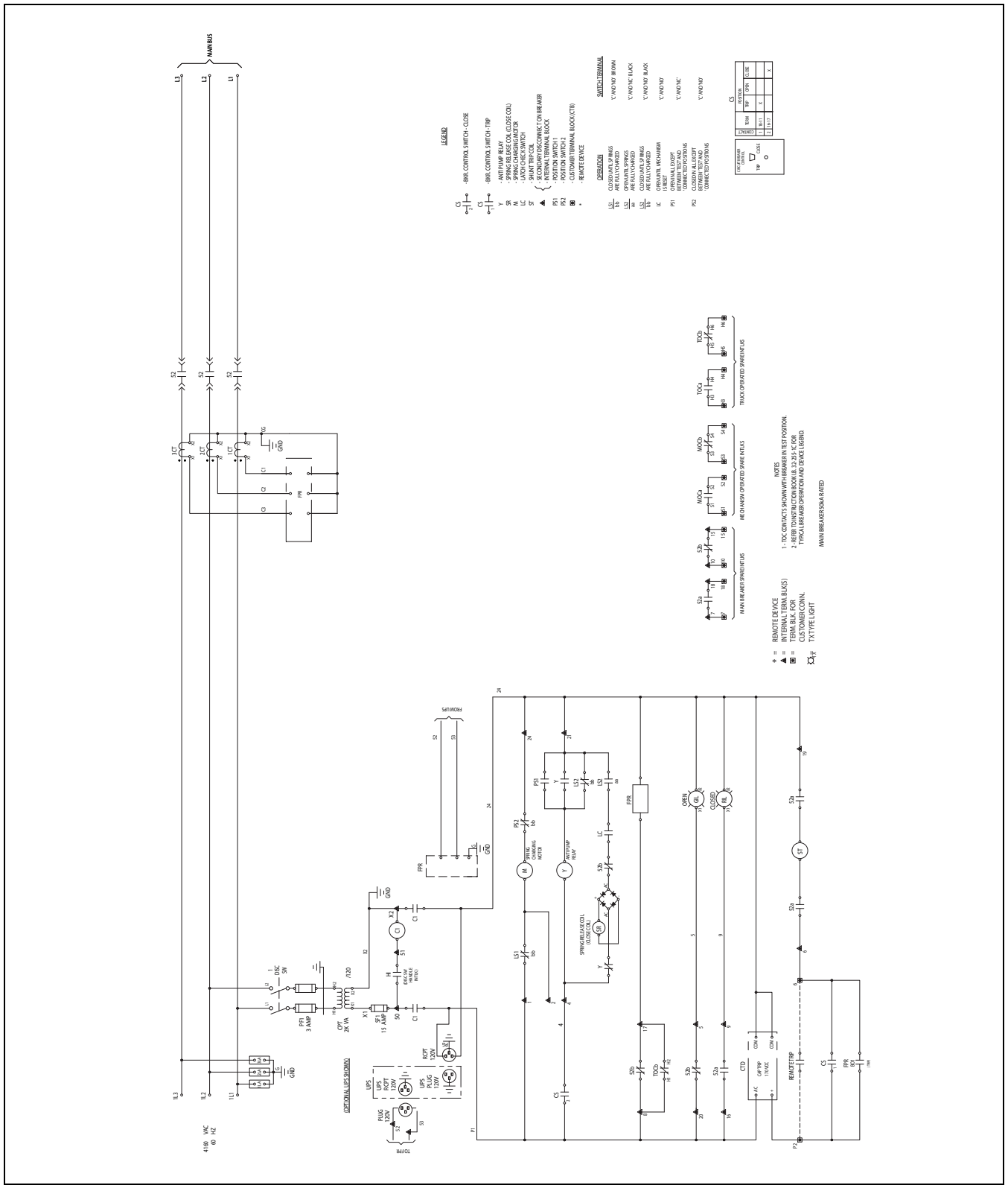

Figure 10.1-4. Typical Wiring Diagram for Main Breaker Ampgard

Table 10.1-5. Starter Maximum Continuous Current Ratings

Starter Class	Enclosure Type		
	NEMA 1	NEMA 12/NEMA 3R	Arc Resistant
Two-high with 400 A 7.2 kV contactors	360 top	330 top	320 top
	360 bottom	330 bottom	320 bottom
Two-high with 400 A 7.2 kV contactors–alternate	320 top	230 top	210 top
	400 bottom ①	370 bottom	350 bottom
One-high with 800 A 7.2 kV contactor	650/750 ①	650	600/750 ①
One-high with 300 A 15 kV contactor	300	300	N/A

① Limited acceleration time and locked rotor current. Contact Eaton for details.

LBS Loadbreak Switch

Table 10.1-6. LBS Switch Ratings

Description	Continuous Amperes	Load-Break Amperes	Fault Close Rating, kA Asymmetrical	System Fault Rating, kA Symmetrical
600 A unfused switch	600	600	40	25
1200 A unfused switch	1200	1200	61	38
600 A fused switch, 450E maximum fuse	450	600	80	50
1200 A fused switch, 450E maximum fuse	450	1200	80	50
600 A fused switch, 750E maximum fuse	600	600	64	40
1200 A fused switch, 750E maximum fuse	750	1200	64	40
1200 A fused switch, 1350E maximum fuse	1200 ②	1200	49	31

② 1200 A rating is for NEMA 1 enclosure with vented covers. NEMA 3R/12 rating is 1000 A.

Type SL, 400 A, 7.2 kV Vacuum Contactor/Starter Ratings

Table 10.1-7. Type SL 400 A Vacuum Contactor Ratings

Rated Utilization Voltage	2200 to 2500 V	3000 to 3600 V	3800 to 4800 V	6000 to 7200 V
Interrupting rating (With 400 A high interrupting contactor)				
NEMA unfused (E1)	8.5 kA	8.5 kA	8.5 kA	8.5 kA
NEMA fused (E2)	50 kA	50 kA	50 kA	50 kA
Application table	200 MVA at 2400 V	285 MVA at 3300 V	400 MVA at 4600 V	570 MVA at 6600 V
Induction motor	1750 hp	2250 hp	3000 hp	4500 hp
Synchronous motor (0.8 PF)	1750 hp	2250 hp	3000 hp	4500 hp
(1.0 PF)	2000 hp	2500 hp	3500 hp	5500 hp
Transformer ③	1500 kVA	2000 kVA	2250 kVA	4000 kVA
Capacitor three-phase	1200 kVAR	1650 kVAR	2100 kVAR	3300 kVAR

Maximum Insulation Voltage: 7200 V

Maximum interrupting current		Arcing time	12 milliseconds (3/4 cycle) or less
(3 operations)	8500 A (High interrupting)	Pickup voltage	80% rated coil voltage
	4500 A (Standard interrupting)	Dropout voltage	60% rated coil voltage
Rated current	400 A enclosed	Control voltages	
IEC make-break capability-AC4		ac	110/120/220/240 (50/60 Hz)
Make	4000 A	dc	125
Break	3200 A	Control circuit burden	
Short-time current		Closing (ac)/(dc)	100V–125 V, 1 kVA/200–250 V, 1.8 kVA
30 seconds	2400 A	Holding (ac)/(dc)	100V–125 V, 40 VA/200–250 V, 50 VA
1 second	6000 A	Auxiliary contact rating	
8.7 milliseconds (0.5 cycle) ④	63 kA peak	Voltage (maximum)	600 V
Standard service altitude	–1000 to +2000 meters	Continuous current	10 A
Optional service altitudes	–3500 to –1001 meters	Making capacity (ac)	7200 VA
	+2001 to +5000 meters	Making capacity (dc)	125 VA
Mechanical life	2.5 million operations	Breaking capacity (ac)	720 VA
Electrical life	300,000 operations	Breaking capacity (dc)	125 VA
BIL	60 kV (1.2 x 50 microseconds)	Latch (when specified)	
Dielectric strength (60 Hz)	20 kV (1 minute)	Mechanical life	250,000 operations
Closing time	80 milliseconds	Trip voltages (dc)	24/125 V
(Energization to contact touch)		Trip voltages (ac)	110/120 V
Opening time	30 to 330 milliseconds (selectable)	Minimum trip voltage	80% rated coil voltage
		Trip burden	
		24 Vdc	400 VA
		125 Vdc	400 VA
		110/120 Vac	400 VA
		Trip time	30 milliseconds
		Weight	60 lb (27 kg) (stab-in/bolt-in)

③ Higher ratings possible depending on transformer magnetizing current. Contact Eaton for more information.
④ Time stated in cycles on 60 Hz base.

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Type SL, 800 A, 7.2 kV Vacuum Contactor/Starter Ratings

Table 10.1-8. Type SL 800 A Vacuum Contactor Ratings

Description	SL 25V830	SL 33V830	SL 50V830	SL 72V830
Rated utilization voltage	2200–2500 V	3000–3300 V	3800–5000 V	6000–7200 V
Interrupting rating NEMA unfused (E1) NEMA fused (E2) NEMA fused (E2)	 12.5 kA 200 MVA at 2300 V 50 kA	 12.5 kA 285 MVA at 3300 V 50 kA	 12.5 kA 408 MVA at 4600 V 50 kA	 12.5 kA 570 MVA at 6600 V 50 kA
Power rating ① Induction motor Synchronous motor (0.8 PF) (1.0 PF) Transformer Capacitor three-phase	 3000 hp 3000 hp 3500 hp 2500 kVA 2400 kVAR	 4000 hp 4000 hp 5000 hp 3500 kVA 3200 kVAR	 5000 hp 5000 hp 6000 hp 4500 kVA 4000 kVAR	 8000 hp 8000 hp 10,000 hp 6000 kVA 4800 kVAR

Maximum Insulation Voltage: 7200 V

Maximum interrupting current (three operations) Rated current IEC make-break capability-AC4 class 3 Make Break Short time current 30 seconds 1 second 8.75 milliseconds (0.5 cycle) Mechanical life Electrical life BIL Dielectric strength (60 Hz) Closing time (energization to contact touch) Opening time	 12,500 A 600/650/720 A enclosed 800 A open 8000 A 6400 A 4320 A 10,800 A 86 kA peak 250,000 operations 200,000 operations At rated current 60 kV (1.2 x 50 microseconds) 18.2 kV (1 minute) 80 milliseconds 50–330 milliseconds, field selectable	Arcing time Pickup voltage Dropout voltage Control voltages (ac)/(dc) Control circuit burden (rated volt) Closing (ac)/(dc) Holding (ac)/(dc) Auxiliary contact rating (L-64) Voltage (maximum) Continuous current Making capacity (ac) Making capacity (dc) Breaking capacity (ac) Breaking capacity (dc) Latch (when specified) Mechanical life Trip voltages (dc) Trip voltages (ac) Tripping voltage Tripping burden 24 Vdc 48 Vdc and 96 Vdc 110 Vac and 220 Vac Weight	12 milliseconds (3/4 cycle) or less 80% rated coil voltage 60% rated coil voltage 110/120/220/240 V (50/60 Hz) 125 Vdc 2600 VA 80 VA 600 V 10A 7200 VA 200 VA 720 VA 200 VA 100,000 operations 24/48/96 V 110/220 V (50/60 Hz) 80% rated coil voltage 1200 VA 400 VA 500 VA 95 lbs (43 kg)

① Other power ratings are available based on the specific load data.

Table 10.1-9. Heat Loss in Watts, at 60 Hz

Contactor Rating	Operating Amperes	Heat Loss
400 A	187 A	400 W
400 A	400 A	800 W
800 A	720 A	1150 W

Type SL, 300 A, 15 kV Vacuum Contactor/Starter Ratings

Table 10.1-10. Type SL 15 kV Vacuum Contactor Ratings

Description	SL12V330	SL15V330
Utilization voltage	10,000–11,000 V	12,400–13,800 V
Interrupting rating EI (unfused) E2 (fused) E2 (fused)	 5 kA 950 MVA at 11,000 V 50 kA	 5 kA 1190 MVA at 13,800 V 50 kA
Induction motor	6000 hp (300 FLA)	7500 hp (300 FLA)
Synchronous motor (0.8 PF)	6000 hp	7500 hp
Synchronous motor (1.0 PF)	6750 hp	8500 hp
Transformer	3800 kVA at 11 kV	6800 kVA at 13.8 kV
BIL	75 kV	95 kV (with arrestors)

Table 10.1-11. Type SL 15 kV Vacuum Contactor Specifications

Specification	Rating
Maximum voltage	15,000 V
Maximum interrupting current (three operations)	5000 A
Rated current	300 A enclosed 300 A open
IEC make-break capability	AC3–make 3000 AC3–break 2400
Short-time current 30 seconds 1 second 8.75 milliseconds	 1800 A 4500 A 43 kA peak
Mechanical life	250,000 operations
Electrical life	200,000 operations
Dielectric strength (60 Hz)	36 kV (1 minute)
BIL	75 kV (1.2 x 50 microseconds)
Closing time	80 milliseconds
Opening time	50 to 330 milliseconds (selectable)
Weight	95 lbs (43 kg)
Arcing time	12 milliseconds (3/4 cycle) or less
Pickup voltage	80% rated coil voltage
Dropout voltage	60% rated coil voltage
Control voltages (ac) (dc)	 110/120/220/240 V (50/60 Hz) 125 V
Control circuit burden (rated voltage) Closing Holding	 2600 VA 80 VA
Auxiliary contact ratings Voltage (maximum) Continuous current Making capacity (ac) Making capacity (dc) Breaking capacity (ac) Breaking capacity (dc)	 600V 10 A 7200 VA 200 VA 720 VA 200 VA
Latch (when specified) Mechanical life Trip voltages (dc) Trip voltages (ac) Tripping voltage Tripping burden 24 Vdc 48 Vdc and 96 Vdc 110 Vac and 220 Vac	 250,000 operations 24/48/96 V 110/220 V (50/60 Hz) 80% rated coil voltage 1200 VA 400 VA 500 VA
Weight	95 lb (43 kg)

Main Breaker Ratings

Table 10.1-12. Available 5/15 kV VCP-W Vacuum Circuit Breaker Types Rated on Symmetrical Current Rating Basis, Per ANSI Standards (Rated K = 1.0)

Identification	Rated Values															
Drawout Circuit Breaker Type	Maximum Voltage (V)	Power Frequency ①	Insulation Level: Power Frequency Withstand Voltage (1 min.)	Insulation Level: Lightning Impulse Withstand Voltage (1.2 x 50 µs)	Continuous Current ②	Short-Circuit Ratings (Reference C37.04-1999 and C37.06-2009 Except as Noted ①): Symmetrical Interrupting Current (I) ②	dc Component (% dc) ③	Asymmetrical Interrupting Current (I_t) ④	Closing and Latching Current (2.6 x I)	Short-Time Withstand Current ⑤	Transient Recovery Voltage Parameters are Based on TD-4: Peak Voltage (E_2) = (u_c)	Time to Peak ($T_2 = t_3 \times 1.137$)	TRV Rise Time (t_3)	RRRV = u_c/t_3 ⑥	Interrupting Time	
Units	kV rms	Hz	kV rms	kV Peak	A rms	kA rms sym	%	kA rms asym Total	kA Peak	rms	kV Peak	µsec	µsec	kV/ µsec	ms	Cycles (60 Hz)
50 VCP-W 50	4.76	60	13.3	60	1200 2000 3000	50	44	59	130	50	8.2	50	44	0.19	50	5
150 VCP-W 50	7.2	60	18.2	60	1200 2000 3000	50	44	59	130	50	25.7	75	66	0.39	50	5

① All circuit breakers are tested at 60 Hz; however, they can also be applied at 50 Hz with no derating.

② Because the voltage range factor K = 1, the short-time withstand current and the maximum symmetrical interrupting current are equal to the rated symmetrical interrupting current.

③ Based on the standard dc time constant of 45 ms (corresponding to X/R of 17 for 60 Hz) and the minimum contact parting time as determined from the minimum opening time plus the assumed minimum relay time of 1/2 cycle (8.33 ms for 60 Hz).

④ The asymmetrical interrupting current, I total, is given by (I_t) = I x Sqrt (1 + 2 x %dc x %dc) kA rms asymmetrical total.

⑤ Duration of short-time current and maximum permissible tripping delay are both 2 seconds for all circuit breakers listed in this table, as required in C37.04-1999, C37.06-2000 and C37.06-2009.

⑥ RRRV can also be calculated as = 1.137 x E_2/T_2.

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Table 10.1-13. VCP-W Breaker Stored Energy Mechanism Control Power Requirements

Rated Control Voltage	Spring Charge Motor: Run Amperes	Spring Charge Motor: Time (Seconds)	Spring Charge Motor: Close or Trip Amperes	UV Trip mA (Maximum)	Voltage Range: Close	Voltage Range: Trip	Indicating Light Amperes
48 Vdc	9.0	6	16	200	38–56	28–56	0.35
125 Vdc	4.0	6	7	80	100–140	70–140	0.35
250 Vdc	2.0	6	4	40	200–280	140–280	0.35
120 Vac	4.0	6	6	—	104–127	104–127	0.35
240 Vac	2.0	6	3	—	208–254	208–254	0.35

Table 10.1-14. Heat Loss in Watts at Full Rating, at 60 Hz

Breaker Rating	1200 A	2000 A	3000 A
5 kV or 7.2 kV	1350 W	1550 W	2250 W

Contactor-Fuse Coordination

The AMGARD starter provides ensured coordination between its fuses, contactor, current transformers, protective relays, and the motor it is controlling.

One of the most critical coordination issues is between the contactor and the starter fuses. The fuses must interrupt faults greater than the interrupting rating of the contactor. The AMPGARD 400 A high interrupting contactor (SL400A-HI) has an 8-cycle dropout time factory setting as standard and will interrupt at 8500 A. The maximum size fuse used with an SL400A-HI contactor is a 450-24R. By comparing the fuse curve with the contactor rating, it can be observed that for faults greater than 8500 A, the fuse will open before the contactor. With faults less than 8500 A, the contactor may clear the fault before the fuse blows, depending on the settings of the protective relays. Refer to **Figure 10.1-5** for an illustration of AMPGARD coordination.

Other vacuum contactors available today may have lower interrupting ratings than the AMPGARD Type SL vacuum contactors. Dropout times also vary, and may be as short as two cycles on other starter designs. Lower interrupting ratings and shorter dropout times can result in fault current levels where the contactor may be required to interrupt a fault greater than its rating. This can result in equipment failure. Refer to **Figure 10.1-6** for an illustration of an improperly coordinated starter.

AMPGARD starters also ensure coordination between other starter components. The current transformers and protective relays are selected to work properly with each other, and to protect the motor. Protective relays like Eaton's EMR-3000 provide optimal motor protection, while also rapidly opening the contactor during fault conditions. This rapid opening signal cannot open the contactor in less than its set dropout time, but it will take the motor off-line in the shortest possible time.

This will help minimize mechanical damage to the motor and may prevent the starter fuses from blowing by allowing the contactor to clear the fault (only if the fault is less than the contactor interrupting rating).

AMPGARD starters use 400 A standard interrupting contactors (SL400-SI) when the contactor is not required to coordinate with the starter main fuse. An example of this application is the run contactor of a reduced voltage starter.

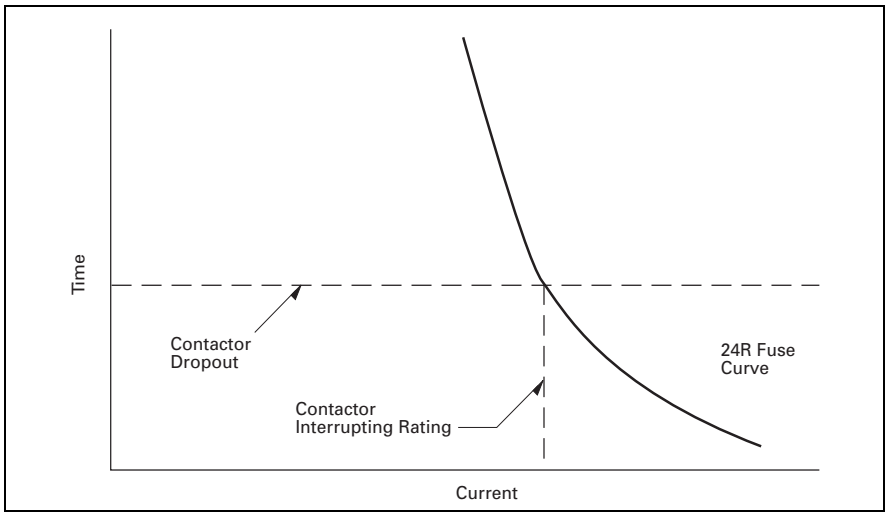

Figure 10.1-5. Proper Contactor Fuse Coordination Found in AMPGARD Starter

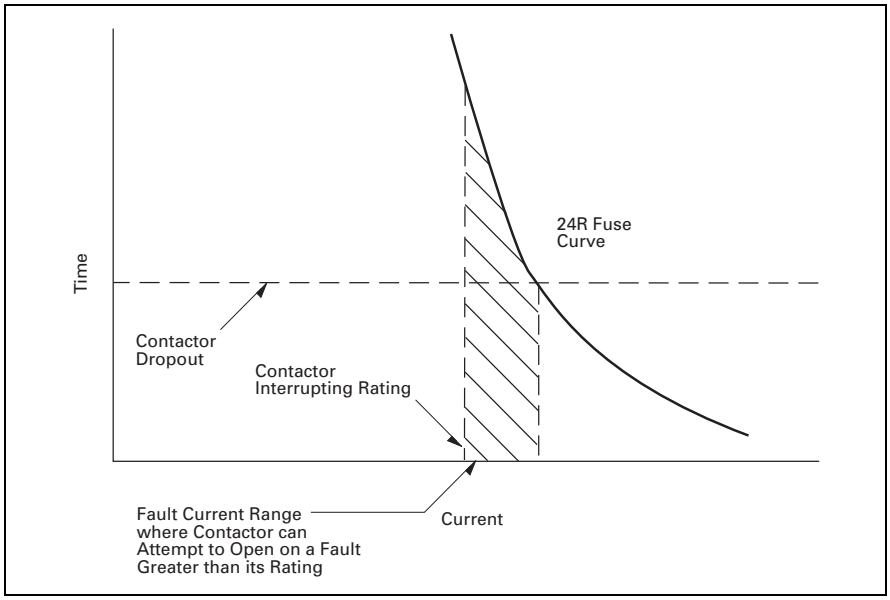

Figure 10.1-6. Contactor Fuses That Are Not Properly Coordinated

10

Protection Considerations

Coordinated with the motor's characteristics, the protective devices in the AMPGARD starter provide motor protection from overload to full system capacity faults.

AMPGARD starters are supplied with an adjustable thermal overload relay as standard.

Multi-function solid-state motor protection relays are a common option on AMPGARD starters. The EMR-3000 is typically provided when a multi-function relay is specified. The EMR-3000 provides many types of protection including overload, locked rotor, ground fault and phase loss/phase unbalance. The EMR-3000 also provides start control logic to protect the motor against excessive starting. The relay may be applied to either across-the-line or reduced voltage starters. On reduced voltage starters, the EMR-3000 can control the transition from reduced to full voltage, offering the greatest protection for the motor and starter. An optional RTD module can be supplied for motors with built-in RTDs. The EMR-4000 can be supplied when voltage monitoring and protection are required.

EMR-3000 Motor Protective Relay

InsulGard™ relays are an available option on AMPGARD starters. The InsulGard provides early warning of increasing partial discharge levels in the starting equipment, cables and motor. This early warning will help the user to better schedule maintenance and avoid unplanned downtime.

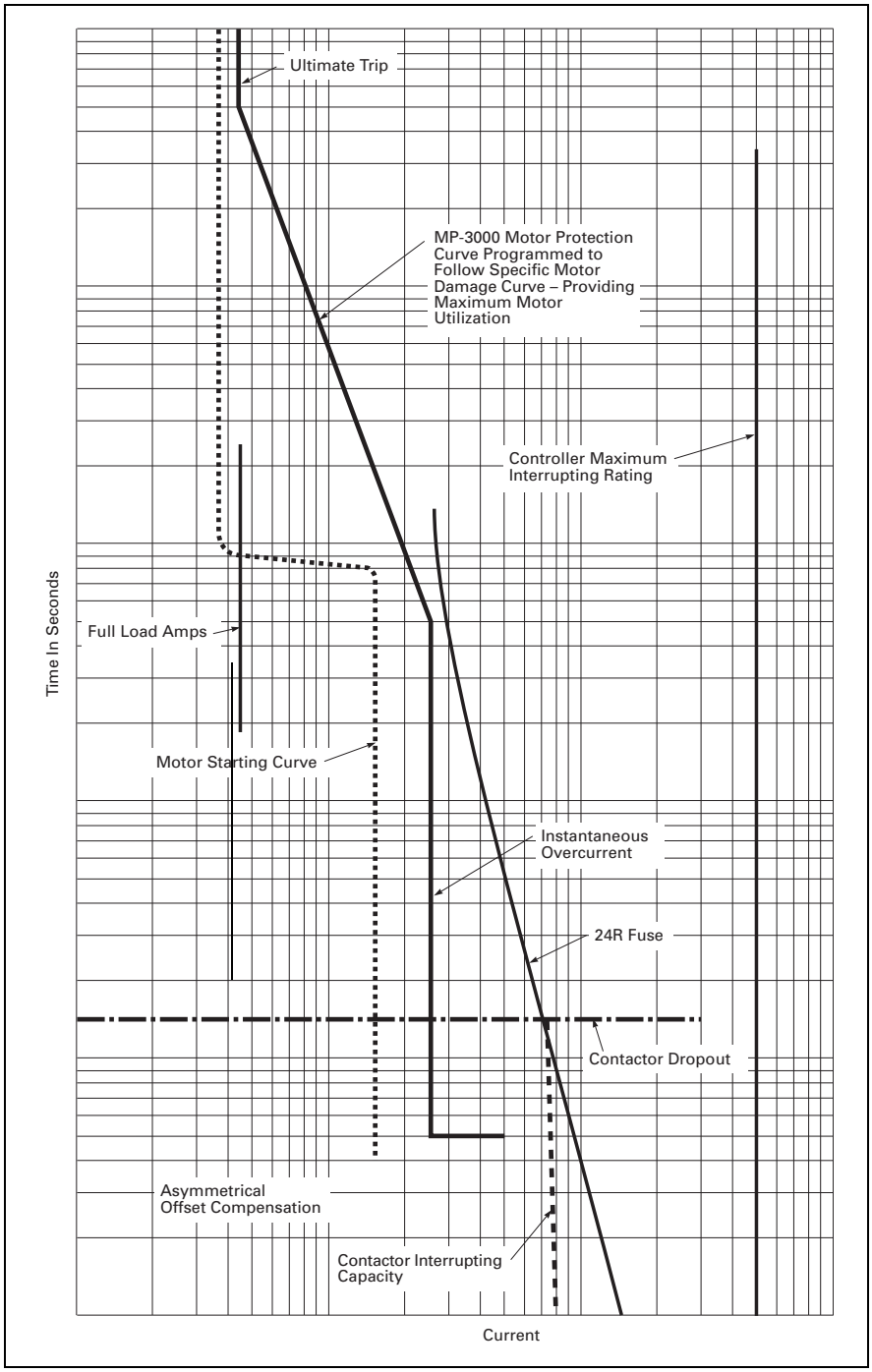

Figure 10.1-7. Full Range Coordinated Protection Between Current Limiting Type CLS Fuses, Vacuum Contactor and Motor Protection Relay

Starter Fuse Information

Table 10.1-15. R-Rated Fuses—Motor Application

Voltage	Starter Size	FLA-Min.	FLA-Max.	Fuse
5 kV	400 A	10.9	18.6	1R
		18.7	31.1	70-2R
		31.2	46.7	100-3R
		46.8	62.3	130-4R
		62.4	74.7	150-5R
		74.8	93.5	170-6R
		93.6	137	200-9R
		137.1	187	230-12R
		187.1	244	390-18R
		244.1	400	450-24R ①
	800 A	400.1	750	800-44R ②
7.2 kV	400 A	10.9	34.2	70-2R
		34.3	46.7	100-3R
		46.8	56.7	130-4R
		56.8	68.4	150-5R
		68.5	85.1	170-6R
		85.2	137	200-9R
		137.1	187	230-12R
		187.1	273	390-18R
		273.1	400	450-24R ①
	800 A	400.1	720	800-44R
15 kV	300 A	1	23.3	40A
		23.4	29.3	50A
		29.4	34.7	65A
		34.8	44	80A
		44.1	56	100A
		56.1	80	125A
		80.1	90.7	150A
		90.8	98.7	175A
		98.8	113.3	200A
		113.4	160	250A
		160.1	200	300A
		200.1	300	400A

① For FLA >360, verify motor LRA and accel times are within allowable fuse characteristics.

② For FLA >720, verify motor LRA and accel times are within allowable fuse characteristics.

Note: For motor applications, fuses are sized based on locked rotor amperes of 6-times full load amperes and acceleration time of 10 seconds.

Table 10.1-16. Current Transformer Application

Voltage	Starter Size	FLA-Min.	FLA-Max.	CT(R:5)
5 kV/7.2 kV	400 A	10	22.9	25
		23	41.9	50
		42	62.9	75
		63	82.9	100
		83	123.9	150
		124	165.9	200
		166	246.9	300
		247	328.9	400
		329	400	600
	800 A	401	492.9	600
		493	656.9	800
		657	750	1000

Note: CT class is C5 or higher. All have sufficient burden capability to drive most electronic overload relays.

Table 10.1-17. E-Rated Fuses—Feeder/Transformer Application

Voltage	Starter Size	FLA-Min.	FLA-Max.	Fuse
5 kV	400 A	1	7.1	10E
		7.2	10.7	15E
		10.8	14.3	20E
		14.4	17.9	25E
		18	21.4	30E
		21.5	28.6	40E
		28.7	35.7	50E
		35.8	46.4	65E
		46.5	57.1	80E
		57.2	71.4	100E
		71.5	89.3	125E
		89.4	107.1	150E
		107.2	125	175E
		125.1	142.9	200E
		143	178.6	250E
		178.7	214.3	300E
		214.4	250	350E
		250.1	285.7	400E
		285.8	321.4	450E
	800 A	321.5	428.6	600E
		428.7	535.7	750E
7.2 kV	400 A	1	7.1	10E
		7.2	10.7	15E
		10.8	14.3	20E
		14.4	17.9	25E
		18	21.4	30E
		21.5	28.6	40E
		28.7	35.7	50E
		35.8	46.4	65E
		46.5	57.1	80E
		57.2	71.4	100E
		71.5	89.3	125E
		89.4	107.1	150E
		107.2	125	175E
		125.1	142.9	200E
		143	178.6	250E
		178.7	214.3	300E
		214.4	250	350E
15 kV	300 A	1	300	400E

Note: For feeder (transformer) applications, fuses are sized for transformer full load amperes times 1.4.

Note: 350E is largest rating available in 7.2 kV rating; 400E rating is largest in 15 kV.

Table 10.1-18. Standard Voltage Transformer, 60 Hz Accuracy

kV Class	Standard Ratios	Burdens at 120 V	Thermal Rating VA at 55 °C	Metering VA at 55 °C
7.2	20, 30, 35, 40, 55, 60	0.3 WXMY 1.2Z	100	25
15	100, 105, 110, 115, 120	0.3 WXMYZ	500	10

Table 10.1-19. Standard Voltage Transformer Ratio Information

Rating—Volts	2400	3600	4200	4800	6600	7200	12,000	12,500	13,200	13,800	14,400
Ratio	20:1	30:1	35:1	40:1	55:1	60:1	100:1	105:1	110:1	115:1	120:1

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Layout Dimensions

Full Voltage Squirrel Cage Starters
Catalog S210 Non-Reversing
Catalog S310 Reversing

Equipment Details

Mounted in the Medium-Voltage Section

- Three incoming line connectors
- Drawout three-pole gang-operated line isolating switch assembly with isolating shutter, external operating handle interlocked to prevent opening the medium-voltage compartment door until the isolating switch is open and grounded
- Vertically mounted current limiting power fuses with pop-up blown fuse indicators
- One magnetic three-pole vacuum contactor with dc operating coils and mechanical interlock to prevent opening the isolating switch when contactor is closed
- One control power transformer (115 V secondary)
- Two CPT primary current limiting fuses
- Four electrical interlocks (2NO, 2NC)
- Three current transformers

Reversing Starter

One additional magnetic three-pole vacuum contactor (duplicate of above), both contactors are mechanically and electrically interlocked.

Mounted in the Low-Voltage Compartment

- Control panel with:
  - One EMR-3000 motor protection relay
  - One interposing control relay
- Set of control circuit terminal blocks
  - One control circuit secondary fuse
  - One run-test circuit

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Specifications

Table 10.1-20. Starter Selection Information—Dimensions in Inches (mm)

Horsepower ①	Volts	Contactor Ampere Rating (Enclosed)	Starter Interrupting Rating (kVA)	Equipment Arrangement Number	Dimensions			Additional Starter Spaces	Weight Lbs (kg)
					Height ②	Width	Depth		
2200–2400 V Non-Reversing									
700/800 ③	2300	400	200,000	1	80 (2032)	36 (914)	30 (762)	1 ⑤	1350 (613)
1500/1750 ④	2300	400	200,000	1	80 (2032)	36 (914)	30 (762)	1 ⑤	1350 (613)
3000	2300	720	200,000	2	80 (2032)	36 (914)	30 (762)	0	1700 (772)
2200–2400 V Reversing									
700/800 ③	2300	400	200,000	3	80 (2032)	36 (914)	30 (762)	0	1800 (817)
1500/1750 ④	2300	400	200,000	3	80 (2032)	36 (914)	30 (762)	0	1800 (817)
3000	2300	720	200,000	4	80 (2032)	36 (914)	30 (762)	0	2400 (1090)
4000–4800 V Non-Reversing									
1250/1500 ③	4600	400	400,000	1	80 (2032)	36 (914)	30 (762)	1 ⑤	1350 (613)
2500/3000 ④	4600	400	400,000	1	80 (2032)	36 (914)	30 (762)	1 ⑤	1350 (613)
5500	4600	720	400,000	2	80 (2032)	36 (914)	30 (762)	0	1700 (772)
4000–4800 V Reversing									
1250/1500 ③	4600	400	400,000	3	80 (2032)	36 (914)	30 (762)	0	1800 (817)
2500/3000 ④	4600	400	400,000	3	80 (2032)	36 (914)	30 (762)	0	1800 (817)
5500	4600	720	400,000	4	80 (2032)	36 (914)	30 (762)	0	2400 (1090)
6600 V Non-Reversing									
2000/2250 ③	6600 ⑥	400	570,000	1	80 (2032)	36 (914)	30 (762)	1 ⑤	1500 (681)
4000/4500 ④	6600 ⑥	400	570,000	1	80 (2032)	36 (914)	30 (762)	1 ⑤	1500 (681)
8000	6600 ⑥	720	570,000	2	80 (2032)	36 (914)	30 (762)	0	1800 (817)
6600 V Reversing									
2000/2250 ③	6600 ⑥	400	570,000	3	80 (2032)	36 (914)	30 (762)	0	1800 (817)
4000/4500 ④	6600 ⑥	400	570,000	3	80 (2032)	36 (914)	30 (762)	0	1800 (817)
8000	6600 ⑥	720	570,000	4	80 (2032)	36 (914)	30 (762)	0	2400 (1090)

① Horsepower based on NEMA standard design B motor at 1800 rpm.
② When horizontal bus is added, height becomes 92.00 inches (2336.8 mm).
③ At higher hp rating, maximum acceleration time is 3.5 seconds.
④ At higher hp rating, maximum acceleration time is 6 seconds.
⑤ Maximum current for two starters in a single structure is 720 A.
⑥ May be applied on 6900 V systems where maximum voltage does not exceed 7200 V.

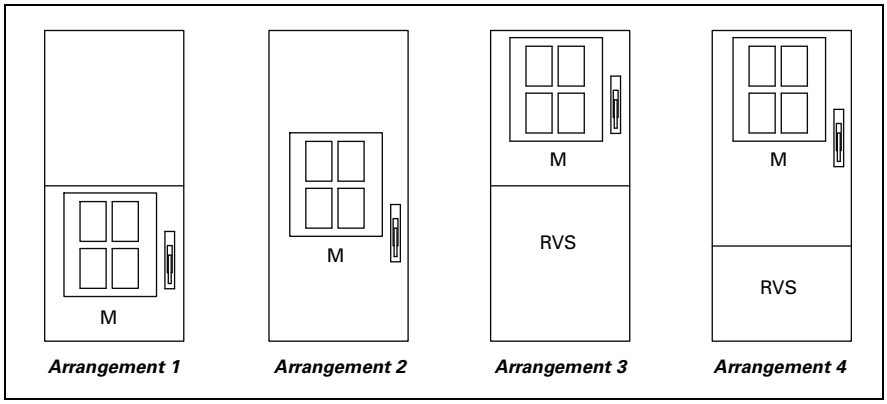

Figure 10.1-8. Starter Arrangements

Dimensions for estimating purposes only.

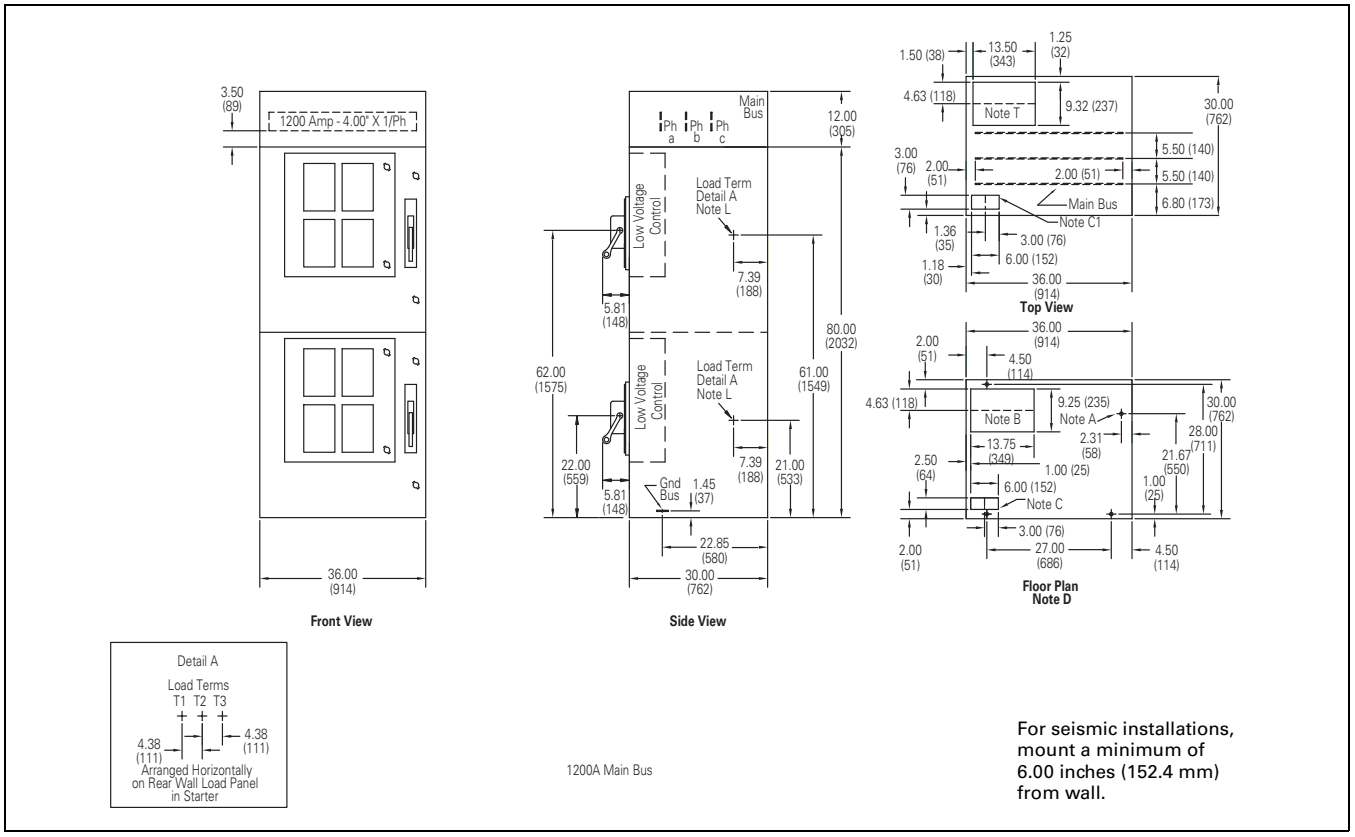

Figure 10.1-9. Arrangement 1 Detail (Full Voltage 400 A)—See Table 10.1-27 on Page 10.1-37 for Notes

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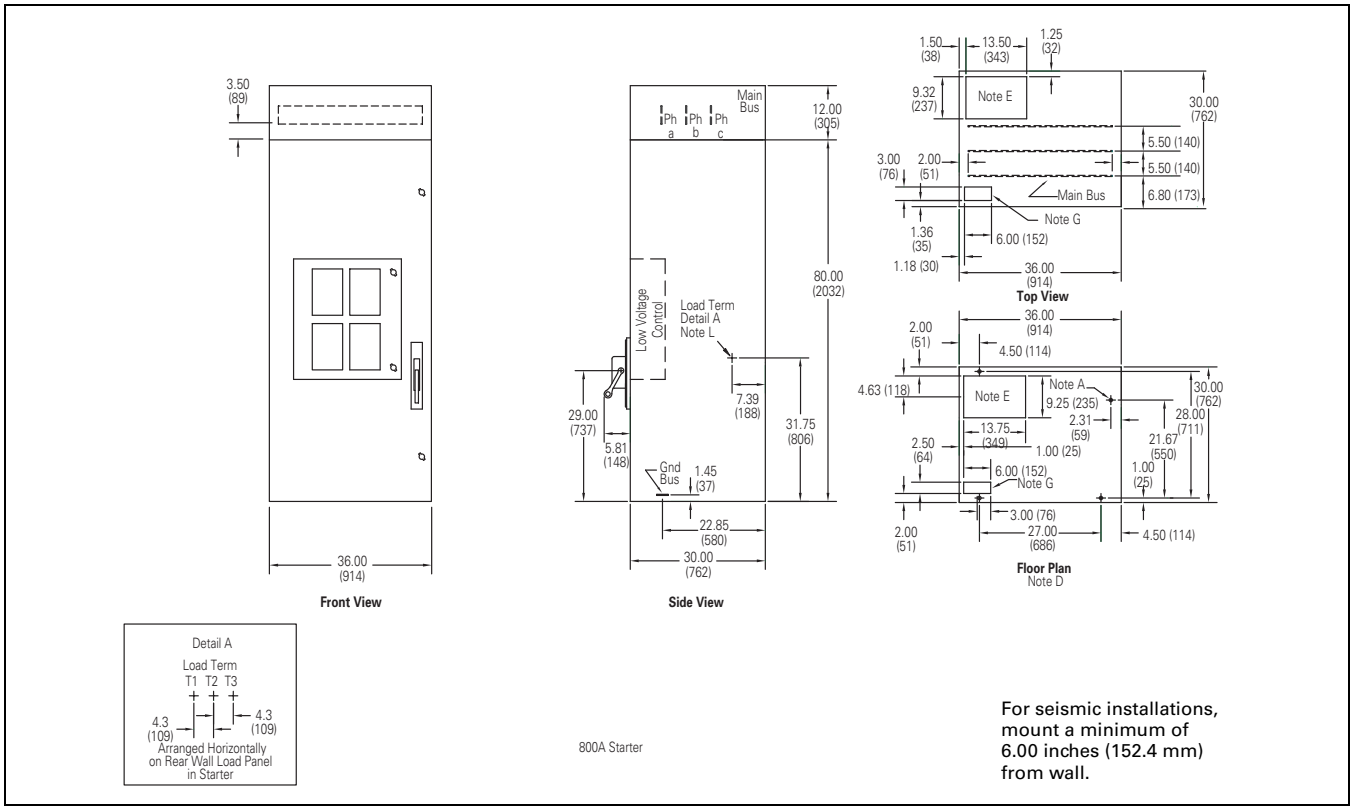

Figure 10.1-10. Arrangement 2 Detail (Full Voltage 800 A)—See Table 10.1-27 on Page 10.1-37 for Notes

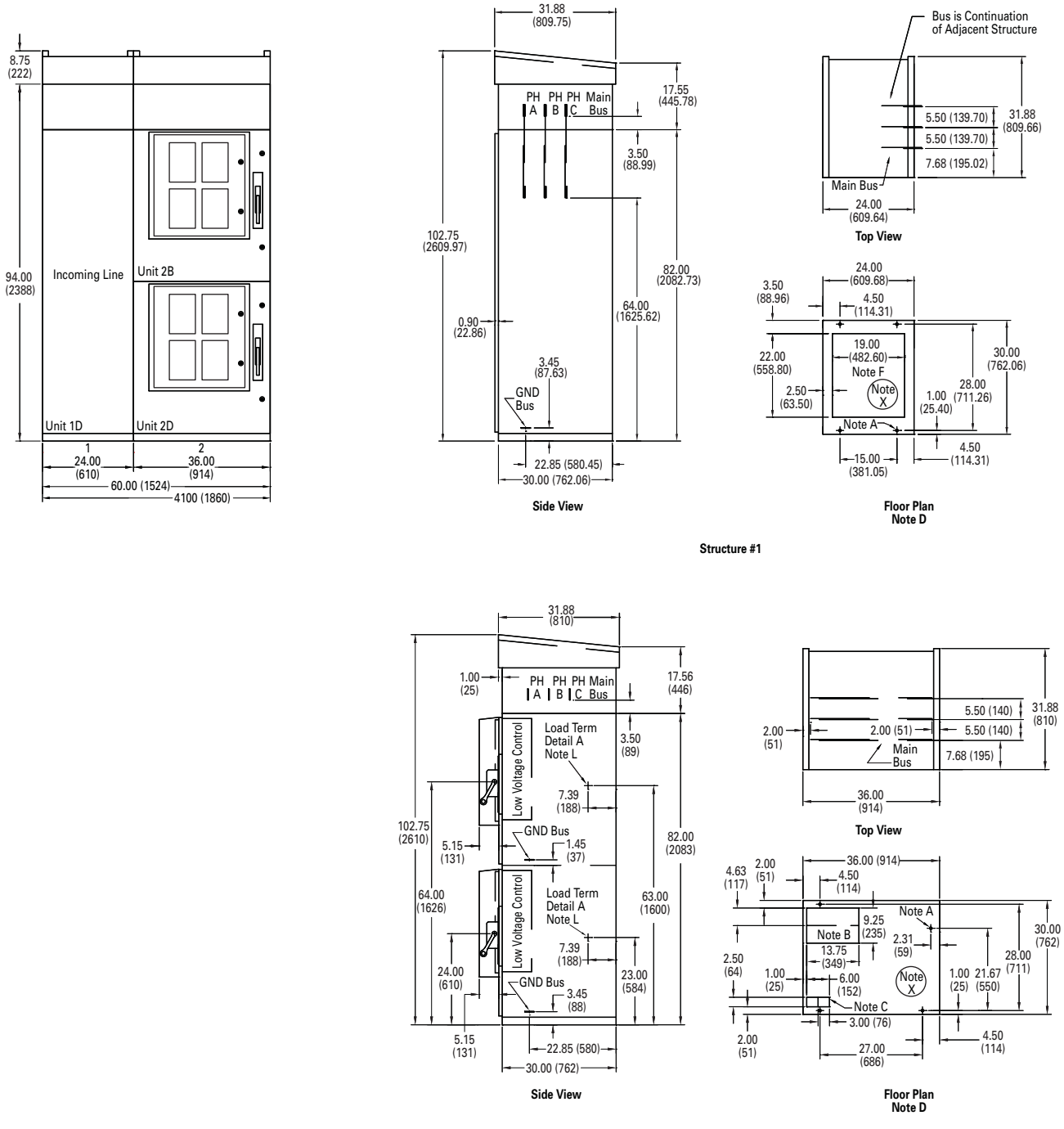

Figure 10.1-11. Arrangement Detail (Full Voltage 400 A) NEMA 3R

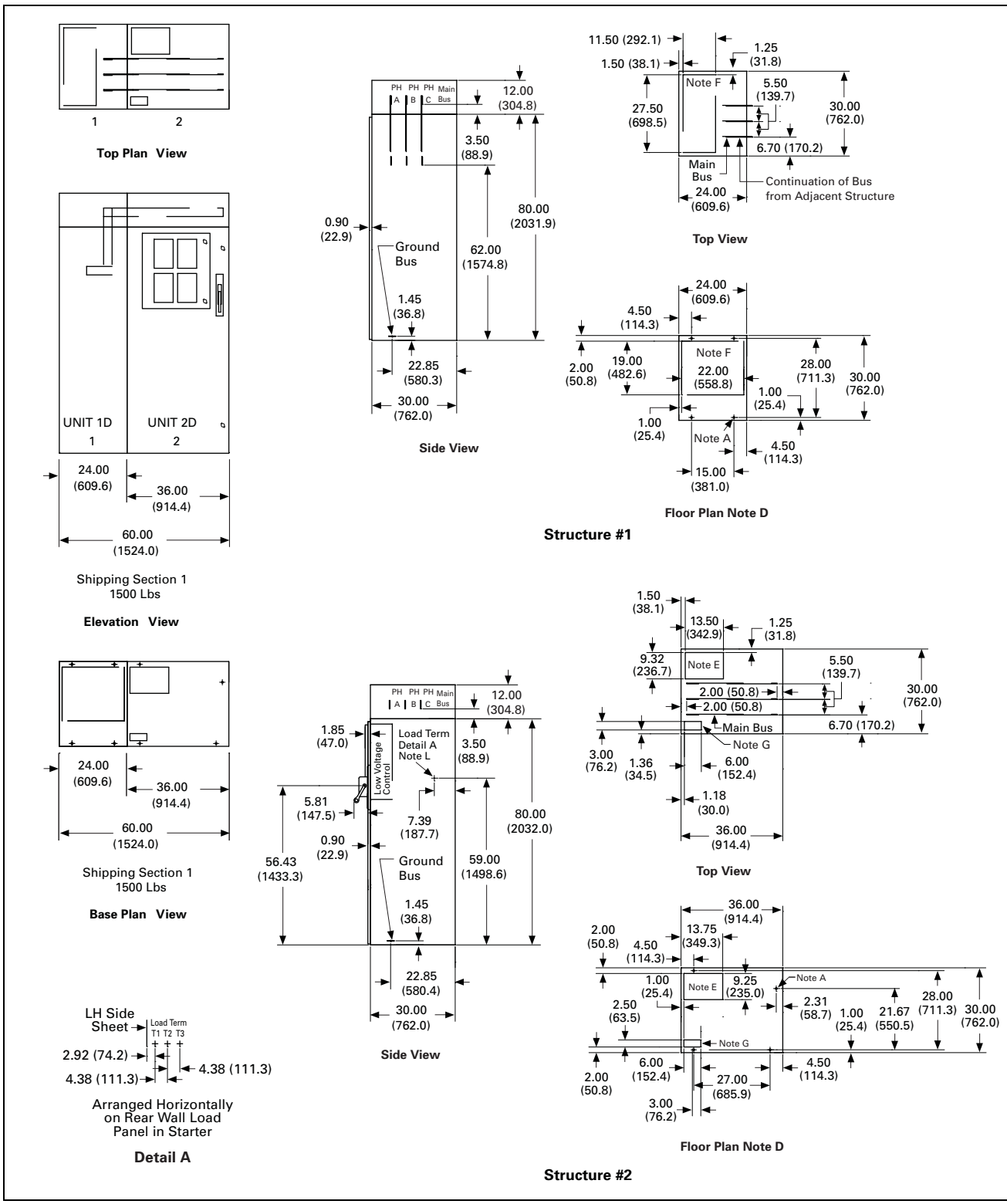

Figure 10.1-12. Arrangement 1 Detail (Full Voltage 15 kV)—See Table 10.1-27 on Page 10.1-37 for Notes

Primary Reactor, Reduced Voltage Starters Catalog S510 Non-Reversing Catalog S710 Reversing

Mounted in the Medium-Voltage Section

- Three incoming line connectors
- One drawout three-pole gang-operated line isolation switch assembly with isolating shutter, external operating handle interlocked to prevent opening the medium-voltage compartment door until the isolating switch is open and grounded
- One vertically mounted current limiting power fuse with pop-up blown fuse indicators
- One magnetic three-pole vacuum contactor with dc operating coils and mechanical interlock to prevent opening the isolation switch when the contactor is closed
- One control power transformer (115 V secondary)
- Two CPT primary current limiting fuses
- Four electrical interlocks (2NO, 2NC)

Reversing Starter

One additional magnetic contactor (duplicate of above), both contactors are mechanically and electrically interlocked.

Mounted in the Low-Voltage Compartment

- One control panel with:
  - ❑ One EMR-3000 motor protection relay
  - ❑ Two interposing relays
- One set of control circuit terminal blocks
  - ❑ One control circuit secondary fuse
  - ❑ One run-test circuit

Reduced Voltage Structure

- One magnetic three-pole vacuum run contactor with dc operating coil and electrical interlocks
- Three current transformers
- One medium-duty starting reactor with 50–65–80% taps

Locked Rotor Amps

- Locked Rotor Amps (LRA) must be specified to ensure proper sizing of reactor

Starting Characteristics

Table 10.1-21. Type 502 Reactor Starting Characteristics

Starter Type	% Motor Voltage	% Motor Current	% Line Current	% Torque
80% tap	80	80	80	64
65% tap ①	65	65	65	42
50% tap	50	50	50	25

① Factory set on 65% tap.

Specifications

Table 10.1-22. Starter Selection Information—Dimensions in Inches (mm)

Horsepower ②	Volts	Contactor Ampere Rating (Enclosed)	Starter Interrupting Rating (kVA)	Equipment Arrangement Number	Dimensions			Weight Lb (kg)
					Height ③	Width	Depth	
2200–2400 V Non-Reversing								
700/800 ④	2300	400	200,000	1	80 (2032)	72 (1829)	30 (762)	2800 (1271)
1500/1750 ⑤	2300	400	200,000	1	80 (2032)	72 (1829)	30 (762)	2800 (1271)
3000	2300	720	200,000	2	80 (2032)	72 (1829)	30 (762)	4000 (1816)
2200–2400 V Reversing								
700/800 ④	2300	400	200,000	3	80 (2032)	72 (1829)	30 (762)	3250 (1476)
1500/1750 ⑤	2300	400	200,000	3	80 (2032)	72 (1829)	30 (762)	3250 (1476)
3000	2300	720	200,000	4	80 (2032)	72 (1829)	30 (762)	4650 (2111)
4000–4800 V Non-Reversing								
1250/1500 ④	4600	400	400,000	1	80 (2032)	72 (1829)	30 (762)	2800 (1271)
2500/3000 ⑤	4600	400	400,000	1	80 (2032)	72 (1829)	30 (762)	2800 (1271)
5500	4600	720	400,000	2	80 (2032)	72 (1829)	30 (762)	4000 (1816)
4000–4800 V Reversing								
1250/1500 ④	4600	400	400,000	3	80 (2032)	72 (1829)	30 (762)	3250 (1476)
2500/3000 ⑤	4600	400	400,000	3	80 (2032)	72 (1829)	30 (762)	3250 (1476)
5500	4600	720	400,000	4	80 (2032)	72 (1829)	30 (762)	4650 (2111)
6600 V Non-Reversing								
2000/2250 ④	6600	400	570,000	1	80 (2032)	72 (1829)	30 (762)	3300 (1498)
4000/4500 ⑤	6600	400	570,000	1	80 (2032)	72 (1829)	30 (762)	3300 (1498)
8000	6600	720	570,000	2	80 (2032)	72 (1829)	30 (762)	4650 (2111)
6600 V Reversing								
2000/2250 ④	6600	400	570,000	3	80 (2032)	72 (1829)	30 (762)	3250 (1476)
4000/4500 ⑤	6600	400	570,000	3	80 (2032)	72 (1829)	30 (762)	3250 (1476)
8000	6600	720	570,000	4	80 (2032)	72 (1829)	30 (762)	4650 (2111)

② Horsepower based on NEMA standard design B motor at 1800 rpm.
③ When horizontal bus is added, height becomes 92.00 inches (2336.8 mm).
④ At higher hp rating maximum acceleration time is 3.5 seconds.
⑤ At higher hp rating maximum acceleration time is 6 seconds.

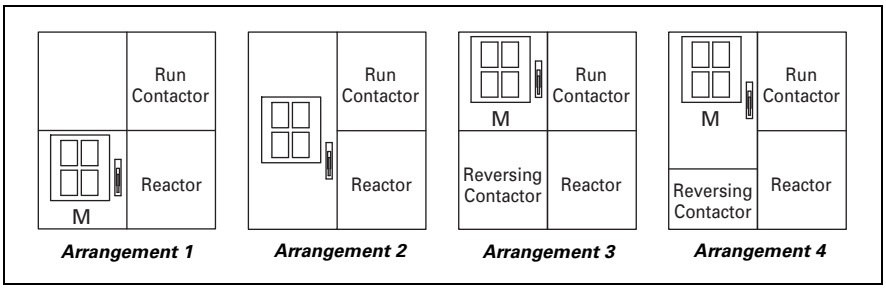

Figure 10.1-13. Starter Arrangements

Dimensions for estimating purposes only.

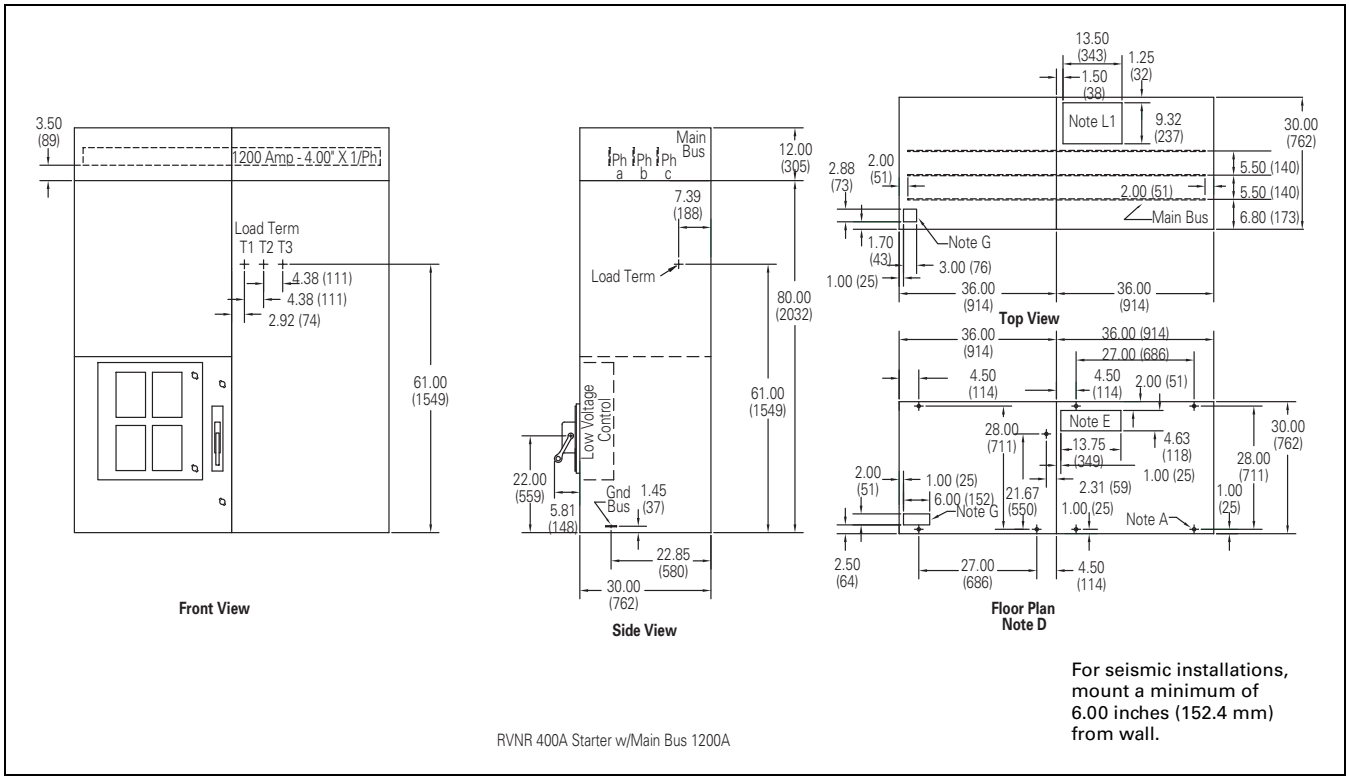

Figure 10.1-14. Arrangement 1 Detail (Reduced Voltage, 400 A)—See Table 10.1-27 on Page 10.1-37 for Notes (this outline applies to both reactor and autotransformer type starters)

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Reduced Voltage Autotransformer Starters Catalog S610 Non-Reversing Catalog S810 Reversing

Mounted in the Medium-Voltage Section

- Three incoming line connectors
- One drawout three-pole gang-operated line isolation switch assembly with isolating shutter, external operating handle interlocked to prevent opening the medium-voltage compartment door until the isolating switch is open and grounded
- Three vertically mounted current limiting power fuses with pop-up blown fuse indicators
- One magnetic three-pole vacuum contactor with dc operating coils and mechanical interlock to prevent opening the isolation switch when the contactor is closed
- One control power transformer (115 V secondary)
- Two CPT primary current limiting fuses
- Four electrical interlocks (2NO, 2NC)

Reversing Starter

One additional magnetic contactor (duplicate of above), both contactors are mechanically and electrically interlocked.

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Mounted in the Low-Voltage Compartment

- One control panel with:
  - ❑ One EMR-3000 motor protection relay
  - ❑ Three interposing relays
- One set of control circuit terminal blocks
  - ❑ One control circuit secondary fuse
  - ❑ One run-test circuit

Reduced Voltage Structure(s)

- One magnetic three-pole vacuum run contactor with dc operating coil and electrically and mechanically interlocked with the starting contactor
- One magnetic two-pole vacuum start contactor with dc operating coil and electrical and mechanical interlocks
- Three current transformers
- One medium-duty starting auto-transformer with 50–65–80% taps
- Three distribution class lightning arresters for high-voltage stress protection on the transformer zero tap

Locked Rotor Amps

- Locked Rotor Amps (LRA) must be specified to ensure proper sizing of autotransformer

Starting Characteristics

Table 10.1-23. Type 602 Auto-transformer Starting Characteristics

Starter Type	% Motor Voltage	% Motor Current	% Line Current	% Torque
80% tap	80	80	67	64
65% tap ①	65	65	45	42
50% tap	50	50	28	25

① Factory set on 65% tap.

Specifications

Table 10.1-24. Starter Selection Information—Dimensions in Inches (mm)

Horsepower ②	Volts	Contactor Ampere Rating (Enclosed)	Starter Interrupting Rating (kVA)	Equipment Arrangement Number	Dimensions			Number of Structures	Weight Lb (kg)
					Height ③	Width	Depth		
2200–2400 V Non-Reversing									
700/800 ④	2300	400	200,000	1	80 (2032)	72 (1829)	30 (762)	2	3100 (1407)
1500/1750 ⑤	2300	400	200,000	1	80 (2032)	72 (1829)	30 (762)	2	3100 (1407)
3000	2300	720	200,000	2	80 (2032)	112 (2844)	30 (762)	3	4800 (2179)
2200–2400 V Reversing									
700/800 ④	2300	400	200,000	3	80 (2032)	72 (1829)	30 (762)	2	3650 (1657)
1500/1750 ⑤	2300	400	200,000	3	80 (2032)	72 (1829)	30 (762)	2	3650 (1657)
3000	2300	720	200,000	4	80 (2032)	112 (2844)	30 (762)	3	5650 (2565)
4000–4800 V Non-Reversing									
1250/1500 ④	4600	400	400,000	1	80 (2032)	72 (1829)	30 (762)	2	3100 (1407)
2500/3000 ⑤	4600	400	400,000	1	80 (2032)	72 (1829)	30 (762)	2	3100 (1407)
5500	4600	720	400,000	2	80 (2032)	112 (2844)	30 (762)	3	4800 (2179)
4000–4800 V Reversing									
1250/1500 ④	4600	400	400,000	3	80 (2032)	72 (1829)	30 (762)	2	3650 (1657)
2500/3000 ⑤	4600	400	400,000	3	80 (2032)	72 (1829)	30 (762)	2	3650 (1657)
5500	4600	720	400,000	4	80 (2032)	112 (2844)	30 (762)	3	5650 (2565)
6600 V Non-Reversing									
2000/2250 ④	6600	400	570,000	1	80 (2032)	72 (1829)	30 (762)	2	3100 (1407)
4000/4500 ⑤	6600	400	570,000	1	80 (2032)	72 (1829)	30 (762)	2	3100 (1407)
8000	6600	720	570,000	2	80 (2032)	112 (2844)	30 (762)	3	4800 (2179)
6600 V Reversing									
2000/2250 ④	6600	400	570,000	3	80 (2032)	72 (1829)	30 (762)	3	3650 (1657)
4000/4500 ⑤	6600	400	570,000	3	80 (2032)	72 (1829)	30 (762)	3	3650 (1657)
8000	6600	720	570,000	4	80 (2032)	112 (2844)	30 (762)	4	5650 (2565)

② Horsepower based on NEMA standard design B motor at 1800 rpm.
③ When horizontal bus is added, height becomes 92.00 inches (2336.8 mm).
④ At higher hp rating, maximum acceleration time is 3.5 seconds.
⑤ At higher hp rating, maximum acceleration time is 6 seconds.

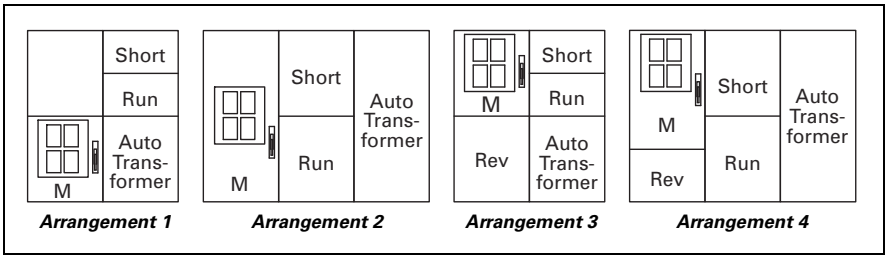

Figure 10.1-15. Starter Arrangements

Dimensions for estimating purposes only.

Full Voltage Synchronous Starters, Brush Type Controller Catalog S241 Non-Reversing Catalog S341 Reversing

Mounted in the Medium-Voltage Section

- Three incoming line connectors
- One drawout three-pole gang-operated line isolation switch assembly with isolating shutter. External operating handle interlocked to prevent opening the medium-voltage compartment door until the isolating switch is open and grounded
- Three vertically mounted current limiting power fuses with pop-up blown fuse indicators
- One magnetic three-pole vacuum contactor with dc operating coils and mechanical interlock to prevent opening the isolation switch when the contactor is closed
- One control power transformer (115 V secondary)
- Two CPT primary current limiting fuses
- Four electrical interlocks (2NO, 2NC)
- Three current transformers

Reversing Starter

One additional magnetic contactor (duplicate of above), both contactors are mechanically and electrically interlocked.

Mounted in the Low-Voltage Compartment

- One control panel with:
  - ❑ One EMR-3000 motor protection relay
  - ❑ One interposing relay
  - ❑ One set of control circuit terminal blocks
  - ❑ One control circuit secondary fuse
  - ❑ One run-test circuit

Mounted in the Upper Compartment or Auxiliary Structure

One brush-type solid-state field panel:

- Mounted on door:
  - ❑ One ac line ammeter, panel type
  - ❑ One dc field ammeter, panel type
  - ❑ One exciter field potentiometer
  - ❑ One set of externally ventilated heatsinks
  - ❑ One graphic display
- Mounted on inside compartment:
  - ❑ One step-down exciter transformer three-phase
  - ❑ One "SCR" power supply panel
  - ❑ One synchronous control board
  - ❑ "MOV" surge protection
  - ❑ One three-phase CT
  - ❑ One ELC controller
  - ❑ One set of control circuit blocks
  - ❑ Three primary fuses
  - ❑ Three secondary fuses
- Mounted on top of starter:
  - ❑ One starting and field discharge resistor

Table 10.1-25. Starter Selection Information—Dimensions in Inches (mm)

Horsepower at 0.8 PF ①	Horsepower at 1.0 PF	Volts	Contactor Ampere Rating (Enclosed)	Starter Interrupting Rating (kVA)	Equipment Arrangement Number	Dimensions			Weight Lb (kg)
						Height ②③	Width	Depth	
2200–2400 V Non-Reversing									
700/800 ④	900/1000 ④	2300	400	200,000	1	80 (2032)	36 (914)	30 (762)	1500 (681)
1500/1750 ⑤	1750/2000 ⑤	2300	400	200,000	1	80 (2032)	36 (914)	30 (762)	1500 (681)
3000	3500	2300	720	200,000	2	80 (2032)	72 (1829)	30 (762)	2350 (1067)
2200–2400 V Reversing									
700/800 ④	900/1000 ④	2300	400	200,000	3	80 (2032)	72 (1829)	30 (762)	2100 (953)
1500/1750 ⑤	1750/2000 ⑤	2300	400	200,000	3	80 (2032)	72 (1829)	30 (762)	2100 (953)
3000	3500	2300	720	200,000	4	80 (2032)	72 (1829)	30 (762)	2900 (1317)
4000–4800 V Non-Reversing									
1250/1500 ④	1500/1750 ④	4600	400	400,000	1	80 (2032)	36 (914)	30 (762)	1550 (704)
2500/3000 ⑤	3000/3500 ⑤	4600	400	400,000	1	80 (2032)	36 (914)	30 (762)	1550 (704)
5500	6000	4600	720	400,000	2	80 (2032)	72 (1829)	30 (762)	2350 (1067)
4000–4800 V Reversing									
1250/1500 ④	1500/1750 ④	4600	400	400,000	3	80 (2032)	72 (1829)	30 (762)	2100 (953)
2500/3000 ⑤	3000/3500 ⑤	4600	400	400,000	3	80 (2032)	72 (1829)	30 (762)	2100 (953)
5500	6000	4600	720	400,000	4	80 (2032)	72 (1829)	30 (762)	2900 (1317)
6600 V Non-Reversing									
2000/2250 ④	2500/2750 ④	7200	400	570,000	1	80 (2032)	36 (914)	30 (762)	1700 (772)
4000/4500 ⑤	5000/5500 ⑤	7200	400	570,000	1	80 (2032)	36 (914)	30 (762)	1700 (772)
8000	10,000	7200	720	570,000	2	80 (2032)	72 (1829)	30 (762)	2500 (1135)
6600 V Reversing									
2000/2250 ④	2500/2750 ④	7200	400	570,000	3	80 (2032)	72 (1829)	30 (762)	2100 (953)
4000/4500 ⑤	5000/5500 ⑤	7200	400	570,000	3	80 (2032)	72 (1829)	30 (762)	2100 (953)
8000	10,000	7200	720	570,000	4	80 (2032)	72 (1829)	30 (762)	2900 (1317)

① Horsepower based on NEMA standard design B motor at 1800 rpm.
② When horizontal bus is added, height becomes 92.00 inches (2336.8 mm).
③ Starting and discharge resistors are mounted on top, add 13.00 inches (330.2 mm) to the height.
④ At higher hp rating maximum acceleration time is 3.5 seconds.
⑤ At higher hp rating maximum acceleration time is 6 seconds.

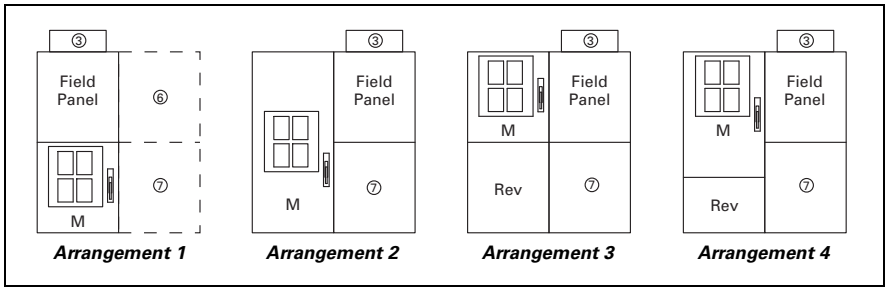

Figure 10.1-16. Starter Arrangements

⑥ When the field panel requirement exceeds 88 A at 125 Vdc or 44 A at 250 Vdc, an auxiliary structure 36.00 inches (914.4 mm) wide is required.
⑦ Mounting location of exciter transformer when field panel requirement exceeds 88 A at 125 Vdc or 44 A at 250 Vdc. Otherwise compartment is blank.

Dimensions for estimating purposes only.

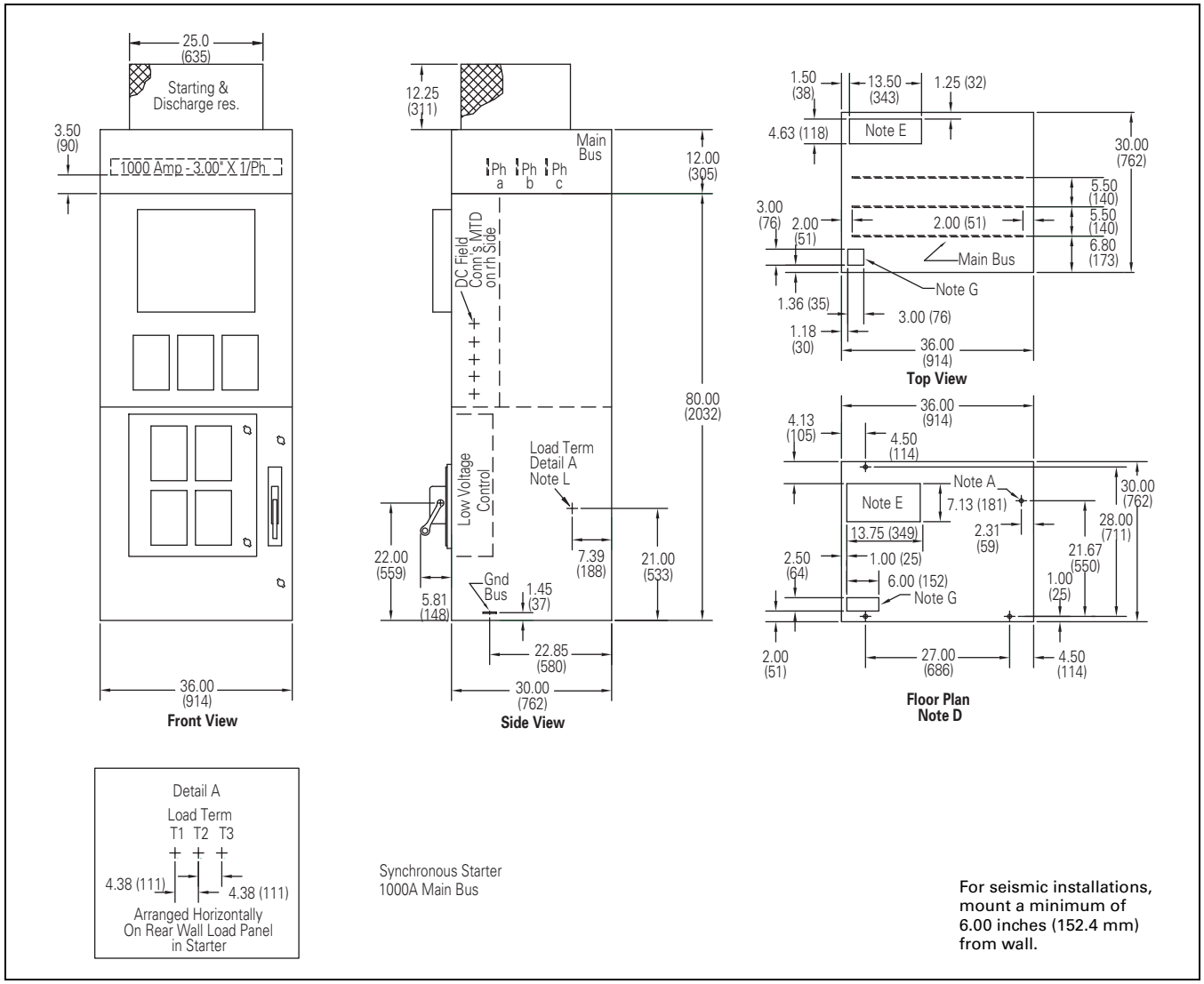

Figure 10.1-17. Arrangement 1 Detail (400 A Starter with Field Panel)—See Table 10.1-27 on Page 10.1-37 for Notes

Reduced Voltage Solid-State Soft Starter AMPGARD MV4S Starters

AMPGARD 400 A Soft Starter

Equipment Details

Mounted in the Medium-Voltage Sections

- Three incoming line connectors
- Drawout three-pole gang-operated line isolating switch assembly with isolating shutter, external operating handle interlocked to prevent opening the medium-voltage compartment door until the isolating switch is open and grounded
- Vertically mounted current limiting power fuses with pop-up blown fuse indicators
- One magnetic three-pole vacuum contactor with dc operating coils and mechanical interlock to prevent opening the isolating switch when contactor is closed
- One control power transformer (115 V secondary)
- Two CPT primary current limiting fuses
- Four electrical interlocks (2NO, 2NC)
- Three current transformers
- Withdrawable SCR truck with fully rated vacuum bypass contactor

Mounted in the Low-Voltage Compartment

- Control panel with:
  - One EMR-3000 motor protection relay
  - One interposing control relay
- Set of control circuit terminal blocks
  - One control circuit secondary fuse
  - One run-test circuit

Mounted in Lower Door Compartment

- Soft start control module with Modbus and RS-232 interface for remote communications
- User interface module with 2 x 20 character LCD display, 12 LEDs, and eight pushbuttons

Table 10.1-26. Starter Selection Information—Dimensions in Inches (mm)

Volts	Horsepower ①②	SCR/Contactor Ampere Rating	Starter Interrupting Rating (AIC)	Dimensions			Add. Starter Spaces	Weight Lb (kg)
				Height ③	Width ④	Depth		
2300 2300	1500 3000	400 720	50,000 50,000	92.00 (2336.8) 92.00 (2336.8)	36.00 (914.4) 72.00 (1828.8)	30.00 (762.0) 30.00 (762.0)	0 0	2000 (908) 4000 (1816)
3300 3300	1800 3600	400 720	50,000 50,000	92.00 (2336.8) 92.00 (2336.8)	36.00 (914.4) 72.00 (1828.8)	30.00 (762.0) 30.00 (762.0)	0 0	2000 (908) 4000 (1816)
4160 4160	2500 5000	400 720	50,000 50,000	92.00 (2336.8) 92.00 (2336.8)	36.00 (914.4) 72.00 (1828.8)	30.00 (762.0) 30.00 (762.0)	0 0	2000 (908) 4000 (1816)

① Horsepower based on NEMA standard design B motor at 1800 rpm.
② Based on maximum acceleration time of 30 seconds.
③ Includes horizontal bus.
④ Does not include incoming line provisions.

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Dimensions for estimating purposes only.

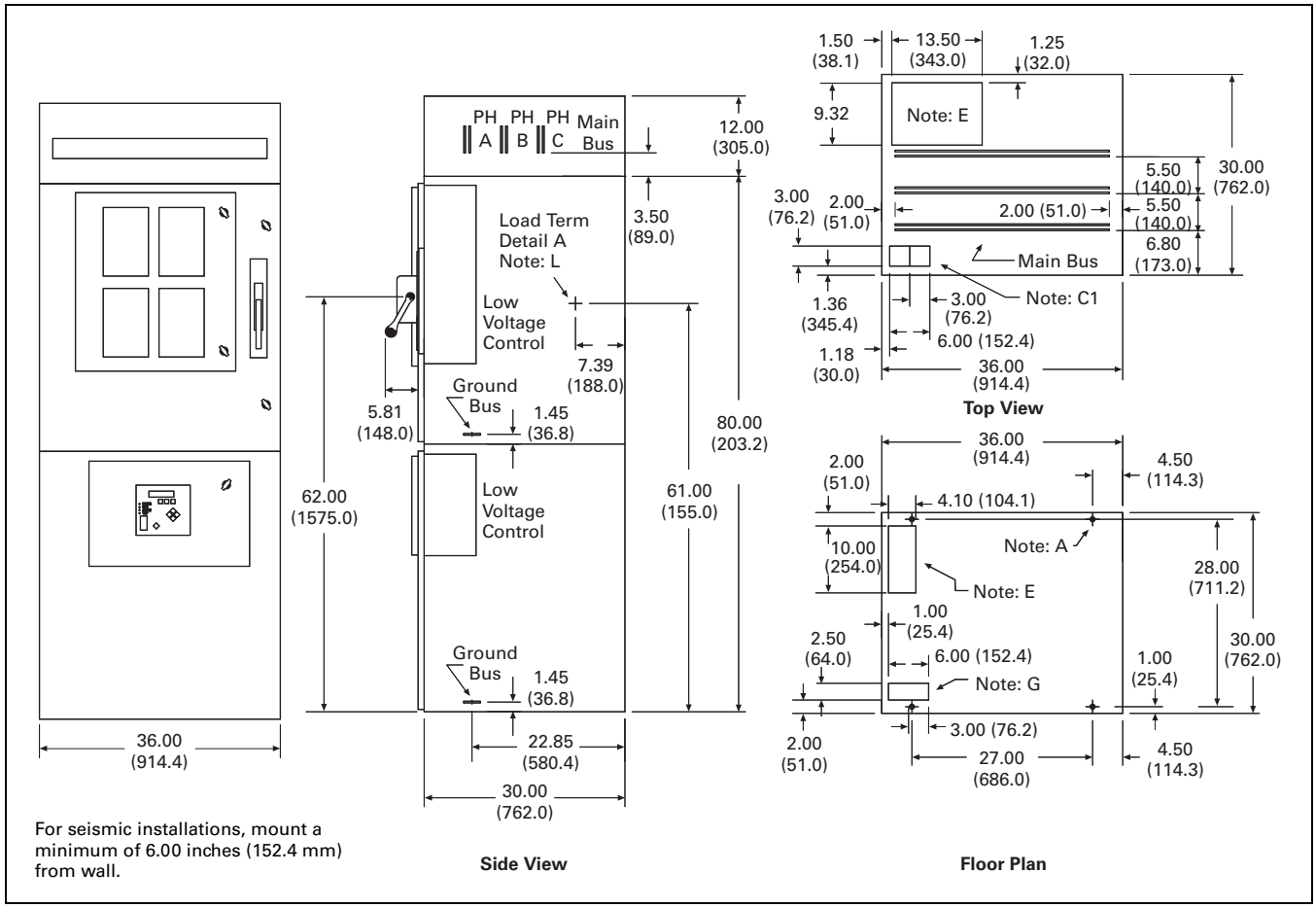

Figure 10.1-18. Arrangement Detail (400 A Solid-State Reduced Voltage)—See Table 10.1-27 on Page 10.1-37 for Notes

Table 10.1-27. Arrangement Detail Notes

Note	Description
Cable Notes	
	400 A starter load connection is designed for maximum of one 500 kcmil or two 350 kcmil.
	800 A starter load connection is designed for maximum of one 750 kcmil or two 500 kcmil.
Arrangement Notes	
A	0.875 dia. typical 4 holes. Mounting studs to extend a maximum of 2.00 inches (50.8 mm) above grade.
B	HV conduit space, load cables for two-high starters. Cables for lower starter enter in front half of conduit space, and cables for upper starter enter in rear half.
B1	HV conduit space, line and load cables for bottom entry stand-alone starters. Line cables should enter in rear half of conduit space, and load cables should enter in front half of conduit space.
C	LV conduit space for two-high starters with bottom entry control conduit. Control wiring for upper starter should enter in left half of conduit space, and lower starter control wiring should enter in right half of conduit space.
C1	LV conduit space for two-high starters with top entry control conduit. Control wiring for upper starter should enter in right half of conduit space, and lower starter control wiring should enter in left half of conduit space.
D	90 ° door swing requires 12.00 inches (304.8 mm) for 12.00-inch (304.8 mm) wide structure, 18.00 inches (457.2 mm) for 18.00-inch (457.2 mm) wide structure, 24.00 inches (609.6 mm) for 24.00-inch (609.6 mm) wide structure, 36.00 inches (914.4 mm) for 36.00-inch (914.4 mm) wide structure and 40.00 inches (1016.0 mm) for 40.00-inch (1016.0 mm) wide structure.
E	HV conduit space, load.
F	HV conduit space, line only.
F1	HV conduit space, line only. Line cables to enter in rear half of conduit space only.
G	LV conduit space only.
L	Load terminations located on rear wall of starter mounted on a load panel. Terminations are arranged horizontally from left to right. T1, T2, T3 left to right at 4.38-inch (111.3 mm) centers.
L1	Load terminations located on rear wall of reduced voltage enclosure mounted on a load panel. Terminations are arranged horizontally from left to right. T1, T2, T3 left to right at 4.38-inch (111.3 mm) centers.
T	HV conduit space, load cables for two-high starters. Cables for lower starter enter in rear half of conduit space, and cables for upper starter enter in front half.
X	Steel bottom with removable lead plates.
Y	Tolerances –0.0 inches +0.25 inches per structure.
Z	Conduits to extend a maximum of 2.00 inches (50.8 mm) into structure.

Incoming Line Switch/PT Layouts—Dimensions in Inches (mm)

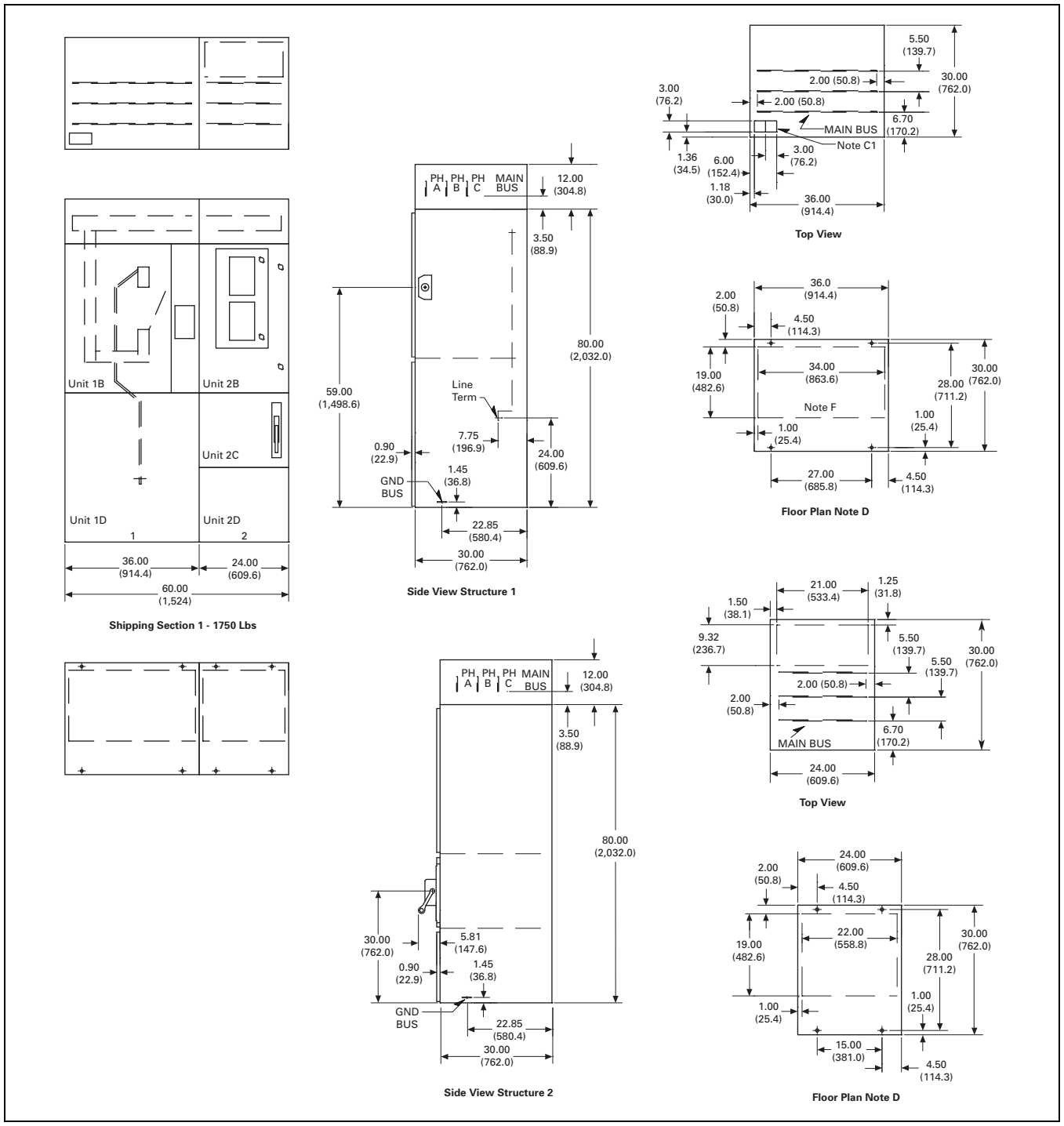

Figure 10.1-19. Incoming LBS, Bottom Entry up to 450 A Fuse, Unfused with Metering Section

Incoming Line Switch/PT Layouts—Dimensions in Inches (mm)

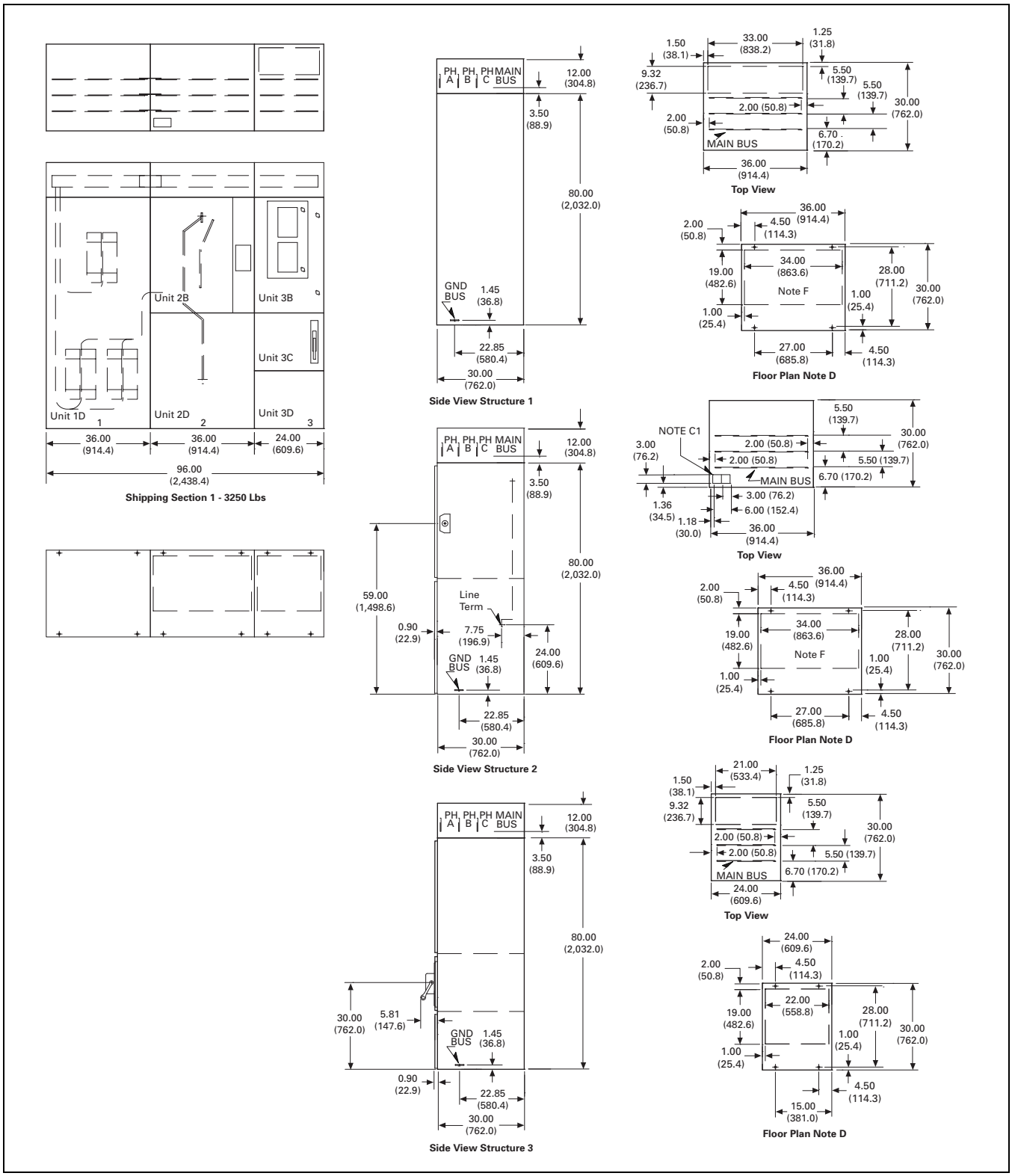

Figure 10.1-20. Incoming LBS, Bottom Entry, 600E/750E/1100E/1350E Fused with Metering Section

10

Tie Switch Layout—Dimensions in Inches (mm)

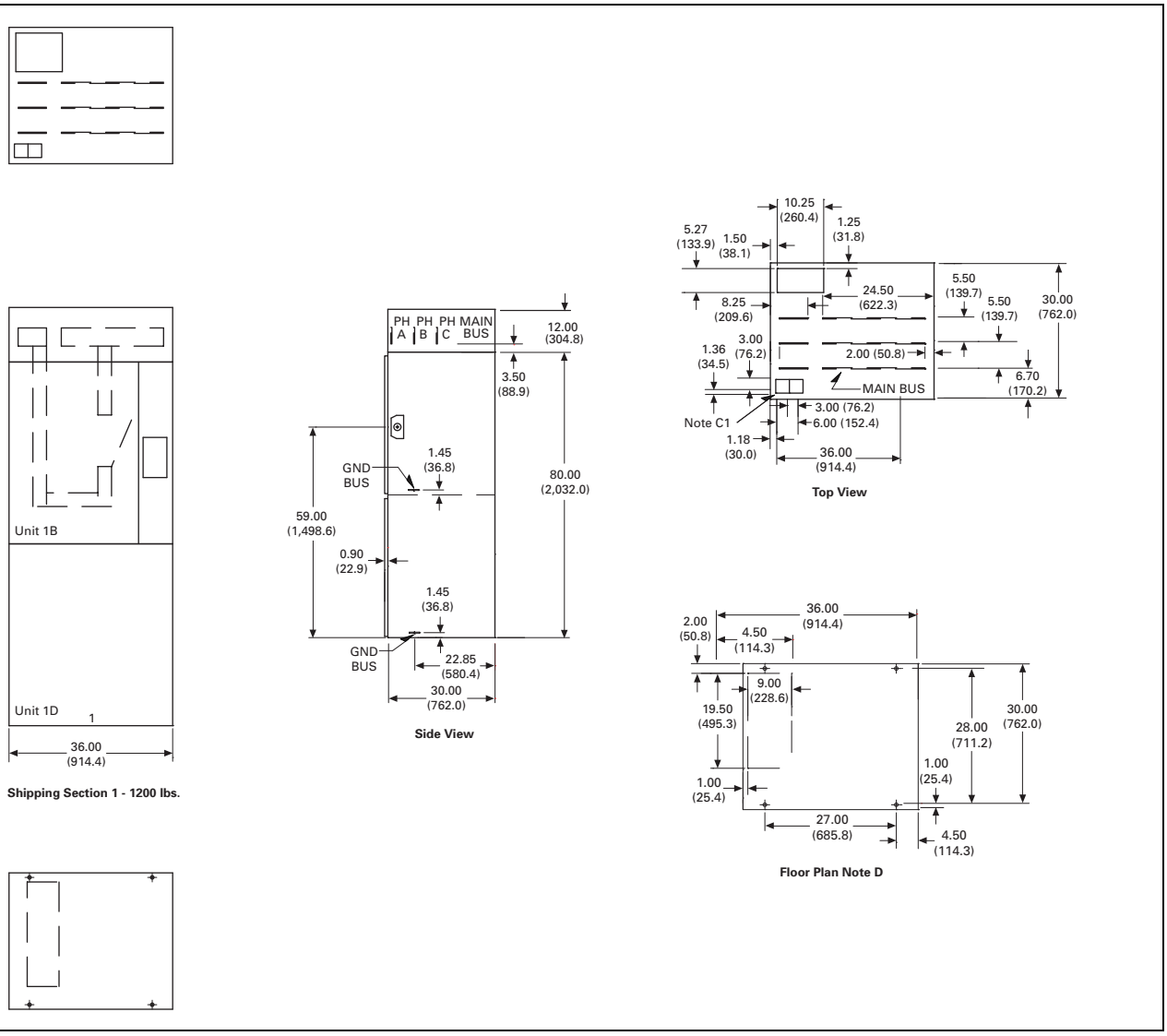

Figure 10.1-21. LBS Tie

Arc-Resistant Starter Layout—Dimensions in Inches (mm)

Notes:
For non-seismic installations, mount a minimum of 3.00 inches (76.2 mm) from wall.

For seismic installations, mount a minimum of 6.00 inches (152.4 mm) from wall.

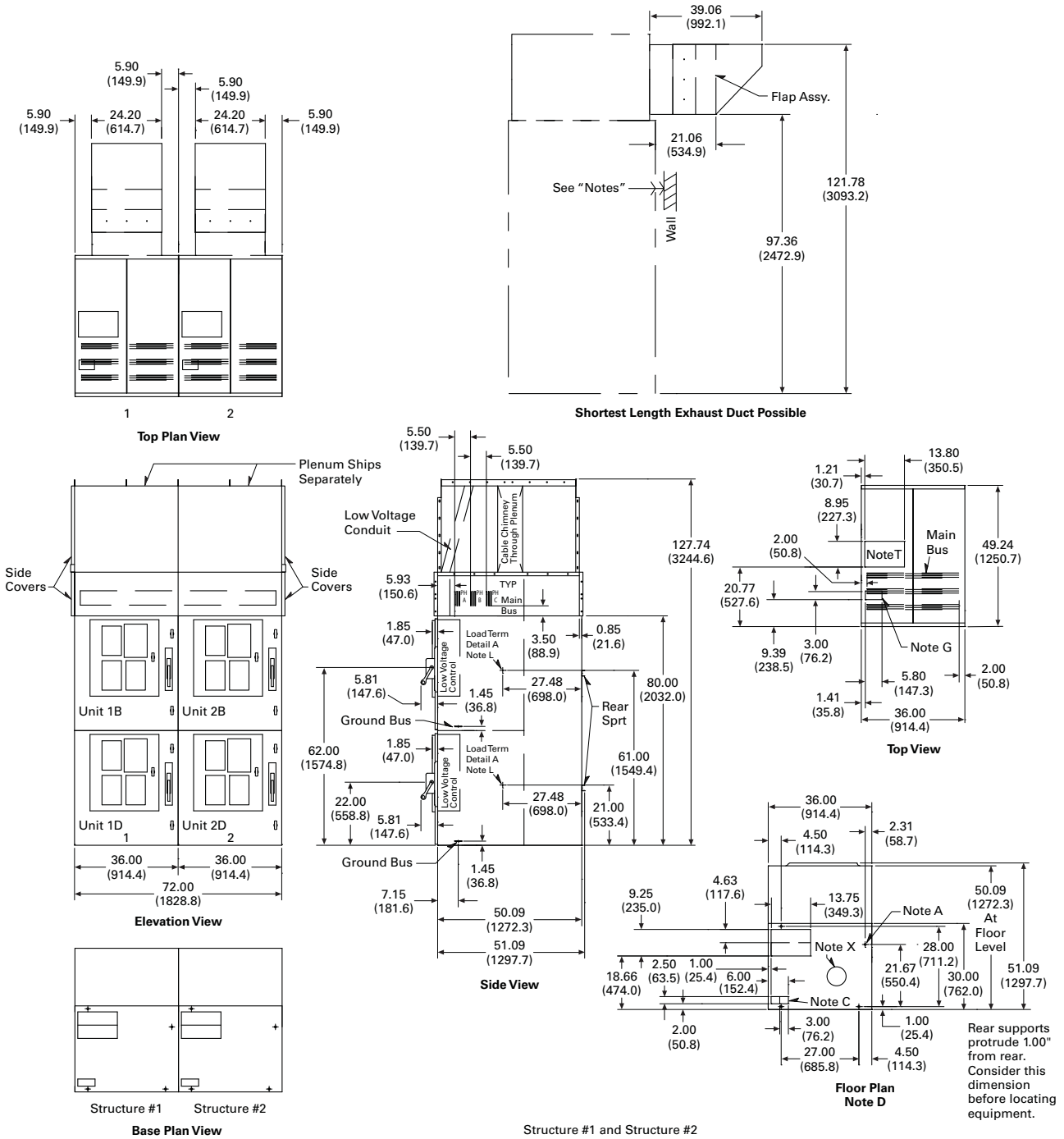

Figure 10.1-22. 50 kA Arc-Resistant, 24.00-Inch (609.6 mm) Incoming Cable Section and Two-High 400 A Starter Section

Main Breaker AMPGARD Layout—Dimensions in Inches (mm)

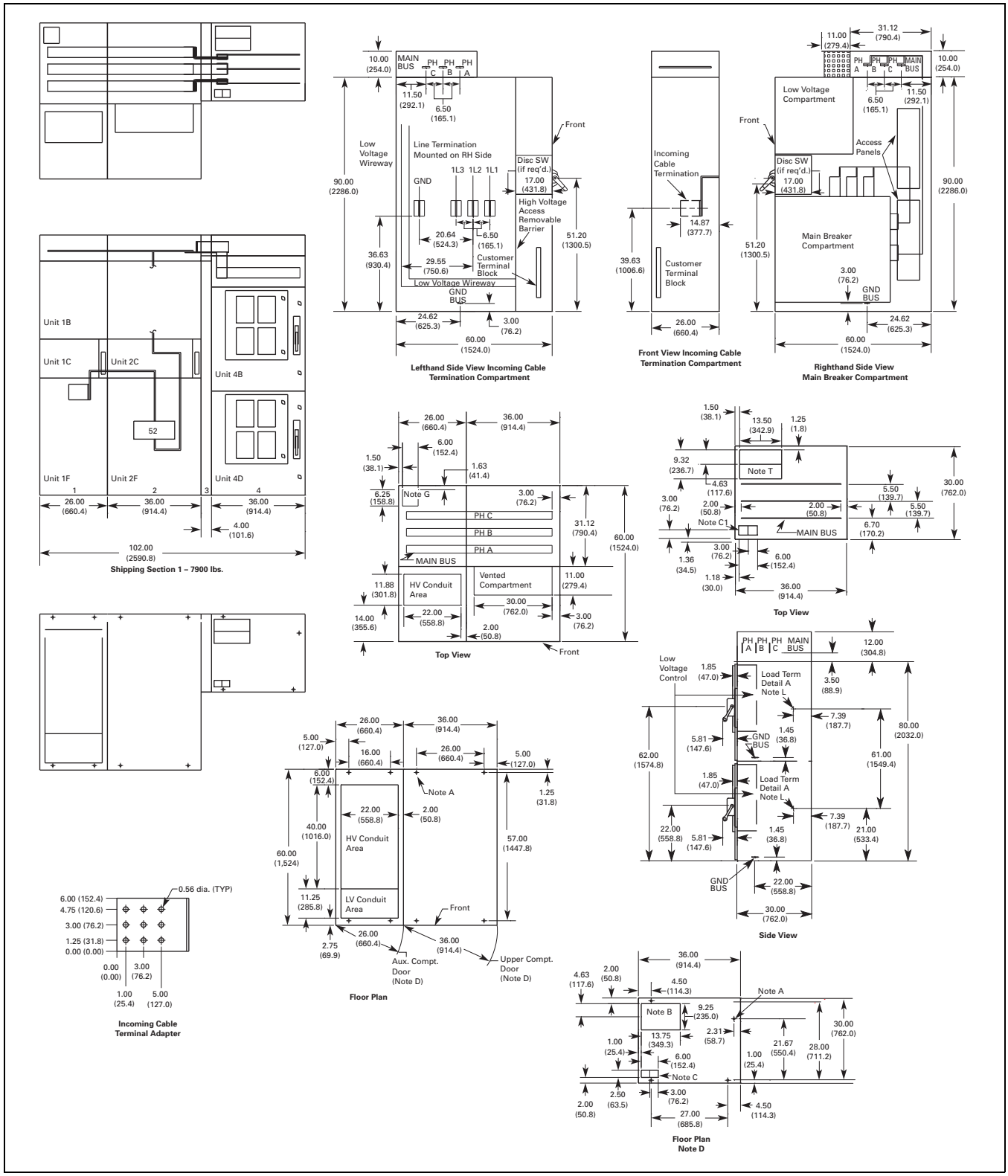

Figure 10.1-23. AMPGARD Main Breaker and Two-High 400 A Starter Section

Incoming Line/PT Layouts—Dimensions in Inches (mm)

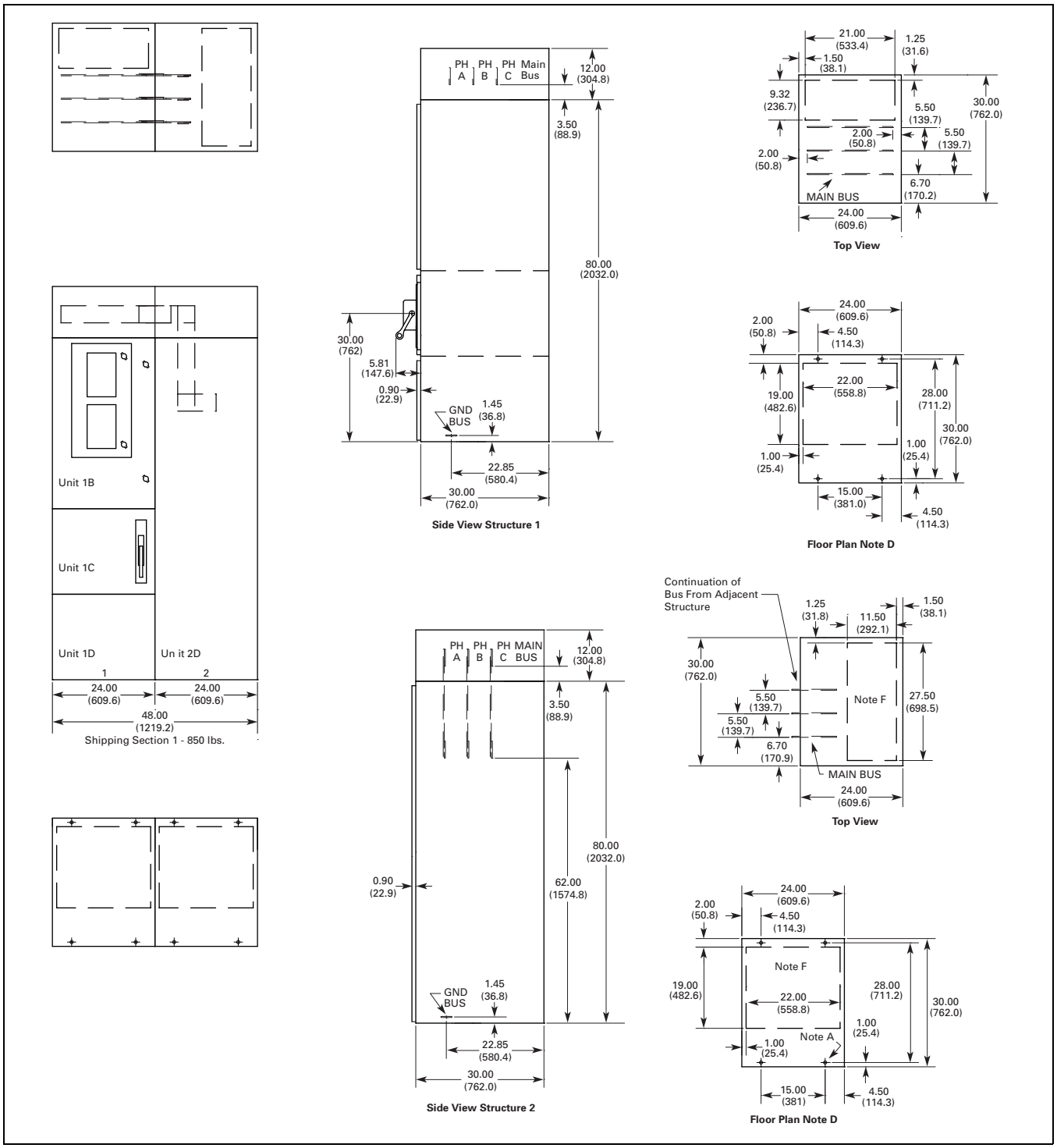

Figure 10.1-24. 24.00-Inch (609.6 mm) Incoming Cable Section with 24.00-Inch (609.6 mm) Metering Section (for Right End of Lineup)

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SC9000 EP Adjustable Frequency Drive, SC9000 with Encapsulated Powerpole

SC9000 EP

General Description

Eaton's SC9000™ Encapsulated Powerpole (EP) medium-voltage adjustable frequency drive (AFD) family provides precise motor control and protection of medium-voltage equipment rated to 2400 V, 3300 V, and 4160 V nominal.

Application Description

The SC9000 EP AFD has a complete offering:

- Precise medium-voltage motor control up to 6000 hp
- Fully integrated drive including an isolation switch, main contactor, 24-pulse isolation transformer, rectifier, and inverter
- Fully compatible with Eaton's entire medium-voltage product family as integrated control gear
- Compliance with IEEE 519 (Recommended Practice and Requirements for Harmonic Control in Electric Power Systems)

Features, Benefits and Functions

Personnel safety: Positive mechanical isolating switch with visible disconnect completely grounds and isolates the AFD from the line power with a mechanically driven isolating shutter, leaving no exposed high voltage. Medium-voltage door is mechanically key locked closed with the isolation switch; low-voltage section has a separate door and is segregated from the medium-voltage section.

Ease of installation: Current limiting fuse, contactor, inverter, and isolation switch assemblies can be easily removed from the enclosure. Line and load terminals are completely accessible from the front.

Ease of maintenance: All components are front accessible to aid routine inspection and/or part replacement, reducing downtime and operational expense. The low Mean Time to Repair (MTTR) equates to time and cost savings.

Smallest industry footprint: The SC9000's specialized design and high density packaging make it one of the smallest footprints per hp in the industry as a fully integrated drive. This size benefit ensures installations in space limited electrical rooms, eliminates the need for additional cable and conduit installations, and in some cases, eliminates the need for additional feeders required by our competitors.

Safety in mind: Mechanical (key) doors interlocked with main disconnect. Bus discharge resistors (dc) reduce capacitors to 50 Vdc in 5 minutes or less.

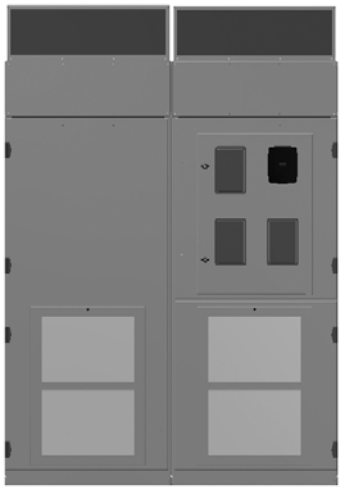
Auxiliary power: Auxiliary power internally derived for control and cooling power.

Designed, built and tested with reliability in mind: Designed for reliability with serviceability in mind, Eaton's encapsulated powerpole design sets the industry standard. The innovative design utilizes conformal coating on control boards and mechanical barriers to prevent damage to adjacent components in the event of a fault. Three-level neutral point clamped (NPC) inverter topology reduces part count, improves reliability, and contributes to the SC9000 EP AFD's low lifecycle costs. Assembled and stored in a cleanroom, inverter Mean Time to Failure (MTTF) is 12.7 years. All active components are burned in and tested at a rated load for functionality up to 24 hours in a temperature controlled test bay (up to 50 °C).

Easy AMPGARD integration: The SC9000 EP AFD can be supplied as a stand-alone AFD or directly connected with other AMPGARD products via a common bus. Known as integrated control gear, this fully integrated solution could align the AFD with a host of other motor control products such as motor starters, load break switches, and main breakers.

Protection through technology: Eaton's encapsulated roll-in/roll-out powerpole inverter reduces potential for environmental contamination of the six separate power poles mounted to the heat pipe assembly. These individually replaceable power poles provide modularity and in field serviceability as an alternative to complete inverter replacement.

SC9000 GP Adjustable Frequency Drive for General Purpose Applications



GP Drive

General Description

The SC9000 general purpose (GP) drive was designed to more quickly meet the needs of our customers requiring simple, yet robust, motor speed control between 100 and 1000 hp ①.

Building on proven SC9000 technology, the SC9000 GP uses a fixed product structure, making it ideal for use in applications where standard components and features meet specifications and rapid commissioning is desired.

In addition, the SC9000 GP can be fed by a remote input transformer and allows for the stacking of integrated filters, making it ideal for retrofit projects and limited spaces.

① 4160 V only at this time.

Application Description

The SC9000 GP has a standard offering:

- Precise motor control from 100 to 1000 hp with 4160 V input
- Fed by a switchgear or contactor assembly
- Cost effective option for when the benefits of an integrated drive or severe service capability is not required
- Compact footprint
- Industry's lowest inverter part count improves uptime
- Standardized architecture reduces lead time
- Roll-in/roll-out inverter simplifies maintenance
- Optional integrated output filters
- Key coordination required with upstream disconnect for safety
- 120 Vac auxiliary power required

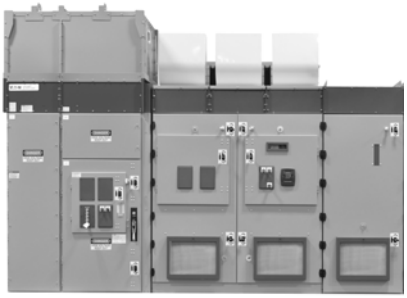
Features, Benefits and Functions

Designed, built and tested with reliability in mind: The SC9000 GP drive incorporates three-level neutral point clamped (NPC) inverter topology, which reduces the number of components and improves reliability. All SC9000 GP power electronic components are stored and assembled in a clean room to prevent surface contamination, which could degrade insulation and thermal performance. All active components are tested under an actual load for functionality and partial discharge. All assembled drives are tested up to 24 hours at rated load in a temperature controlled test bay up to 50 °C ambient.

Personnel safety: The low-voltage bucket is separated from the medium-voltage components permitting quick diagnostics and routine maintenance without taking the drive offline.

Ease of maintenance: The SC9000 GP drive utilizes a roll-in/roll-out inverter to permit easy serviceability in the field. A spare inverter can be stocked on site to quickly swap out inverters with reduced down time.

SC9000 AR Adjustable Frequency Drive



AR Drive

General Description

Continuing with Eaton's legacy of leadership in arc flash safety products, the SC9000 EP MV drive is designed to protect personnel in danger of arcing faults by containing and redirecting arc energy away from the user. Further, the drive is the industry's first fully integrated arc-resistant MV drive certified to CSA C22.2 No.22-11 and witness-tested to IEEE C37.20.7 at a third-party high power laboratory.

The SC9000 EP arc-resistant is designed with a robust arc-resistant Type 2B enclosure to provide the strength needed to resist the forces of arc events up to 50 kA and provide worker protection from the front, sides and rear of the enclosure, even with the control doors open. Enclosure controls arc blast energy through safe exhaust locations while an embedded exhaust cooling system significantly reduces the temperature of exhaust gas.

Application Description

- Industry's first fully integrated arc-resistant MV drive certified to CSA C22.2 No.22-11 and witness-tested to IEEE C37.20.7 at a third-party high power laboratory
- ANSI Type 2B enclosure engineered to resist the forces of arc events up to 50 kA and protect workers on the front, sides, and rear of the enclosure; even with open control doors
- IEEE 519 guideline for harmonic control and reactive compensation of static power converters
- UL® 347A for MV power conversion equipment and cUL® standards
- RoHS compliant

Features, Benefits and Functions

- Venting system directs arc gasses out of the top of the enclosure
- In the event of an arc blast, enclosure technologies provide strength and direct fault byproducts to the proper exhaust locations
- Arc exhaust cooling technology significantly reduces the temperature of exhaust gas
- Patented short-circuit protection limits available arc fault energy
- Unique arc fault detection circuits eliminate the possibility of an arc fault when powering up the drive
- Patented inverter encapsulation prevents the propagation of a fault
- Encapsulated powerpole inverter with heat pipe technology helps increase power density, reduce overall equipment size, and protect sensitive electronic components in harsh environments
- Industry's lowest inverter part count improves uptime
- Modular powerpole design and roll-in/roll-out inverter simplifies maintenance
- Fully compatible with Eaton's AMPGARD MV control solutions in an MV lineup under a common bus

Personnel Safety Features

Interlocks

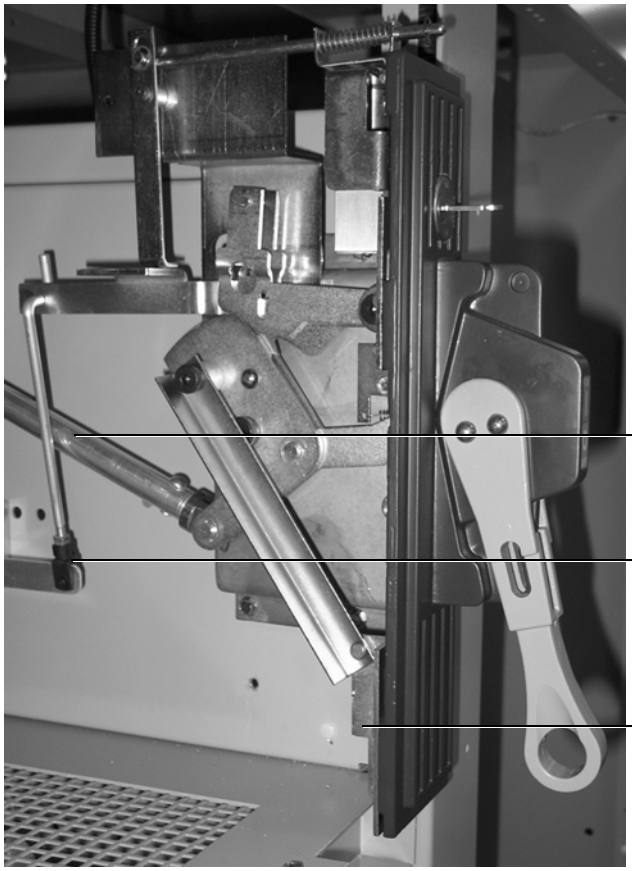
Interlocking on SC9000 EP standard and arc-resistant model (AFDs) includes:

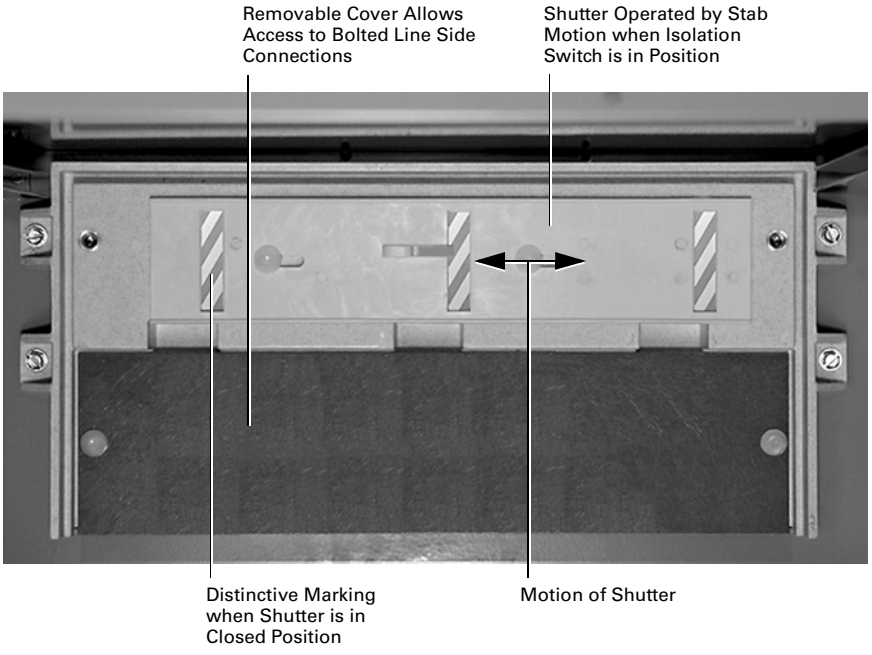
- Isolating switch mechanism locks the medium-voltage door closed when the switch is in the ON position
- Standard key interlocks on all medium-voltage doors
- When door is open, interlock prevents operating handle from being moved inadvertently to ON position
- When contactor is energized, isolating switch cannot be opened or closed

Additional Safety Features

- Provision for a padlock on the isolating switch handle in OFF position
- Shutter barrier between line terminals and isolation switch stabs is mechanically driven
- Distinctive marking on back of switch assembly appears when shutter barrier is in position and starter is completely isolated from the line
- Grounding clips provide a positive grounding of the SC9000 EP (and model) AFD and main fuses when the isolating switch is opened
- High- and low-voltage circuits are compartmentalized and isolated from each other
- The drawout isolation switch is easily removed by loosening two bolts in the back of the switch. The shutter remains in place when the switch is withdrawn
- Grounding device is provided for shorting the dc bus to ground before entering the medium-voltage compartments

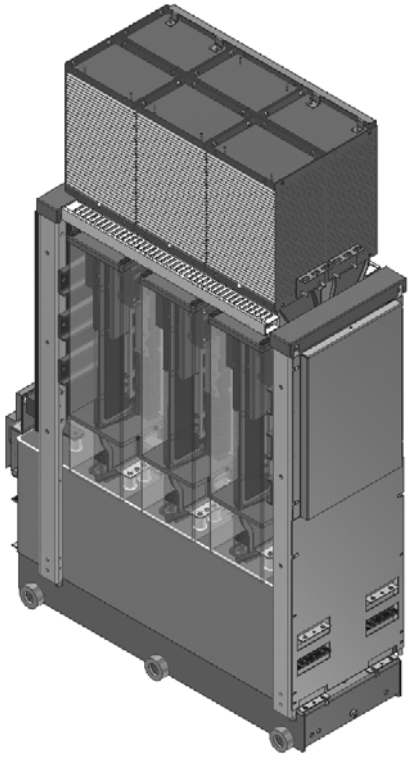
See **Page 10.1-2** for details on the Mechanical Non-Loadbreak Isolating Switch.





Shutter Mechanism and Finger Barrier Isolation of Incoming Line Bus (Shown with Removable Portion of Isolation Switch Removed)

Modular Roll-in/Roll-out Stab-in Three-Phase Inverter



Six-Pack, Roll-In/Roll-Out Inverter (Side Sheets Not Shown). Up to 3700 hp on Single Inverter

General Description

The roll-in/roll-out three-phase inverter module employs an insulation and buswork system to obtain the highest power density rating in the market. Heat pipe technology is used to cool active power components in the inverter.

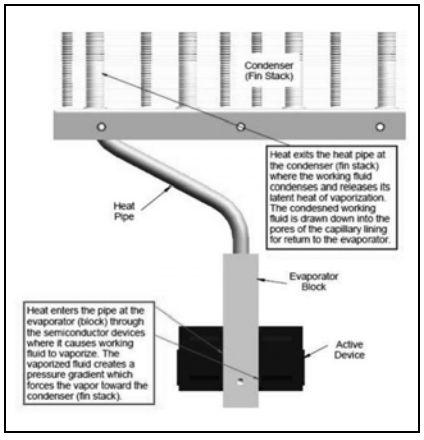


Figure 10.2-1. Heat Pipe Thermal Management System

This method of heat removal from the inverter is up to 10 times more efficient than traditional air-cooling methods, resulting in less required airflow for quieter and more efficient operation. The thermal management system has been subjected to temperatures of –50 °C to model cold weather transport without the rupture of any heat pipes. It is also important to note that thermal management performance was unaffected by the extreme cold storage.

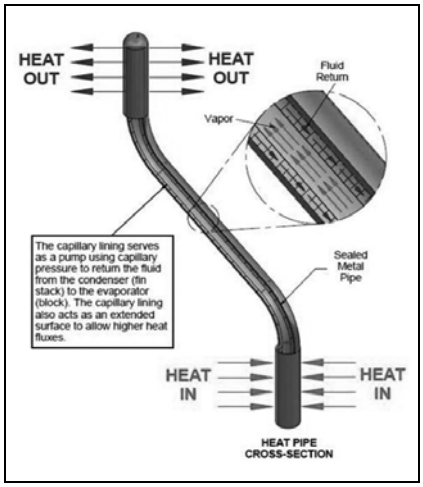
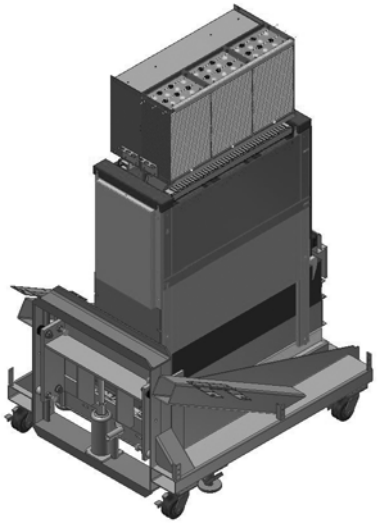


Figure 10.2-2. Heat Pipe Construction

Eaton's cooling methodology and encapsulation of medium-voltage components produce a harsh-environment inverter that protects active power devices from environmental conditions and airborne contaminants thereby eliminating potential causes of failures.

In the event of a failure, the modular roll-in/roll-out inverter design minimizes downtime. The inverter can partially withdraw from the structure for repairs without ever having to fully remove the inverter. For even faster return to service, the inverter can be fully withdrawn from the structure. A spare inverter can then be quickly reinstalled. The drive is then ready to restart the motor with minimal downtime.



Inverter Replacement System

Optional inverter extraction tool is available for removal of inverter for maintenance or repair of inverter.

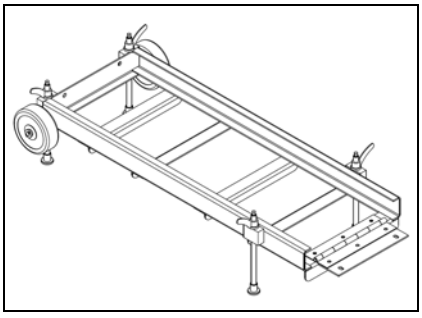
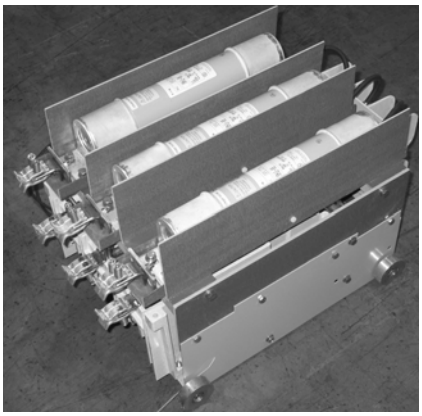


Figure 10.2-3. Optional Inverter Extraction Tool

10

Type SL Vacuum Contactor Stab-in with Wheels, Fuses, and Line and Load Fingers



400 A Stab-In Contactor and Fuse Assembly

General Description

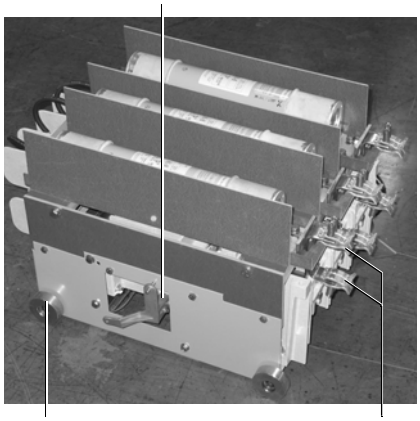
400 A Vacuum Contactors

The standard stab-in SL contactor is mounted on wheels and rolls into the SC9000 EP standard and arc-resistant model (AFDs) structure. Contactor line and load fingers engage cell-mounted stabs as the contactor is inserted into the SC9000 EP standard and arc-resistant model (AFDs) incoming cell. The contactor is held in position by a bolt and bracket combination. It can be easily withdrawn from the SC9000 EP standard and arc-resistant model (AFDs) incoming cell by removing the bolt holding the contactor against the bracket and disconnecting the isolation switch interlock. The contactor can be removed from the SC9000 EP standard and arc-resistant model (AFDs) after disconnecting the medium-voltage cables going to the control transformer.

800 A Vacuum Contactors

The 800 A SL Contactor is available in the SC9000 EP standard and arc-resistant model (AFDs) Frames D and E and is rated at 720 A enclosed.

The 800 A contactor is mounted on wheels and has similar features to the stab-in 400 A contactor.



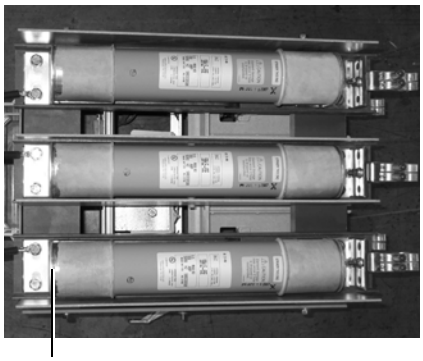
Stab-In Contactor Mechanical Interlock and Fingers

Current Limiting Fuses

SC9000 EP standard and arc-resistant model (AFDs) use Eaton's Type HLE power fuses with special time/current characteristics. The fuse is coordinated with the contactor to provide maximum motor/transformer utilization and protection. The standard mounting method for power fuses is bolted onto the contactor assembly.

Interruption is accomplished without expulsion of gases, noise or moving parts. Type HLE fuses are mounted in a horizontal position. When a fault has been cleared, an indicator in the front of the fuse, normally depressed, pops up to give visible blown fuse indication.

The control circuit primary fuses are also current limiting.



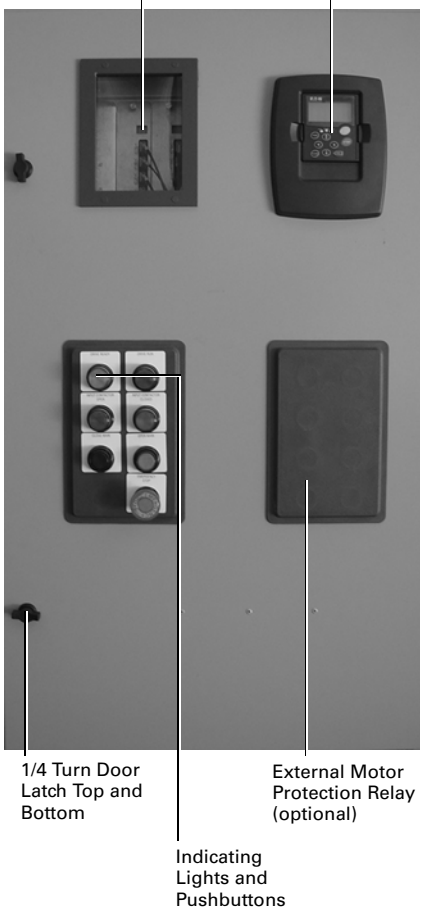
Blown Fuse Indicating Device

See **Page 10.1-4** for detailed information on current limiting fuses.

See **Page 10.1-23** for detailed information on contactor-fuse coordination.

Isolated Low-Voltage Control

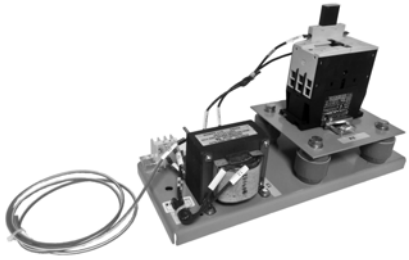
The low-voltage door has four cutouts as standard.



SC9000 EP AFD Low-Voltage Door Closed

The device panel and optional Eaton motor protection relays fit in the low-voltage door. The standard SC9000 keypad can be removed for plug-in of a laptop via a serial connection. A standard viewing window allows visual verification of the SC9000 AFD status. The low-voltage control panel is behind the low-voltage door and is completely isolated from the medium-voltage compartment. The medium-voltage door is locked closed and interlocked with the isolation switch.

Pre-Charge Circuit



SC9000 EP Pre-Charge Circuit

The SC9000 utilizes two innovative pre-charging methods to protect the transformer and other sensitive components from the damaging effects of high in-rush currents.

The pre-charge circuit design uses the control power circuit for dc link capacitor charging to increase the life of affected components.

The Soft-Mag design leverages the higher impedance of the blower transformer and careful calculations to softly introduce the proper voltage and phase to the main transformer eliminating high in-rush currents while simultaneously pre-charging the capacitors in the inverter.

Standards and Certifications

UL and CSA Certification

All SC9000 models are designed, assembled and tested to meet all applicable standards: NEMA ICS6, NEMA ICS7, IEEE 519, IEEE 1100, UL 347A and CSA C22.2. The major components (contactor, isolating switch, fuses, transformer and inverter active devices) are UL recognized.

UL or CSA labeling of a specific AFD requires review to ensure that all requested modifications and auxiliary devices meet the appropriate standards. Refer to factory when specified.

Seismic Qualification EP Units Only

The equipment and major components are seismic certified and meet the applicable seismic requirements of the current International Building Code (IBC) and California Building Code (CBC).

Refer to **Tab 1** for information on seismic qualification for this and other Eaton products.

SC9000 EP Options

Integrated Control Gear Under One Main Bus Options

- AMPGARD main/feeder breaker
- Incoming line section
- Load break switches
- Output contactor
- Full voltage non-reversing starter bypass ①
- Reduced voltage solid-state bypass ①
- Reduced voltage auto-transformer bypass ①
- Reduced voltage primary reactor bypass ①
- Full voltage non-reversing additional starters
- Reduced voltage solid-state additional starters
- Reduced voltage auto-transformer additional starters
- Synchronous starters
- Classic AMPGARD transition

① Available on GP model via cable connections.

Enclosure Options

NEMA 1 Gasketed is standard and the only enclosure option at this time. If an outdoor installation is required, Eaton can supply the AFDs and other electrical equipment in a modular building called an Integrated Power Assembly (see **Tab 38**).

Monitoring and Protection Options

- Powerware UPS control power backup (see **Tab 33, Section 33.2**)
- EMRs
- Eaton Power Xpert meters (see **Tab 3**)
- Eaton EMR-4000 motor protection relays with RTDs (see **Tab 4, Section 4.2**)
- Eaton EMR-5000 motor protection relays with RTDs (see **Tab 4, Section 4.2**)
- Redundant fans with automatic switchover ②
- Motor RTD protective device

Standard Protection

- Electronic overload (49)
- Instantaneous overcurrent (50)
- ac time overcurrent (51)
- Underload (37)
- Current imbalance (46)
- Line/load phase loss (46)
- Line/dc bus overvoltage (59)
- Line/dc bus undervoltage (27)
- Line phase rotation (47)
- Lockout/start inhibit (86)
- Load ground fault (50N/59G)

Standard Monitoring

- Frequency reference
- Output frequency
- dc bus voltage
- Motor voltage
- Motor current
- Motor power %
- Total kWh
- Run time
- Unit temperature

(See IB020002EN for more details)

Communications Options (All Models)

- Johnson Controls N2
- Modbus TCP
- Modbus
- PROFIBUS® DP ②
- DeviceNet ②
- BACnet
- CANopen
- LonWorks® ②
- EtherNet/IP

② EP family only.

Output Filters All Models

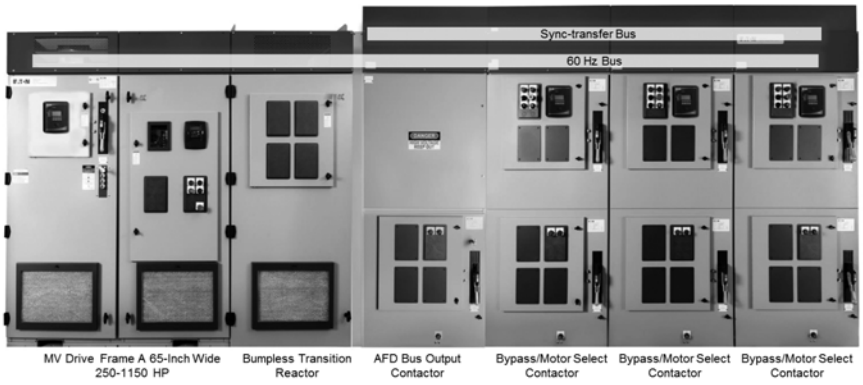
Drive output filters are recommended for longer cable lengths between the drive and motor.

Table 10.2-1. Recommended Output Filter Application

Motor Type	Motor Lead Length (ft)	
	dv/dt Filter	Sine Filter
Non-inverter duty rated	120	1250
Inverter duty rated	300	1250

See **Page 10.2-23** for dimensional details.

Synchronous Transfer Control with SC9000 EP



Synchronous Transfer Control System

General Description

Synchronous transfer systems help maximize capital efficiency by controlling multiple motors with one adjustable frequency drive.

Most manufacturers' synchronous transfer control systems have multiple drive output and motor select contactors that are (typically) interconnected via cables to allow the AFD to manage multiple motors.

With the SC9000 EP and Eaton's integrated medium-voltage control gear design; the double bus design, drive output, and motor select contactors are all close-coupled under a common bus with no cables, providing a more compact design and superior performance.

Closed Transition Transfer Control Operation

Operation of Eaton's Closed Transition Transfer Control System is described and illustrated below. **Figure 10.2-4** shows the elements that make up an SC9000 EP Synchronous Transfer system.

Control Elements, Colors, and Symbols

De-Energized
Energized Feeder Bus
Energized AFD Bus
Closed Contactor

PLC—Transfer Programmable Logic Controller

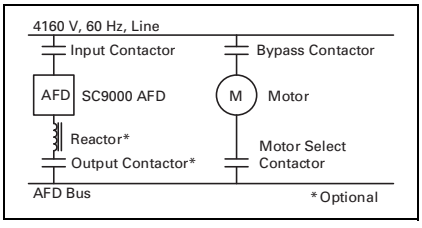


Figure 10.2-4. Closed Transition Synchronous Transfer Elements

Sequence of Operation

Start Sequence

- Customer sends start signal to PLC
- PLC closes appropriate motor select contactor
- PLC sends run command to AFD
- AFD closes output contactor and pre-charges
- AFD closes input contactor (**Figure 10.2-5**)
- AFD ramps motor to reference frequency

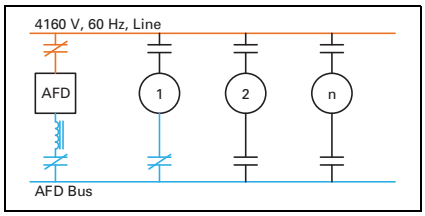


Figure 10.2-5. AFD Starts Motor #1

- Customer sends sync up signal to PLC
- PLC sends sync up command to AFD
- AFD locks output to match line voltage
- AFD sends sync acknowledgement to PLC
- PLC closes bypass contactor
- PLC opens motor selector (**Figure 10.2-6**)

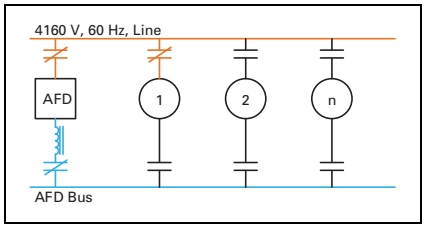


Figure 10.2-6. AFD Transfers Motor #1

- AFD stops inverter
- AFD opens drive output contactor (**Figure 10.2-7**)
- PLC removes sync up and run command from AFD

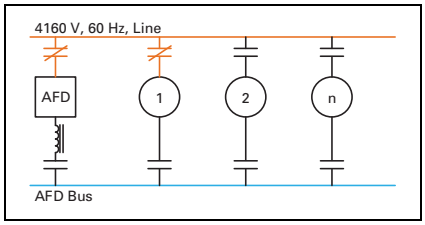


Figure 10.2-7. Motor #1 on Bypass

Sync Down Sequence

- Customer sends signal to PLC to sync down motor
- AFD pre-charges
- AFD closes main input contactor
- AFD locks to line voltage
- AFD closes drive output contactor
- AFD sends sync acknowledgment to the PLC

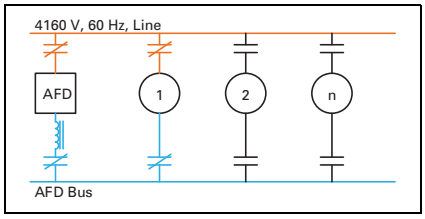


Figure 10.2-8. AFD Synched to Input

- PLC closes motor select (**Figure 10.2-8**)
- PLC sends command to AFD to turn on inverter
- PLC opens bypass contactor (**Figure 10.2-9**)
- AFD ramps motor to reference frequency

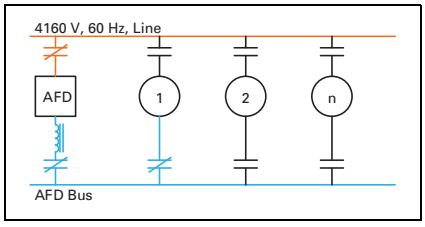
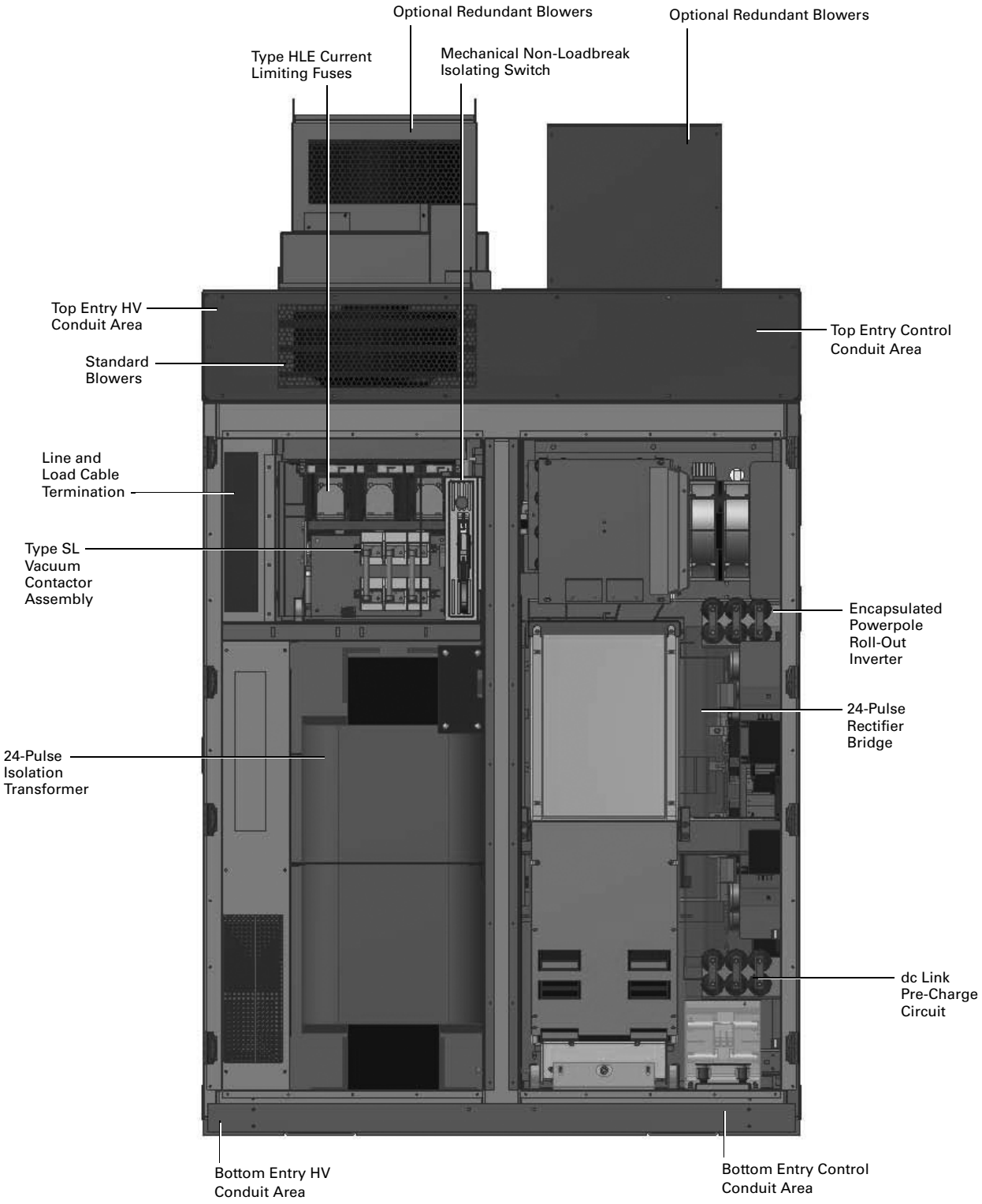


Figure 10.2-9. AFD Running Motor #1

SC9000 EP Fully Integrated Frame A AFD
(300–1150 hp at 4160 V)
(300–700 hp at 3300 V)
(300–500 hp at 2400 V)



Layout Dimensions—Frame A AFD
(300–1150 hp at 4160 V) (300–700 hp at 3300 V) (300–500 hp at 2400 V)

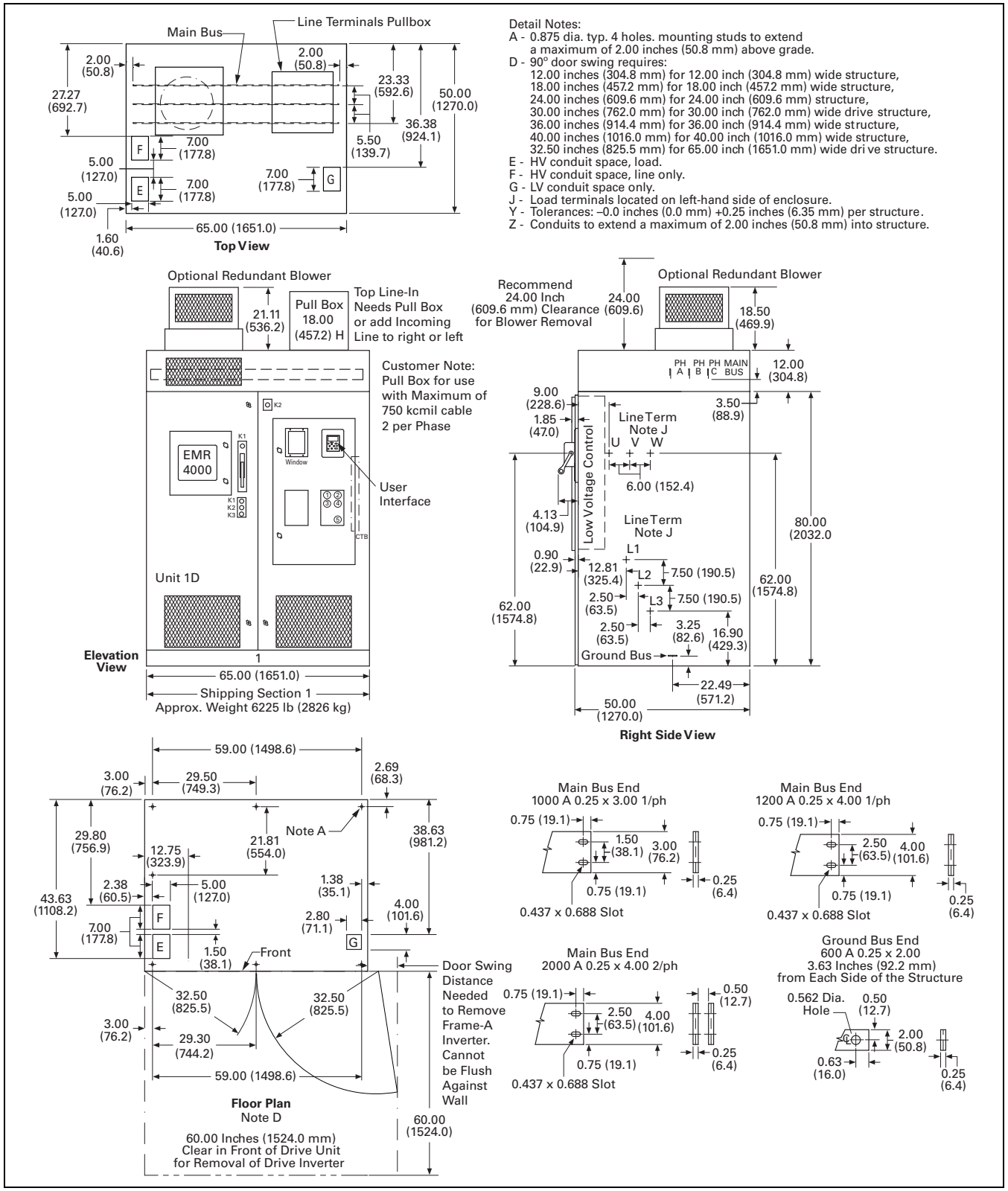
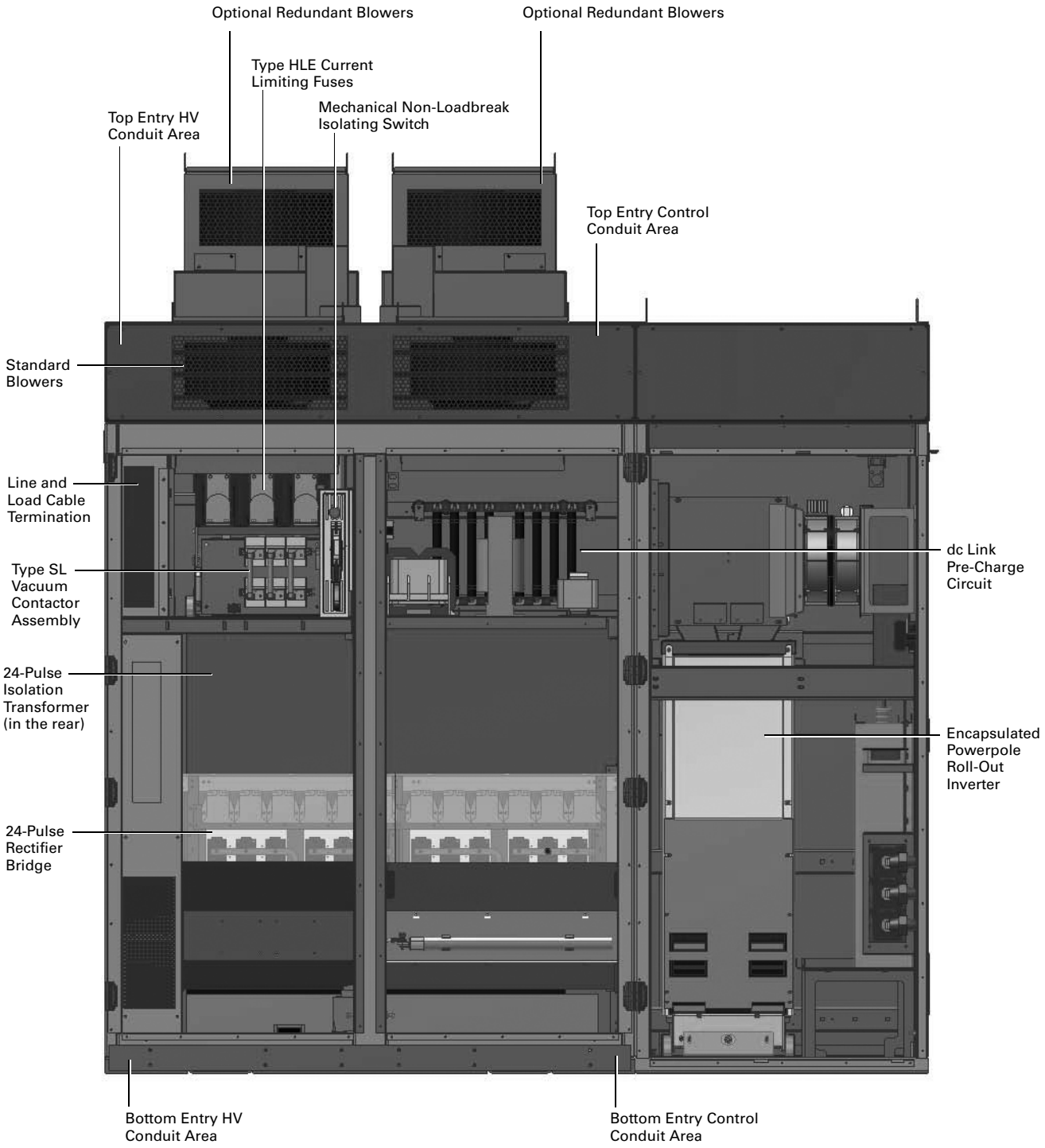


Figure 10.2-10. SC9000 EP AFD Frame A Maximum Dimensions and Incoming Line Layouts—Dimensions in Inches (mm)

SC9000 EP Fully Integrated Frame B AFD
(1000–2000 hp at 4160 V)
(800–1500 hp at 3300 V)
(600–1000 hp at 2400 V)



Layout Dimensions—Frame B AFD
(1000–2000 hp at 4160 V) (800–1500 hp at 3300 V) (600–1000 hp at 2400 V)

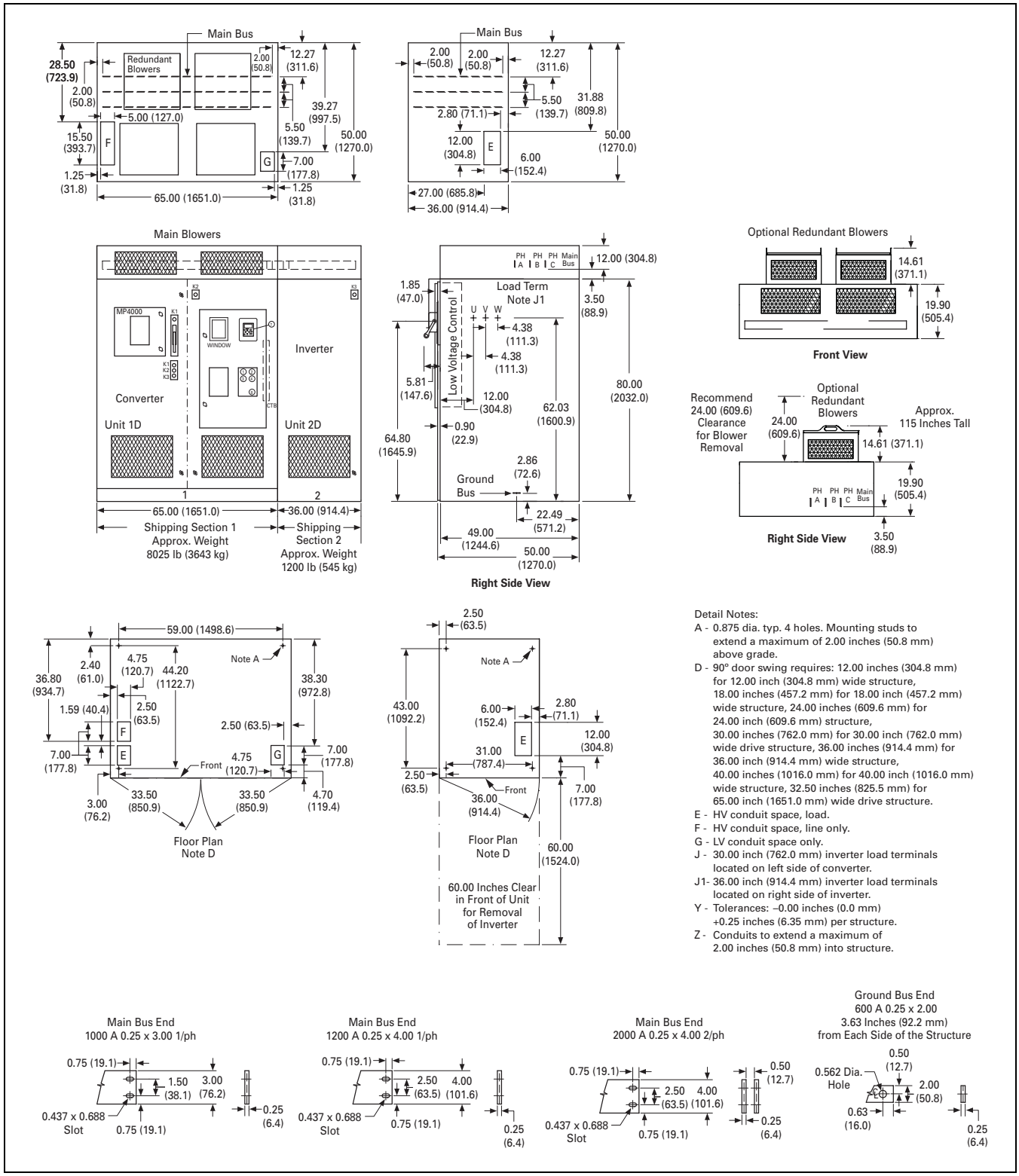
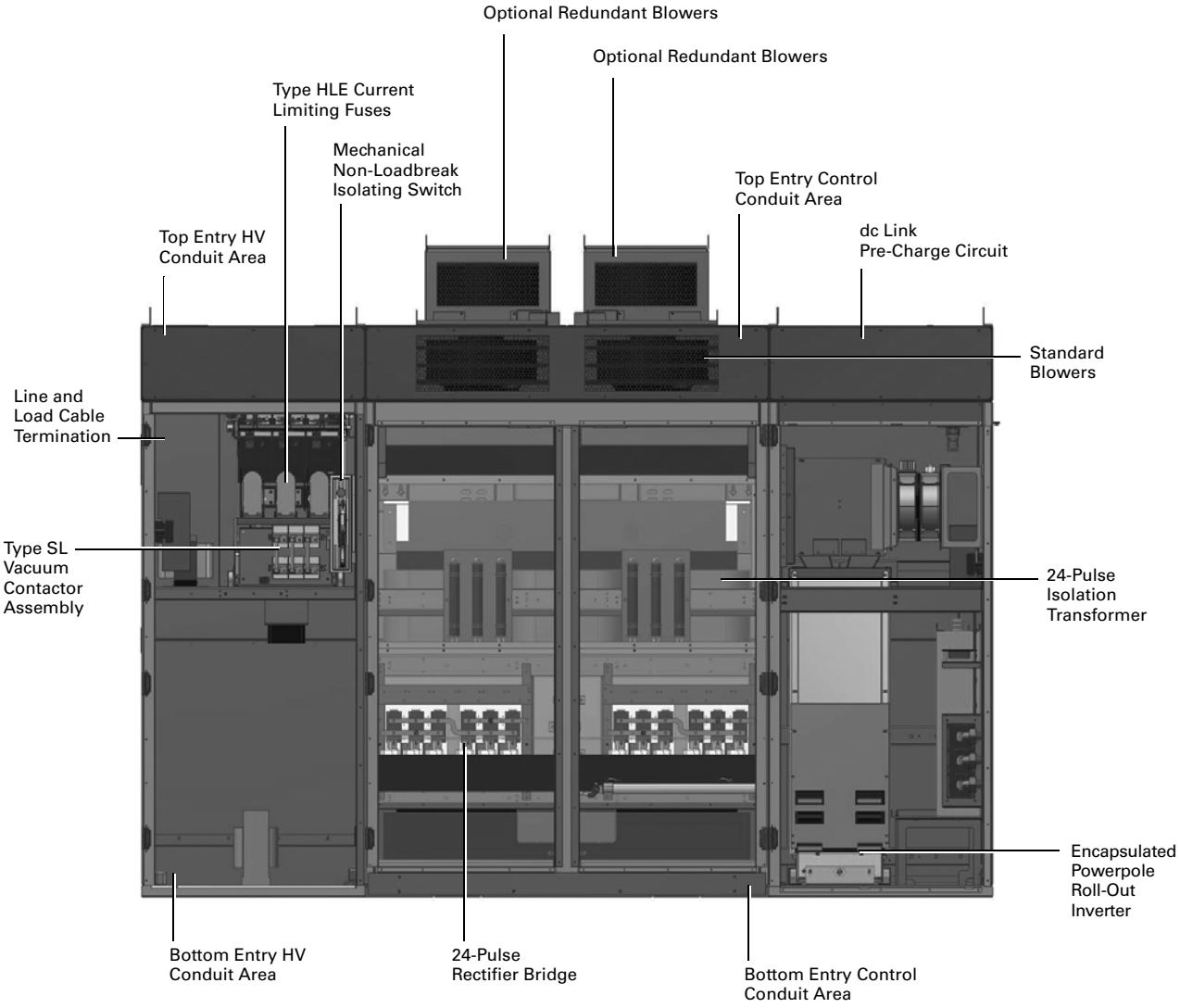


Figure 10.2-11. SC9000 EP AFD Frame B Maximum Dimensions and Incoming Line Layouts—Dimensions in Inches (mm)

SC9000 EP Fully Integrated Frame C AFD
(2250–3000 hp at 4160 V)
(1750–2000 hp at 3300 V)
(1250–1750 hp at 2400 V)



Note: See **Page 10.2-7** for dimensional details.

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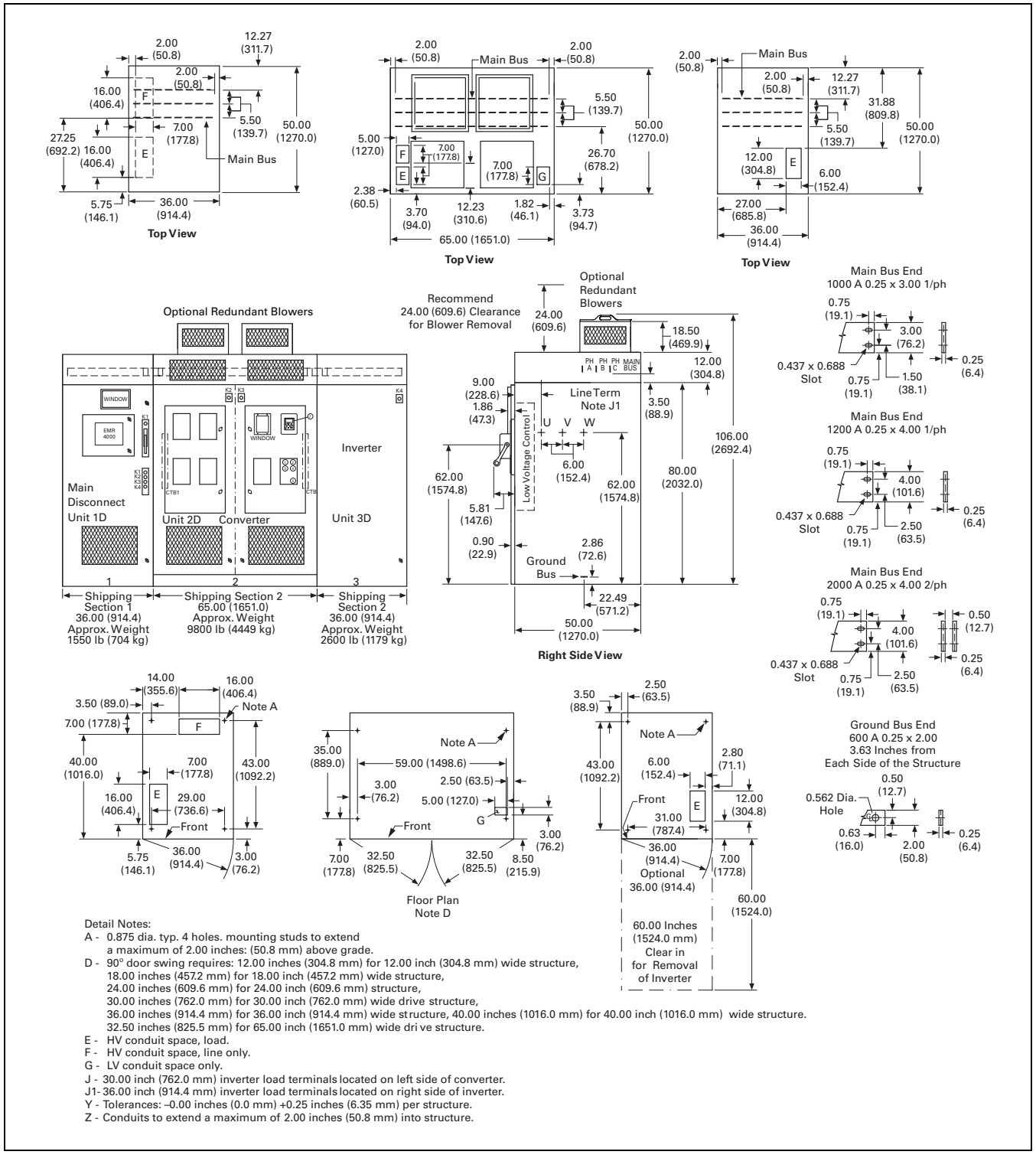
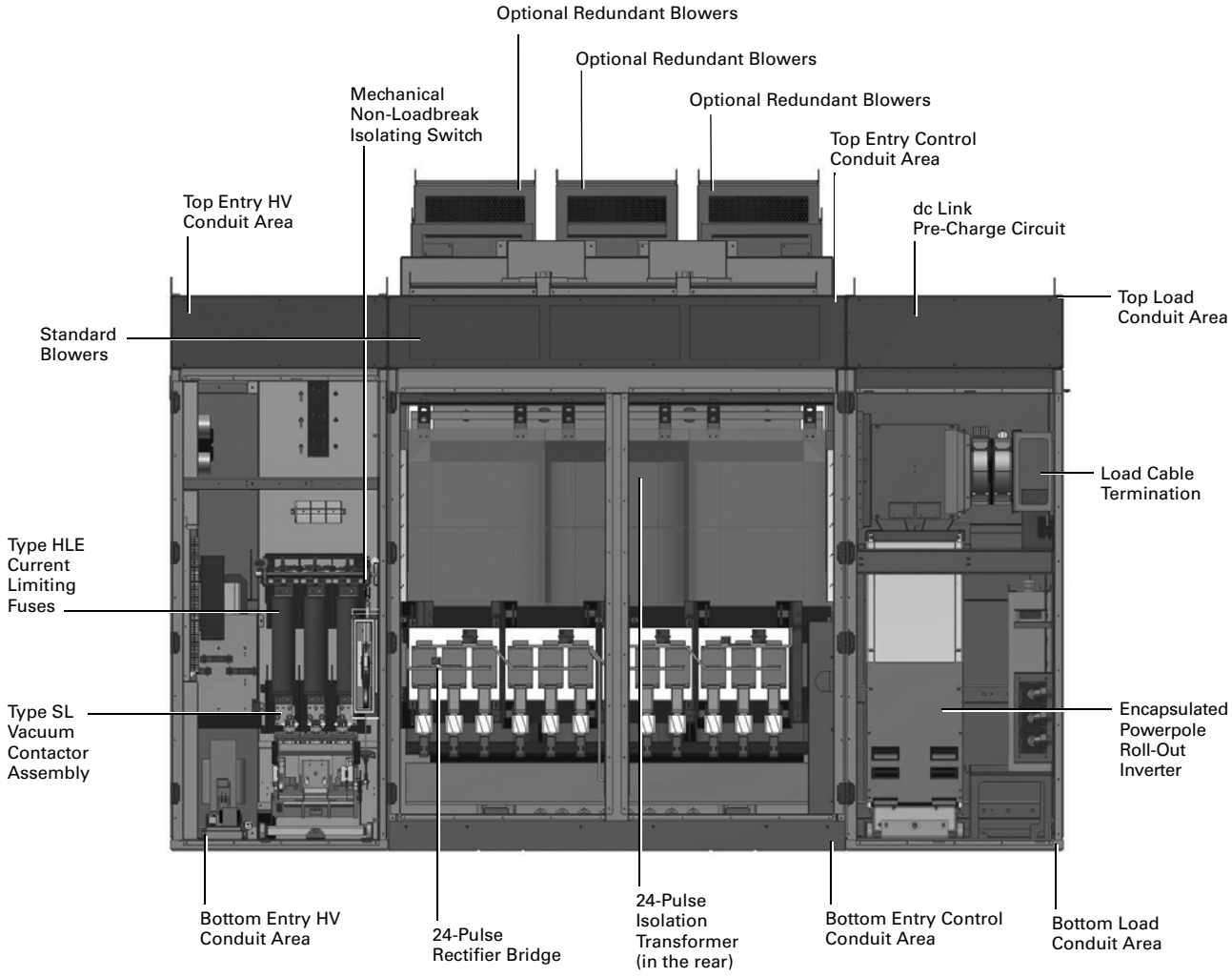
Layout Dimensions—Frame C AFD
(2250–3000 hp at 4160 V) (1750–2000 hp at 3300 V) (1250–1750 hp at 2400 V)



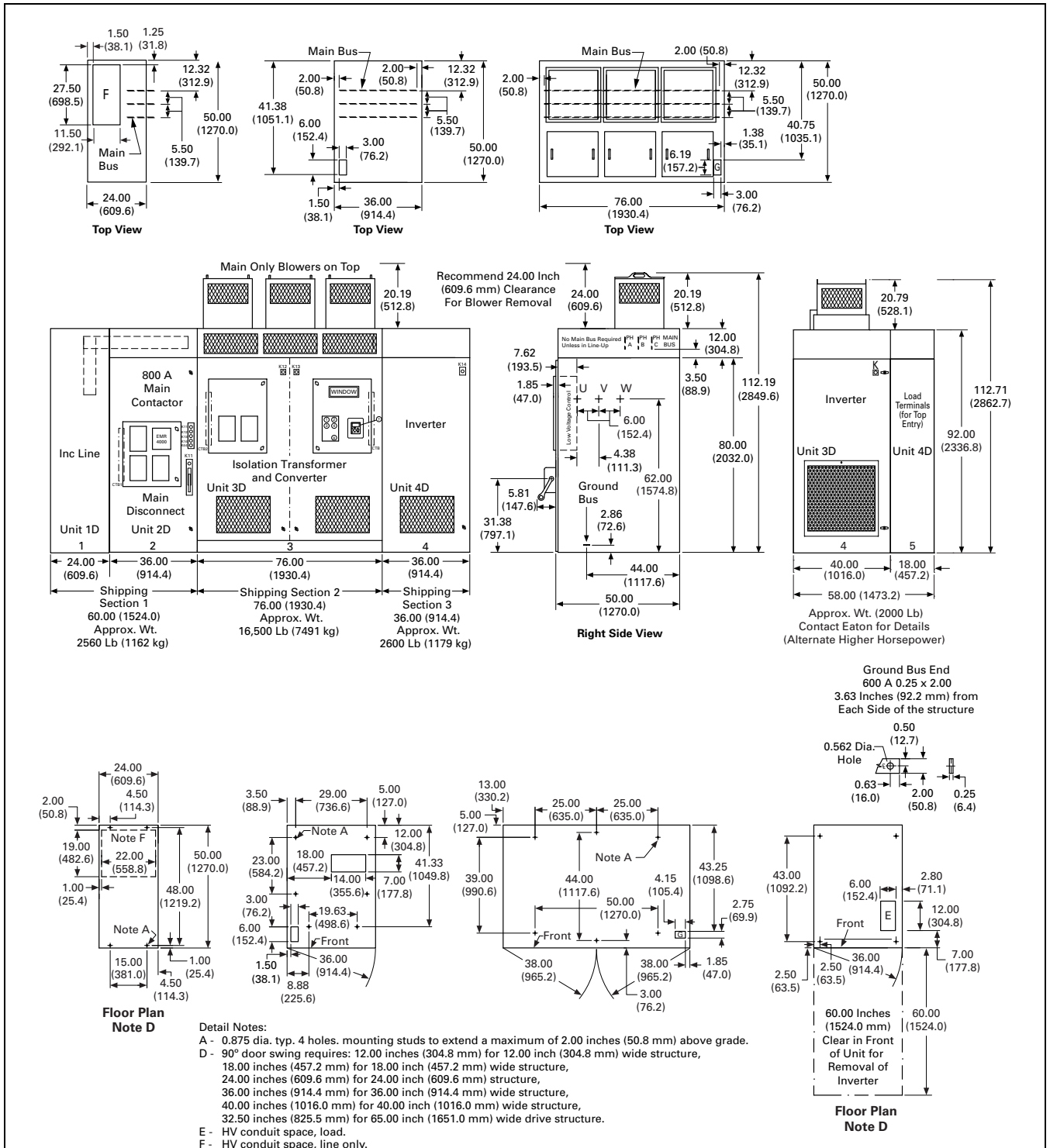
Detail Notes:
A - 0.875 dia. typ. 4 holes. mounting studs to extend a maximum of 2.00 inches: (50.8 mm) above grade.
D - 90° door swing requires: 12.00 inches (304.8 mm) for 12.00 inch (304.8 mm) wide structure, 18.00 inches (457.2 mm) for 18.00 inch (457.2 mm) wide structure, 24.00 inches (609.6 mm) for 24.00 inch (609.6 mm) structure, 30.00 inches (762.0 mm) for 30.00 inch (762.0 mm) wide drive structure, 36.00 inches (914.4 mm) for 36.00 inch (914.4 mm) wide structure, 40.00 inches (1016.0 mm) for 40.00 inch (1016.0 mm) wide structure. 32.50 inches (825.5 mm) for 65.00 inch (1651.0 mm) wide drive structure.
E - HV conduit space, load.
F - HV conduit space, line only.
G - LV conduit space only.
J - 30.00 inch (762.0 mm) inverter load terminals located on left side of converter.
J1- 36.00 inch (914.4 mm) inverter load terminals located on right side of inverter.
Y - Tolerances: –0.00 inches (0.0 mm) +0.25 inches (6.35 mm) per structure.
Z - Conduits to extend a maximum of 2.00 inches (50.8 mm) into structure.

Figure 10.2-12. SC9000 EP AFD Frame C Maximum Dimensions and Incoming Line Layouts—Dimensions in Inches (mm)

SC9000 EP Fully Integrated Frame D AFD (Single Inverter)
(3000–4500 hp at 4160 V)
(2250–3000 hp at 3300 V)
(2000–2500 hp at 2400 V)



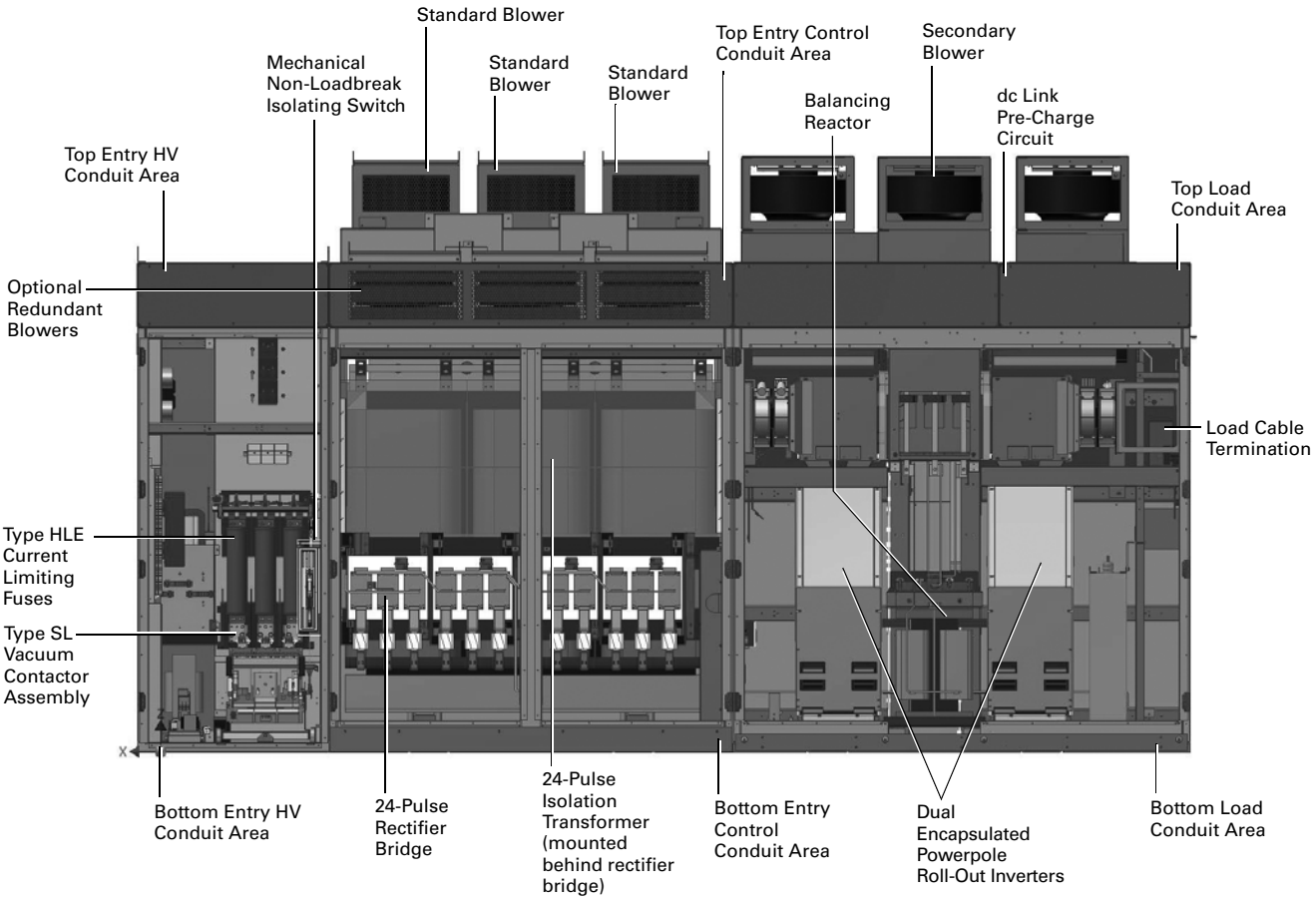
Layout Dimensions—Frame D AFD (Single Inverter)
(3000–4500 hp at 4160 V) (2250–3000 hp at 3300 V) (2000–2500 hp at 2400 V)



Detail Notes:
A - 0.875 dia. typ. 4 holes. mounting studs to extend a maximum of 2.00 inches (50.8 mm) above grade.
D - 90° door swing requires: 12.00 inches (304.8 mm) for 12.00 inch (304.8 mm) wide structure,
18.00 inches (457.2 mm) for 18.00 inch (457.2 mm) wide structure,
24.00 inches (609.6 mm) for 24.00 inch (609.6 mm) structure,
36.00 inches (914.4 mm) for 36.00 inch (914.4 mm) wide structure,
40.00 inches (1016.0 mm) for 40.00 inch (1016.0 mm) wide structure,
32.50 inches (825.5 mm) for 65.00 inch (1651.0 mm) wide drive structure.
E - HV conduit space, load.
F - HV conduit space, line only.
G - LV conduit space only.
J - Load terminals located on right-hand side of enclosure.
Y - Tolerances: –0.00 inches (0.0 mm) +0.25 inches (6.35 mm) per structure.
Z - Conduits to extend a maximum of 2.00 inches (50.8 mm) into structure.

Figure 10.2-13. SC9000 EP AFD Frame D (Single Inverter) Maximum Dimensions and Incoming Line Layouts—Dimensions in Inches (mm)

SC9000 EP Fully Integrated Frame D AFD (Parallel Inverters) (3750–4500 hp at 4160 V) (2250–3000 hp at 3300 V)



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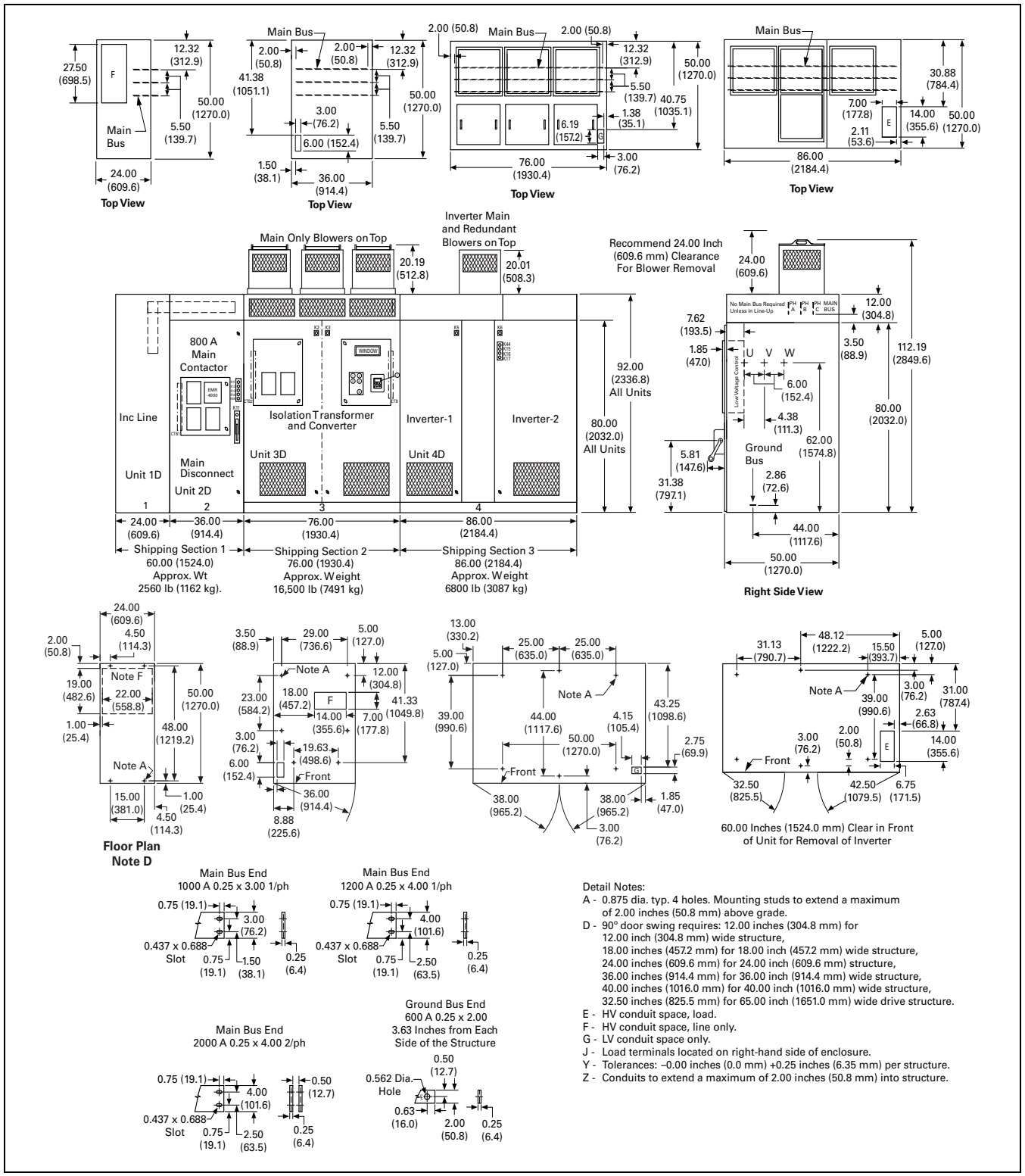
Layout Dimensions—Frame D AFD (Parallel Inverters) (3750–4500 hp at 4160 V) (2250–3000 hp at 3300 V)



Detail Notes:
A - 0.875 dia. typ. 4 holes. Mounting studs to extend a maximum of 2.00 inches (50.8 mm) above grade.
D - 90° door swing requires: 12.00 inches (304.8 mm) for 12.00 inch (304.8 mm) wide structure, 18.00 inches (457.2 mm) for 18.00 inch (457.2 mm) wide structure, 24.00 inches (609.6 mm) for 24.00 inch (609.6 mm) structure, 36.00 inches (914.4 mm) for 36.00 inch (914.4 mm) wide structure, 40.00 inches (1016.0 mm) for 40.00 inch (1016.0 mm) wide structure, 32.50 inches (825.5 mm) for 65.00 inch (1651.0 mm) wide drive structure.
E - HV conduit space, load.
F - HV conduit space, line only.
G - LV conduit space only.
J - Load terminals located on right-hand side of enclosure.
Y - Tolerances: –0.00 inches (0.0 mm) +0.25 inches (6.35 mm) per structure.
Z - Conduits to extend a maximum of 2.00 inches (50.8 mm) into structure.

Figure 10.2-14. SC9000 EP AFD Frame D (Parallel Inverters) Maximum Dimensions and Incoming Line Layouts—Dimensions in Inches (mm)

Layout Dimensions—Frame E AFD (4750–6000 hp at 4160 V) (3250–4000 hp at 3300 V)

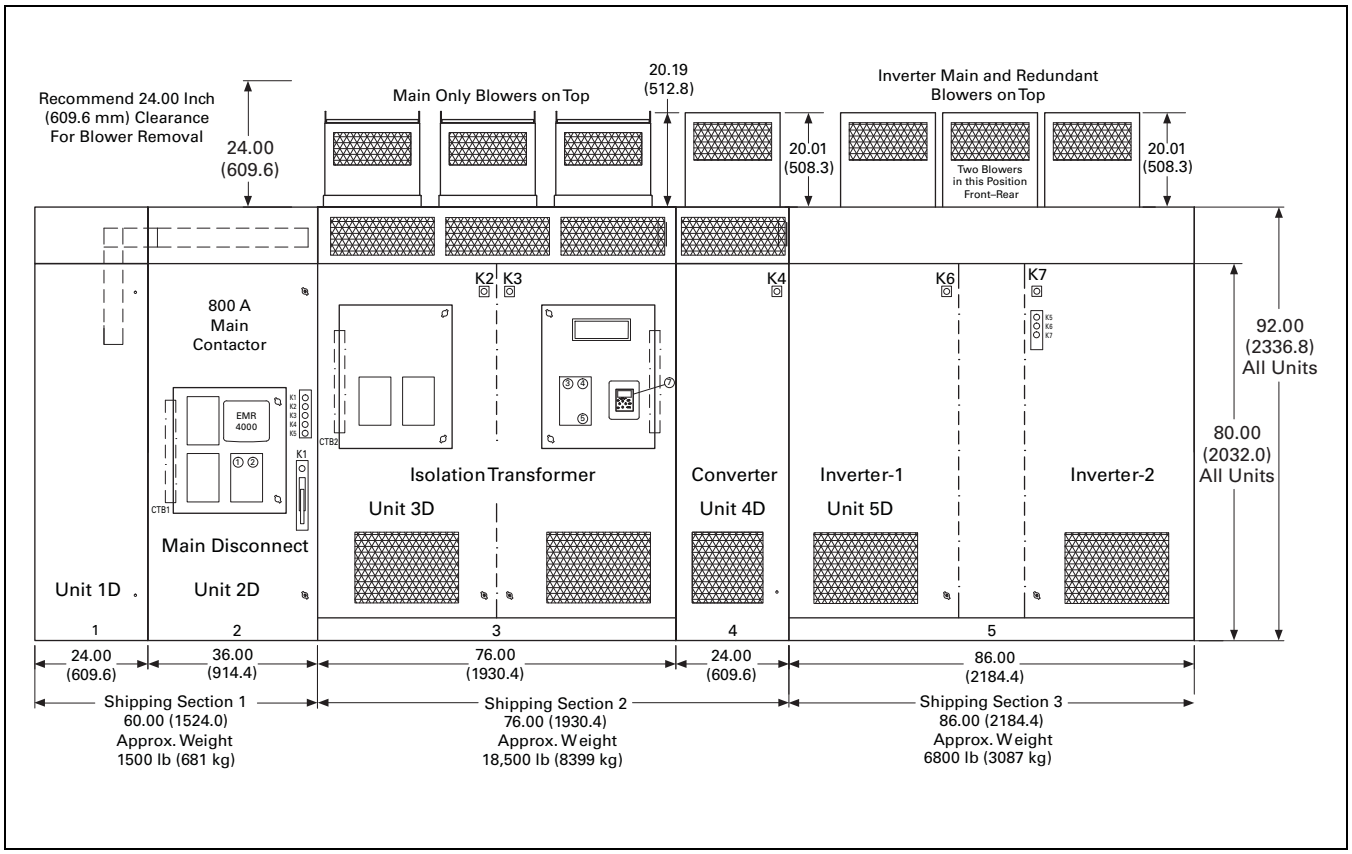


Figure 10.2-15. SC9000 EP Frame E—Dimensions in Inches (mm)

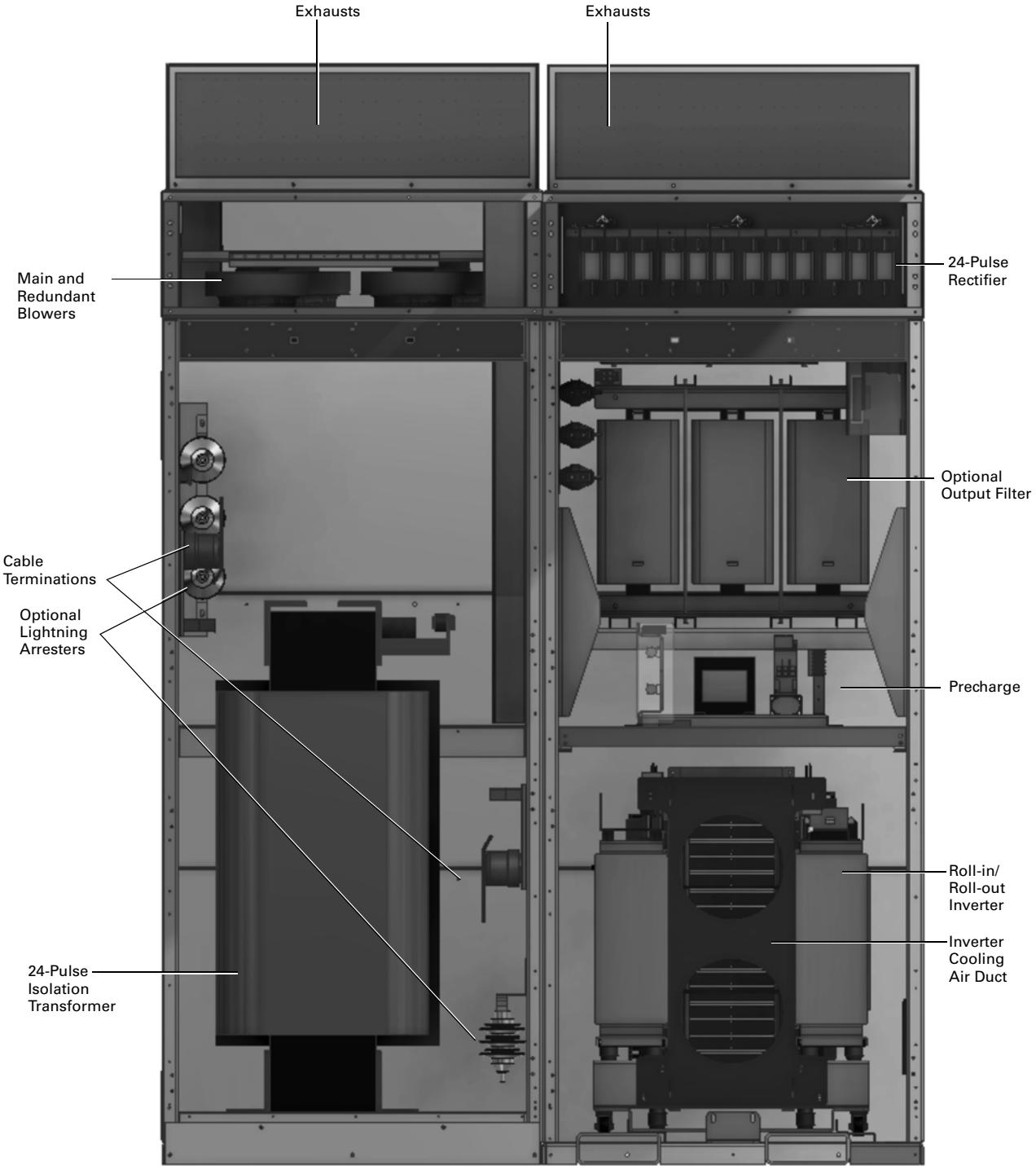
Table 10.2-2. SC9000 EP Frame E—Dimensions in Inches (mm)

Output Voltage	Motor		Cabinet Size			Redundant Blower
	FLA	hp	Width	Height	Depth	Height
3300 ① 4160	520–640 620–713	3250–4000 5000–6000	222.00 (5638.8) 222.00 (5638.8)	92.00 (2336.8) 92.00 (2336.8)	50.00 (1270.0) 50.00 (1270.0)	12.10 (307.3) 12.10 (307.3)

① 3300 V, 50 Hz.

10

SC9000 GP Frame A AFD
(100–1000 hp at 4160 V)



Layout Dimensions—GP Frame A AFD (100–1000 hp at 4160 V)

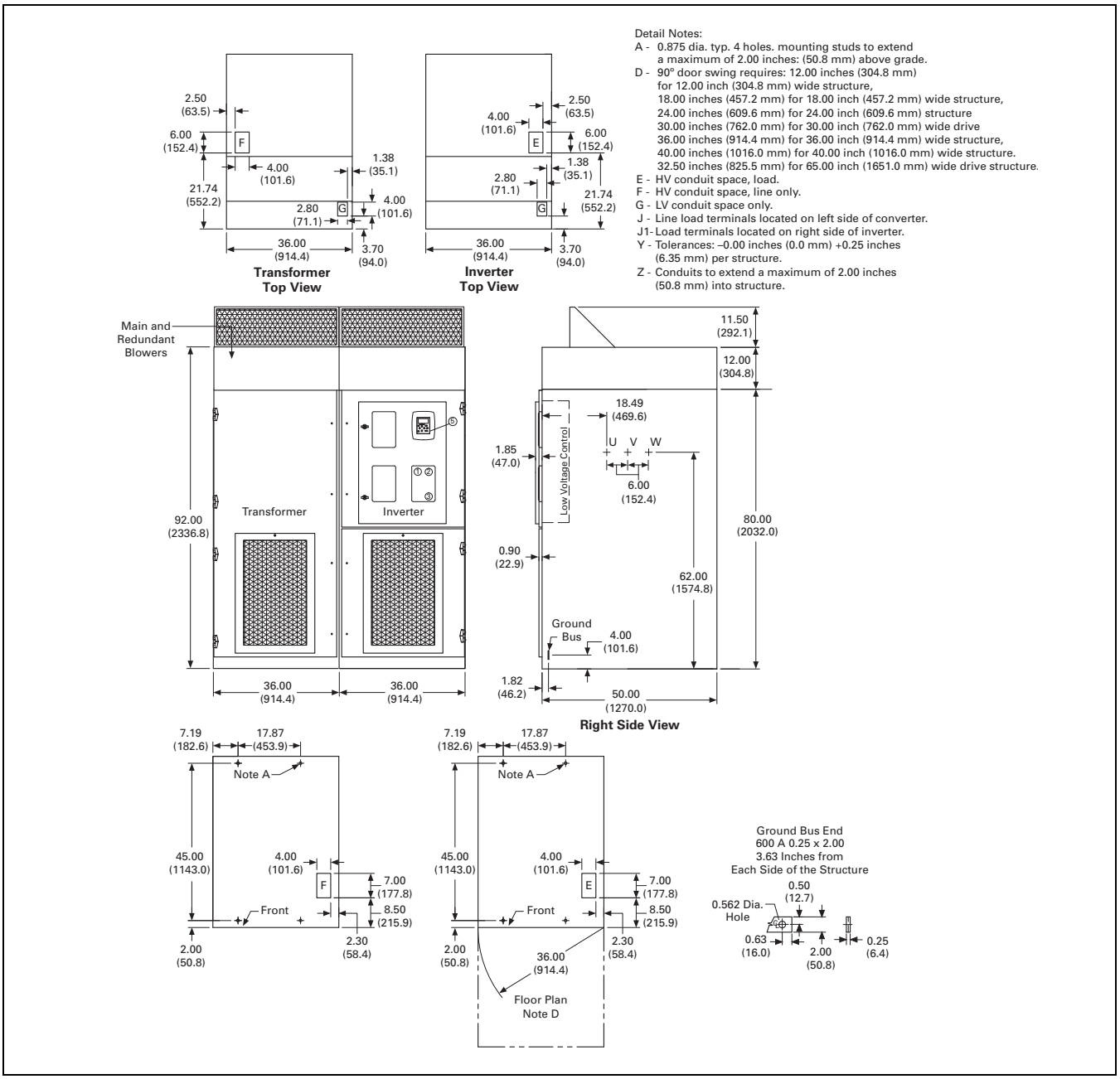


Figure 10.2-16. SC9000 GP AFD Frame A Maximum Dimensions and Incoming Line Layouts—Dimensions in Inches (mm)

10

Layout Dimensions—Arc-Resistant Frame C AFD (300–3000 hp at 4160 V) (300–2000 hp at 3300 V) (300–1750 hp at 2400 V)

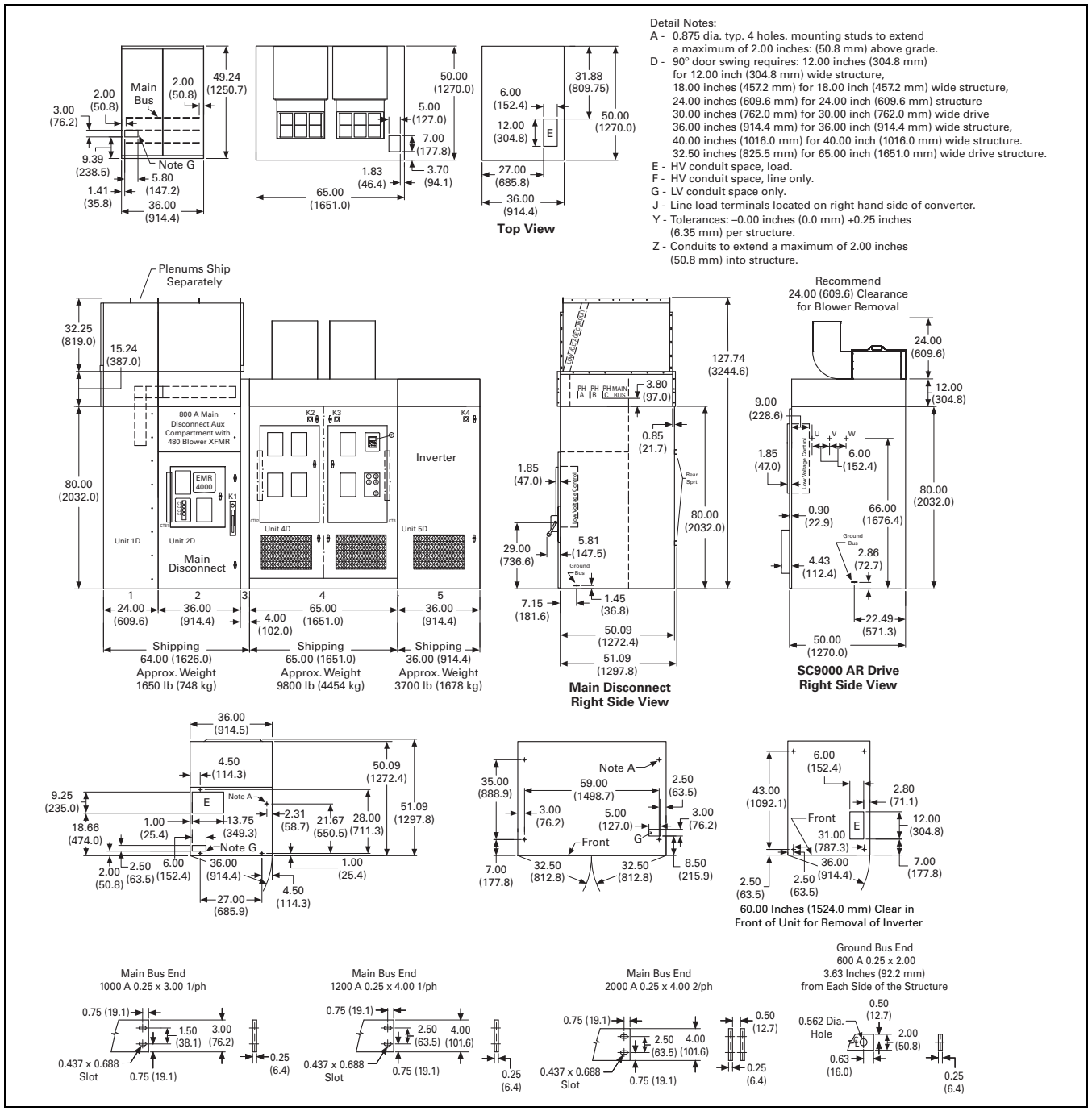


Figure 10.2-17. SC9000 AFD Frame C Maximum Dimensions and Incoming Line Layouts—Dimensions in Inches (mm)

Table 10.2-3. SC9000 AFD Frame C—Dimensions in Inches (mm)

Arc Rating	Exhaust Duct Configurations	Minimum Clearance to Obstructions in Inches (mm)				Minimum Ceiling Height in Inches (mm)
		Non-Seismic		Seismic		
		Size	Rear	Size	Rear	
50 kA	Open Top	80.00 (2032.0)	80.00 (2032.0)	80.00 (2032.0)	80.00 (2032.0)	144.00 (3657.6)
	Side, Front, Rear	4.00 (101.6)	4.00 (101.6)	6.00 (152.4)	6.00 (152.4)	124.00 (3149.6)

Layout Dimensions—Arc-Resistant Frame D AFD (Single Inverters) (3000–3700 hp at 4160 V) (2250–3000 hp at 3300 V) (2000–2500 hp at 2400 V)

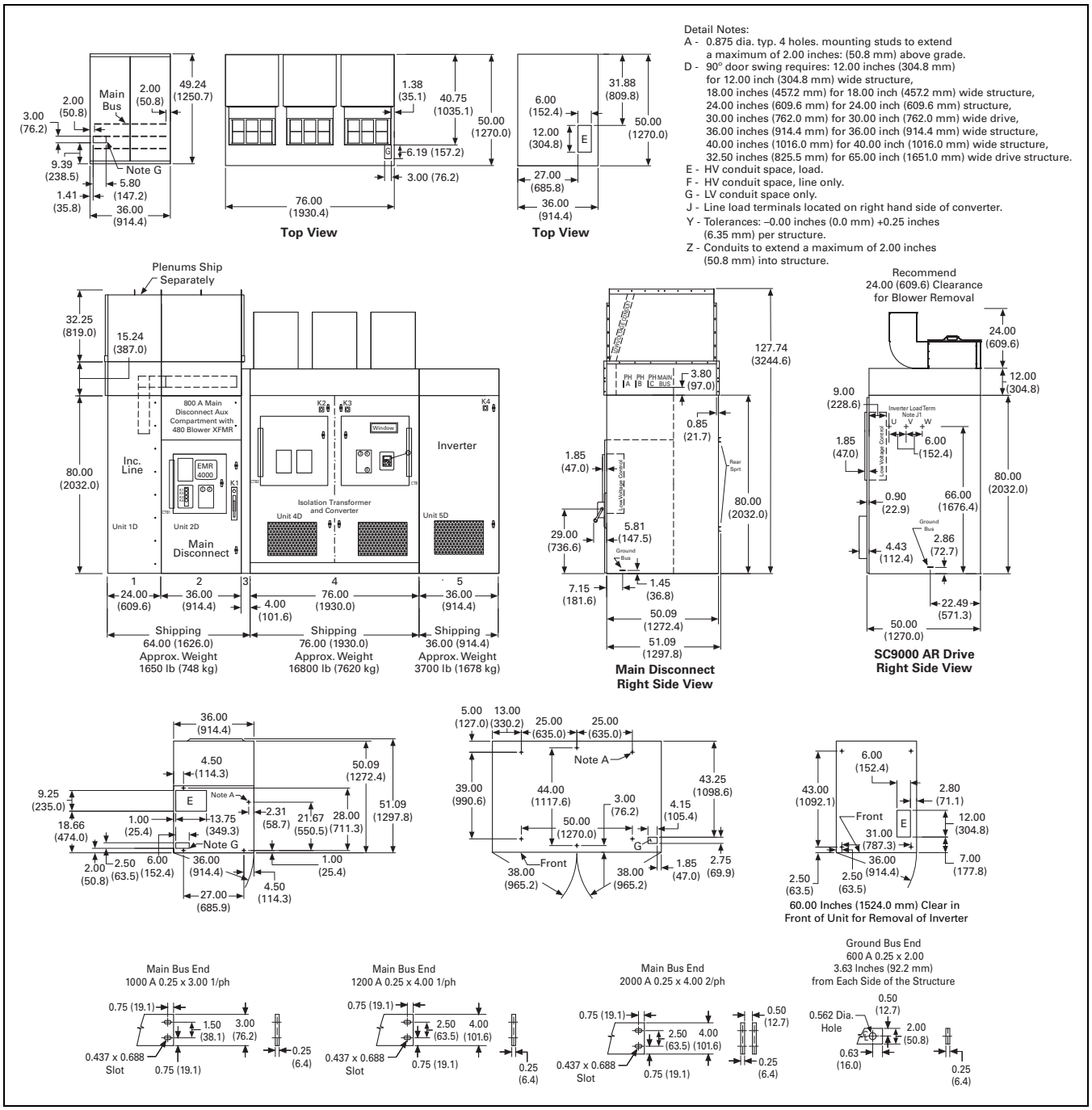


Figure 10.2-18. SC9000 AFD Frame D Maximum Dimensions and Incoming Line Layouts—Dimensions in Inches (mm)

Table 10.2-4. SC9000 AFD Frame D—Dimensions in Inches (mm)

Arc Rating	Exhaust Duct Configurations	Minimum Clearance to Obstructions in Inches (mm)				Minimum Ceiling Height in Inches (mm)
		Non-Seismic		Seismic		
		Size	Rear	Size	Rear	
50 kA	Open Top	80.00 (2032.0)	80.00 (2032.0)	80.00 (2032.0)	80.00 (2032.0)	144.00 (3657.6)
	Side, Front, Rear	4.00 (101.6)	4.00 (101.6)	6.00 (152.4)	6.00 (152.4)	124.00 (3149.6)

Layout Dimensions—Arc-Resistant Frame D AFD (Parallel Inverters) (3750–4500 hp at 4160 V) (2250–3000 hp at 3300 V)

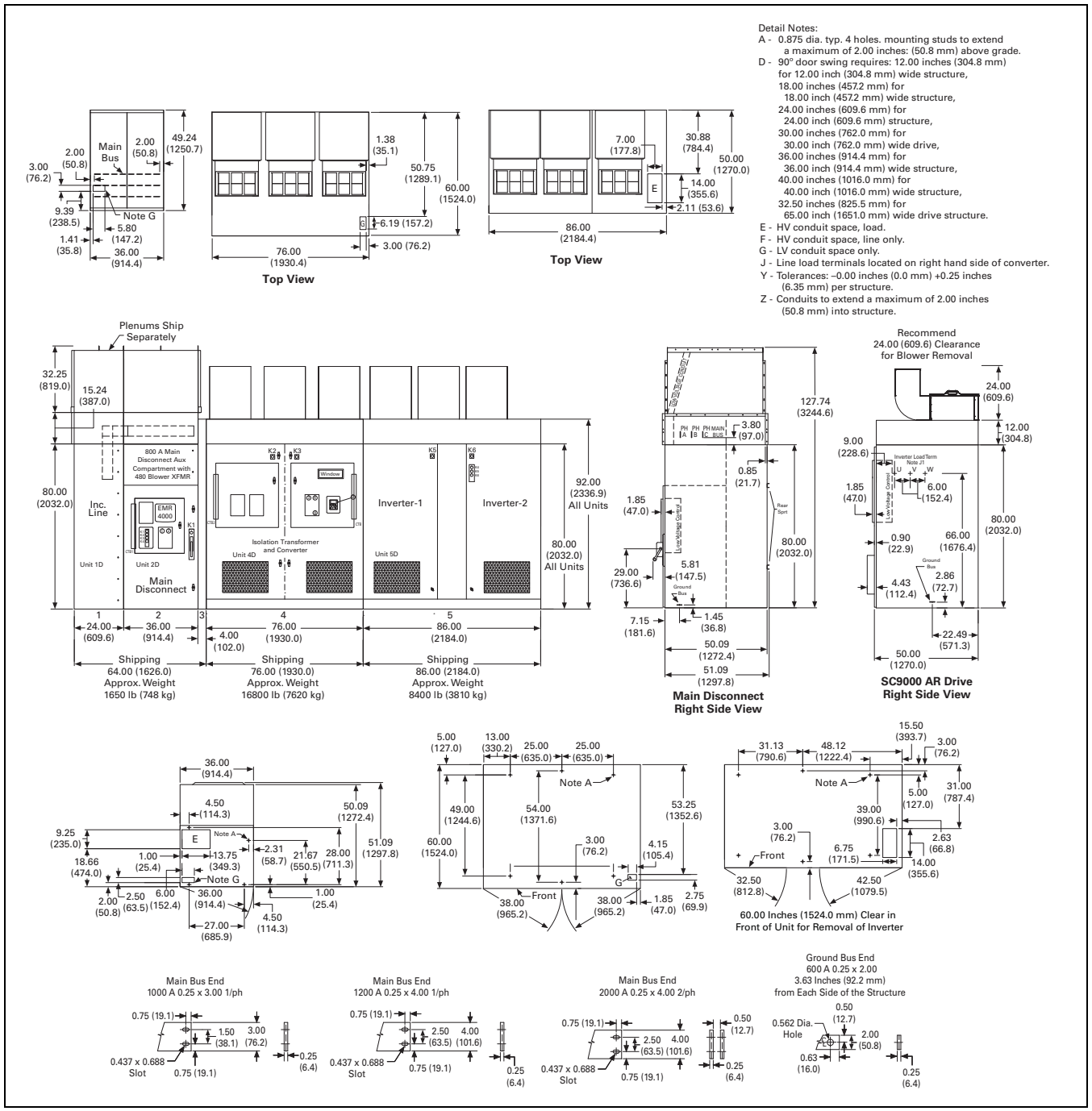


Figure 10.2-19. SC9000 AFD Frame D (Parallel Inverters) Maximum Dimensions and Incoming Line Layouts—Dimensions in Inches (mm)

Table 10.2-5. SC9000 AFD Frame D—Dimensions in Inches (mm)

Arc Rating	Exhaust Duct Configurations	Minimum Clearance to Obstructions in Inches (mm)				Minimum Ceiling Height in Inches (mm)
		Non-Seismic		Seismic		
		Size	Rear	Size	Rear	
50 kA	Open Top	80.00 (2032.0)	80.00 (2032.0)	80.00 (2032.0)	80.00 (2032.0)	144.00 (3657.6)
	Side, Front, Rear	4.00 (101.6)	4.00 (101.6)	6.00 (152.4)	6.00 (152.4)	124.00 (3149.6)

Layout Dimensions—Arc-Resistant Frame E AFD (4750–6000 hp at 4160 V) (3250–4000 hp at 3300 V)

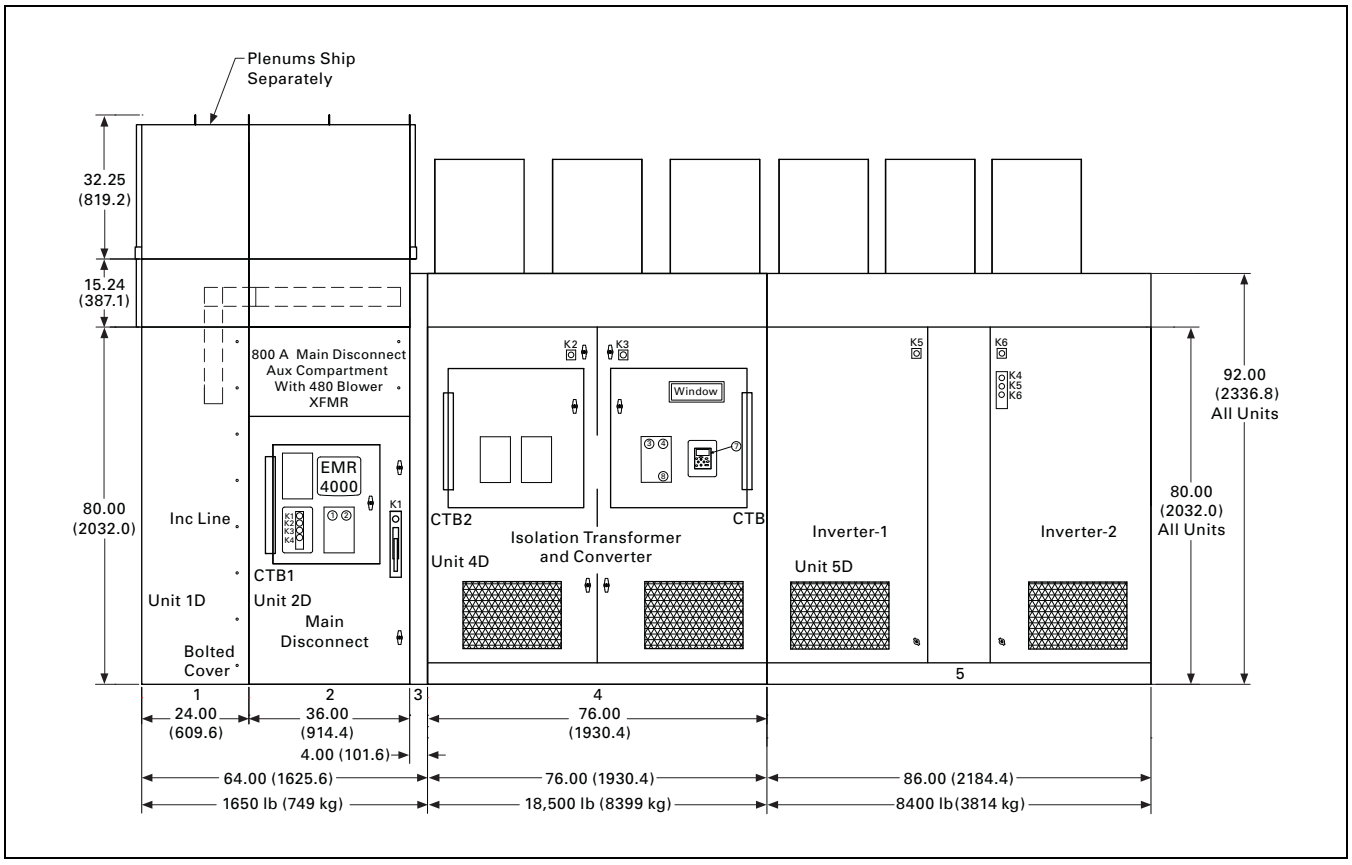


Figure 10.2-20. SC9000 EP Frame E—Dimensions in Inches (mm)

Table 10.2-6. SC9000 EP Frame E—Dimensions in Inches (mm)

Output Voltage	Motor		Cabinet Size			Redundant Blower
	FLA	hp	Width	Height	Depth	Height
3300 ① 4160	520–640 620–713	3250–4000 5000–6000	222.00 (5638.8) 222.00 (5638.8)	92.00 (2336.8) 92.00 (2336.8)	60.00 (1524.0) 60.00 (1524.0)	12.10 (307.3) 12.10 (307.3)

① 3300 V, 50 Hz.

Layout Dimensions—Integrated AMPGARD Main Breaker for EP Only (Metal-Enclosed)

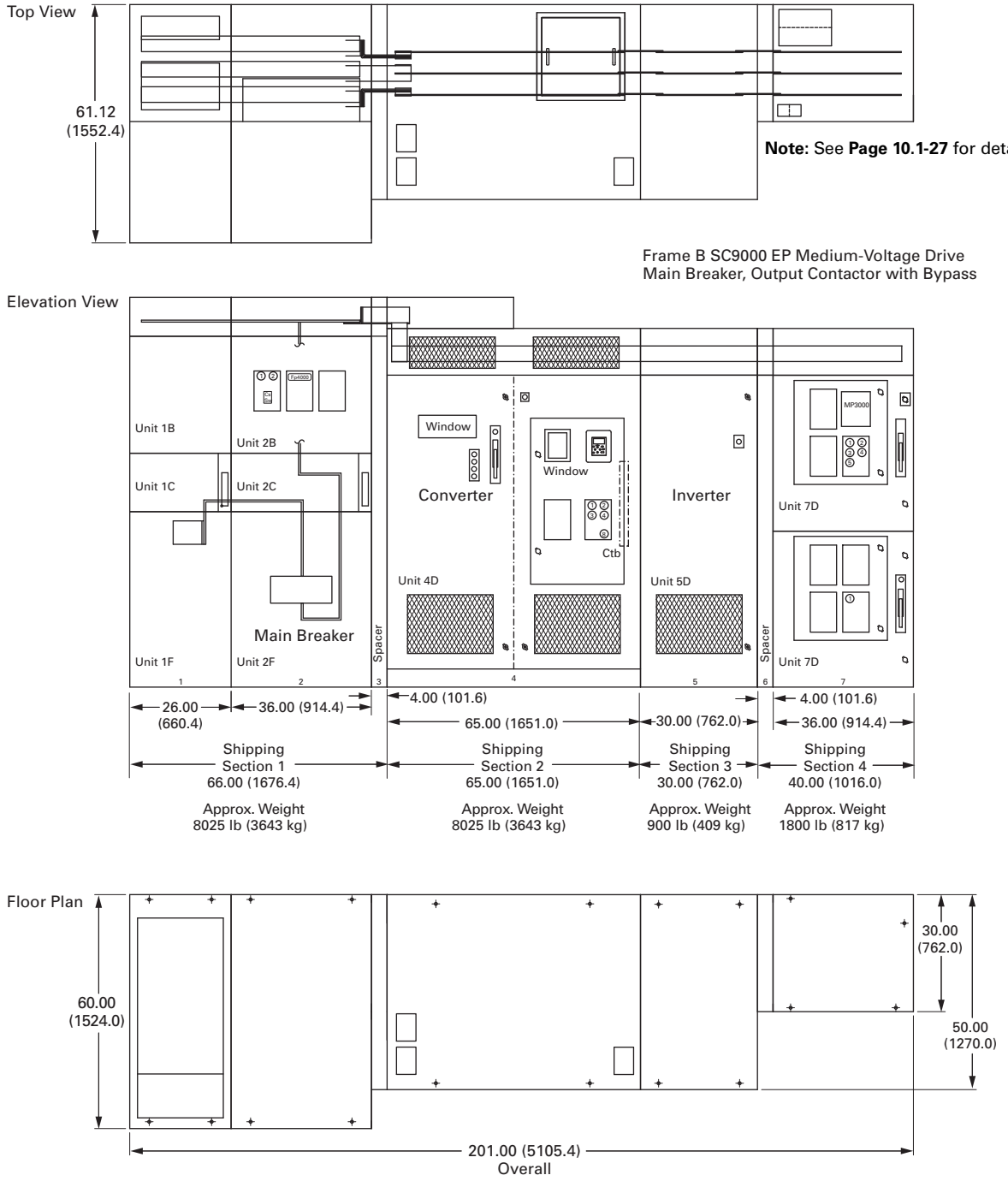
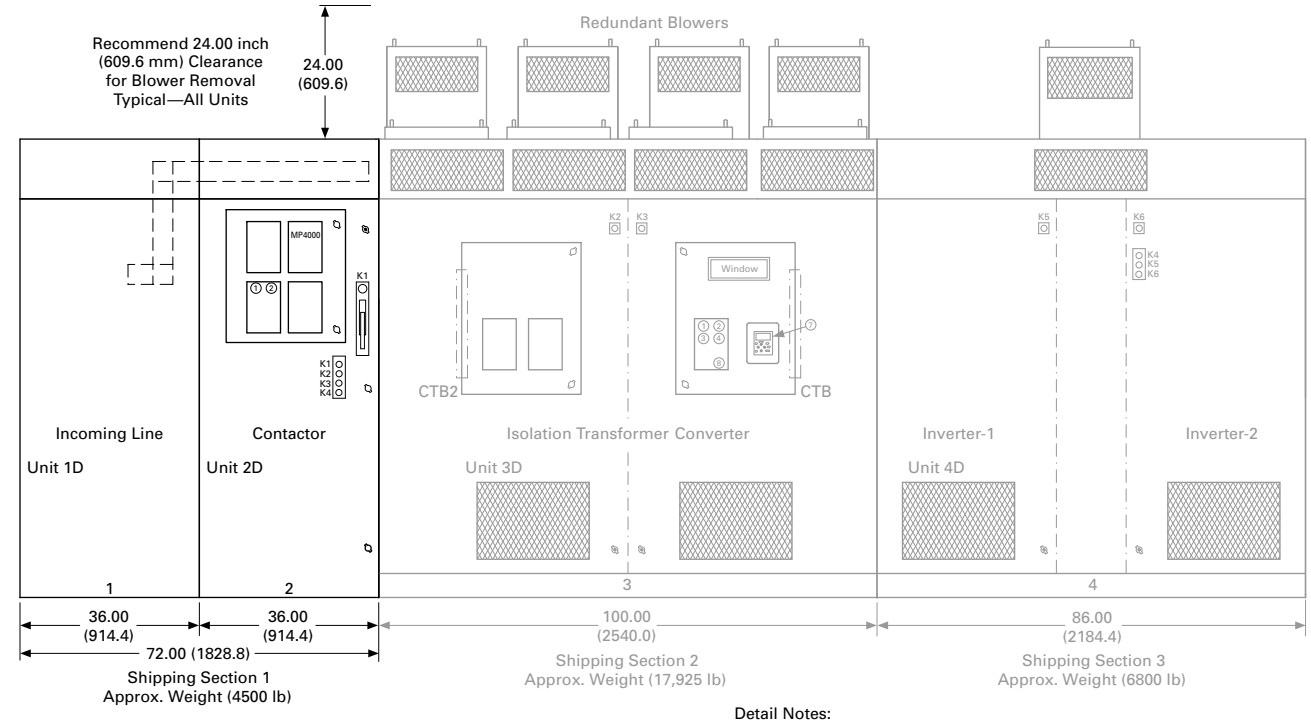
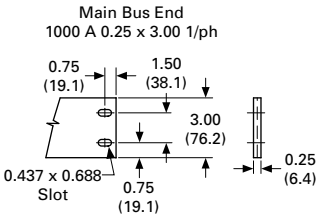


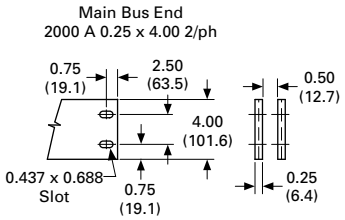
Figure 10.2-21. Eaton Medium-Voltage Integrated Control Gear with Main Breaker Dimensions—(See Page 10.1-6 for Information on Main Bus. Refer to Eaton for Larger hp Layouts and Detailed Assembly Dimensions.)

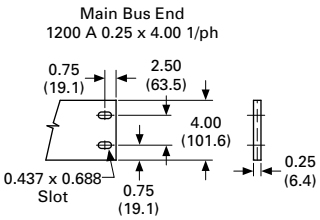
Note: For exact conduit locations and descriptions, please see **Page 10.1-42**.

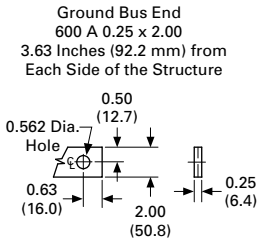
Layout Dimensions—Optional 15 kV Input Voltage Compartment (Not Arc-Rated)











Detail Notes:
A - 0.875 dia. typ. 4 holes. Mounting studs to extend a maximum of 2.00 inches (50.8 mm) above grade.
D - 90° door swing requires: 12.00 inches (304.8 mm) for 12.00 inch (304.8 mm) wide structure, 18.00 inches (457.2 mm) for 18.00 inch (457.2 mm) wide structure, 24.00 inches (609.6 mm) for 24.00 inch (609.6 mm) structure, 30.00 inches (762.0 mm) for 30.00 inch (762.0 mm) wide drive structure, 36.00 inches (914.4 mm) for 36.00 inch (914.4 mm) wide structure, 40.00 inches (1016.0 mm) for 40.00 inch (1016.0 mm) wide structure. 32.50 inches (82.6 mm) for 65.00 inch (1651.0 mm) wide drive structure.
E - HV conduit space, load.
F - HV conduit space, line only.
G - LV conduit space only.
J - Load terminals located on right side of inverter. Option—load terminals located on left side of converter.
Y - Tolerances: –0.0 inches (0.0 mm) +0.25 inches (6.4 mm) per structure.
Z - Conduits to extend a maximum of 2.00 inches (50.8 mm) into structure.

Kirk Key Interlock

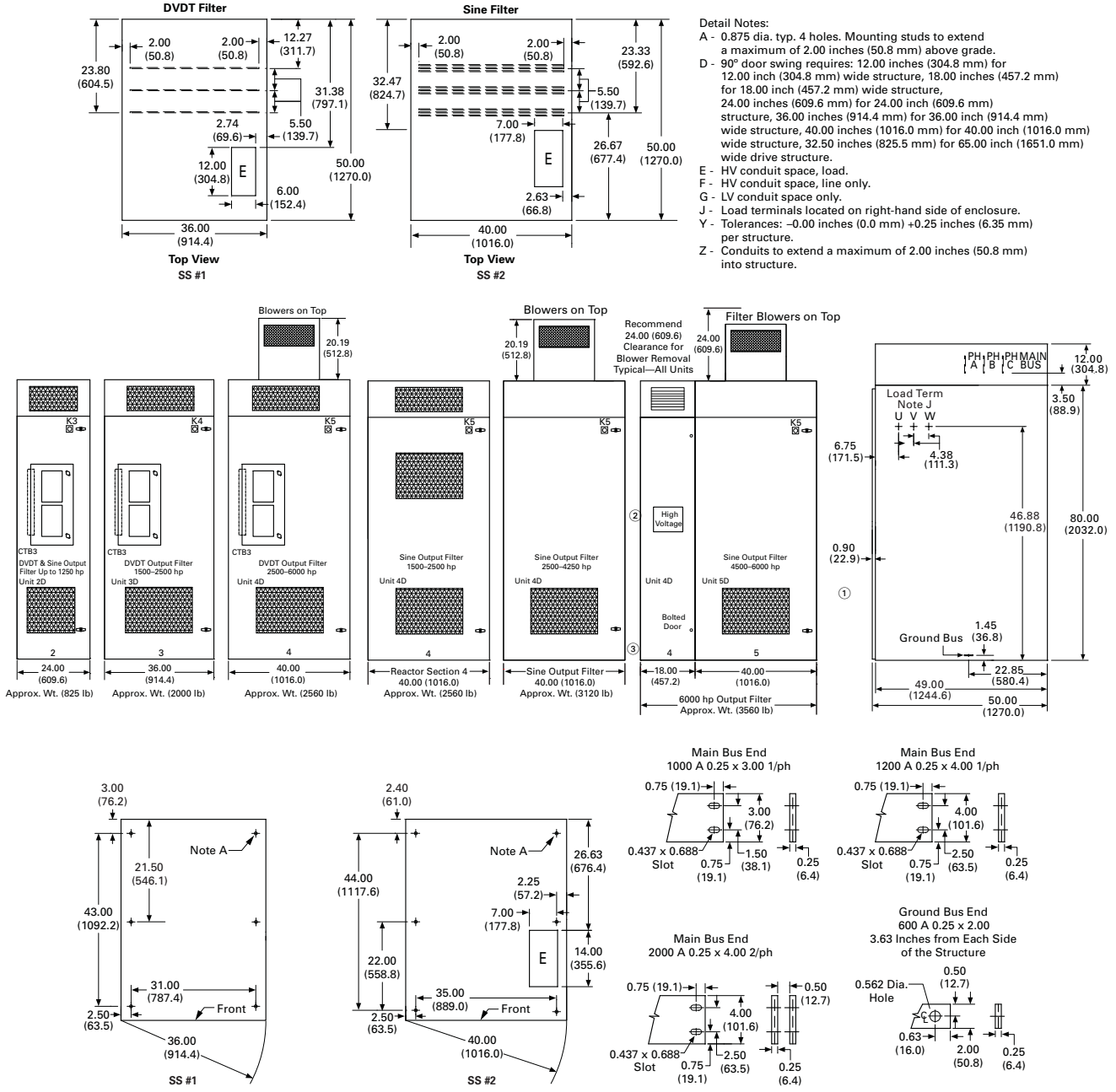
	Description
K1	Drive must be off. Main contactor must be open, ISW must be open to release K1. K1 is released when K2, K3, K4 are turned to transfer block.
K2, K3	Can only be released by K1. K2, K3 are used to open the converter doors on Unit 7D.
K4	Can only be released by K1. K4 is used to open the second transfer block on Unit 8D.
K5, K6	Can only be released by K4. K5, K6 are used to open the inverter doors on Unit 8D.

Figure 10.2-22. SC9000 EP Frame D (4500 hp) 4160 V with High-Voltage Input (for Reference Only, Available in All Frame Sizes)

Adjustable Frequency Drives With High-Voltage Input

The fully integrated SC9000 EP can be designed to receive input voltages from 2.4 to 13.8 kV, with output voltages of 2400 V, 3300 V and 4160 V, with 50 or 60 Hz available. The high-voltage input option eliminates the need of a separate distribution transformer, reduces overall footprint and simplifies overall installation. Please consult the factory for drive dimensions and incoming line section requirements.

Layout Dimensions —SC9000 EP Standard and Arc-Resistant Model AFDs Output Filters



① Varies for sine (depends on option), 46.88 (1190.8) standard, dv/dt 57.88 (1470.2).
② 10.92 (277.4) sine.
③ 9.00 for dv/dt.

Figure 10.2-23. SC9000 EP AFD Output Filter Maximum Dimensions and Incoming Line Layouts—Dimensions in Inches (mm)

Layout Dimensions—SC9000 EP Standard and Arc-Resistant Model AFDs Synchronous Transfer Systems

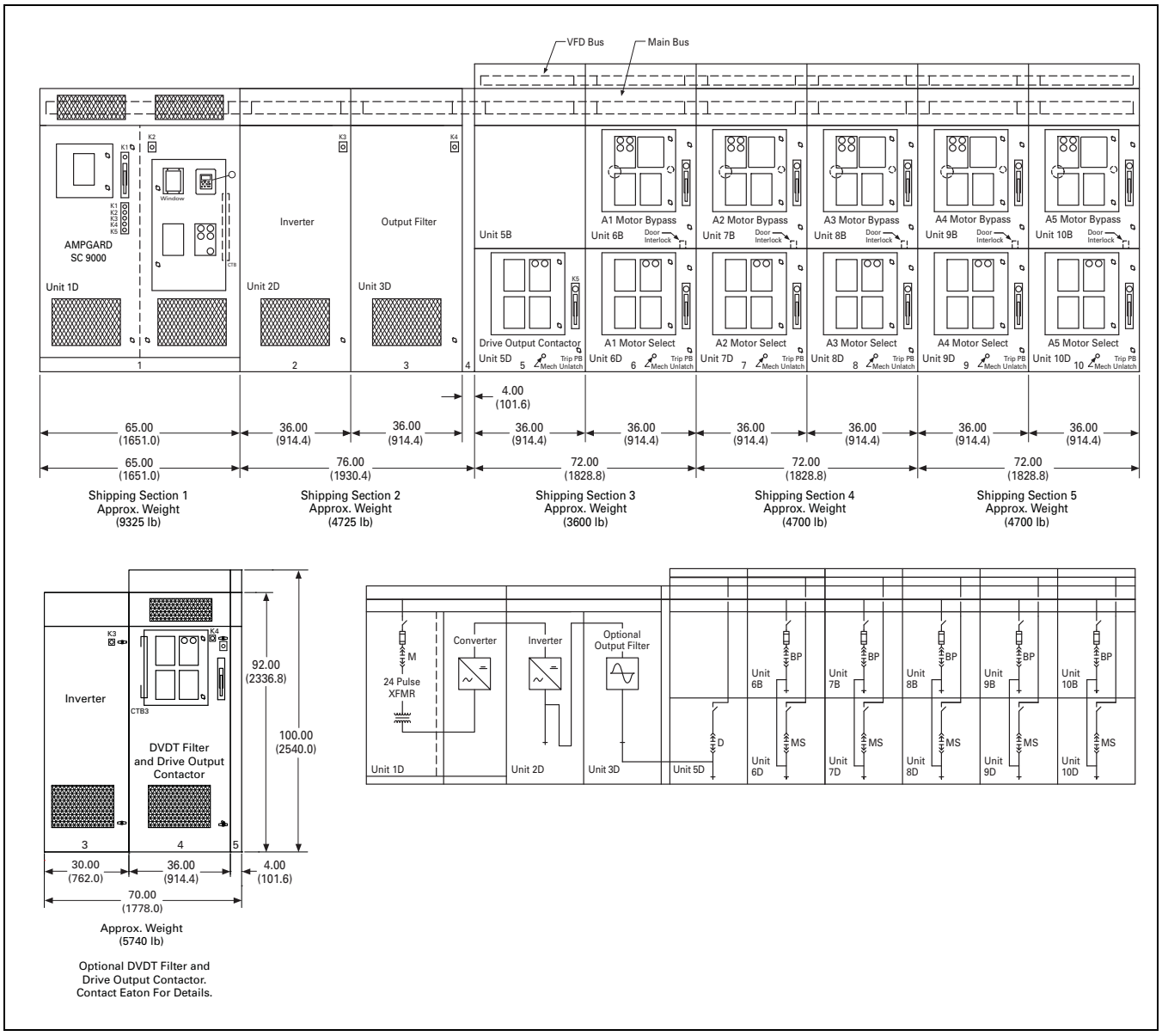


Figure 10.2-24. SC9000 EP Synchronous Transfer System with Five MV Starters (For Reference Only)

Technical Data

Table 10.2-7. Design Specifications

Description	NEMA			IEC
	GP	EP	EP Arc-Resistant	EP
Power rating	100–1000 hp (75–750 kW)	300–6000hp (150–4474 kW)	300–6000hp (150–4474 kW)	223–4474 kW
Motor type	Induction and synchronous	Induction and synchronous	Induction and synchronous	Induction and synchronous
Input voltage rating	4160 V	2400–13800 V	2400–4160 V	2 400–15,000 V
Input voltage tolerance	+/–10% of nominal	+/–10% of nominal	+/–10% of nominal	+/–10% of nominal
Power loss ride-through	5 cycles (std.)	5 cycles (std.)	5 cycles (std.)	5 cycles (std.)
Input protection	Metal oxide varistor	Metal oxide varistor	Metal oxide varistor	Metal oxide varistor
Input frequency	60 Hz, +/–5%	50/60 Hz, +/–5%	50/60 Hz, +/–5%	50/60 Hz, +/–5%
Input power circuit protection	Customer supplied	Contactor/fuses	Contactor/fuses	Contractor/fuses
Input impedance device	Isolation transformer	Isolation transformer	Isolation transformer	Isolation transformer
Output voltage	0–4160 V	0–2400 V 0–3300 V 0–4160 V	0–2400 V 0–3300 V 0–4160 V	0–2 400 V 0–3 300 V 0–4 160 V
Inverter design	PWM	PWM	PWM	PWM
Inverter switch	IGBT	IGBT	IGBT	IGBT
Enclosure	NEMA 1, gasketed and filtered	NEMA 1, gasketed and filtered	ANSI 2B, gasketed and filtered	IP20
Ambient temperature (without derating)	+32 °F to +104 °F	+32 °F to +104 °F	+32 °F to +104 °F	0 °C to +40 °C
Storage and transport temperature	–40°F to +170 °F	–40 °F to +170 °F	–40 °F to +170 °F	–40 °C to +76 °C
Relative humidity	95% noncondensing	95% noncondensing	95% noncondensing	95% noncondensing
Altitude (without derating)	0–3300 ft	0–3300 ft	0–3300 ft	0–1000 m
Seismic	—	2006 IBC	—	2006 IBC
Standards	NEMA, cUL, UL, ANSI, IEEE	NEMA, cUL, UL, ANSI, IEEE	NEMA, cUL, UL, ANSI, IEEE, CSA	IEC
Cooling	Air cooling	Air-cooling advanced heat pipe technology	Air-cooling advanced heat pipe technology	Air-cooling advanced heat pipe technology
Average watts loss ①	23 watts/hp	23 watts/hp	23 watts/hp	23 watts/hp
Input power factor	>0.98	>0.98	>0.98	>0.98
Number of inverter IGBTs	IGBTs	IGBTs	IGBTs	IGBTs
2400 V	—	12	12	12
3300 V	—	12	12	12
4160 V	12	12 (2)	12 (2)	12
IGBT PIV rating	PIV	PIV	PIV	PIV
2400 V	—	3300 V	3300 V	3300 V
3300 V	—	6500 V	6500 V	6500 V
4160 V	6500 V	6500 V	6500 V	6500 V
Rectifier designs	24-pulse	24-pulse	24-pulse	24-pulse
Rectifier switch	Diode	Diode	Diode	Diode
Rectifier switch failure mode	Non-rupture, non-arc	Non-rupture, non-arc	Non-rupture, non-arc	Non-rupture, non-arc
Rectifier switch cooling	Air-cooled	Air-cooled	Air-cooled	Air-cooled
Output waveform to motor	Sinusoidal current/voltage	Sinusoidal current/voltage	Sinusoidal current/voltage	Sinusoidal current/voltage
Speed regulation	0.1% without tach feedback	0.1% without tach feedback	0.1% without tach feedback	0.1% without tach feedback
Output frequency range	1–120 Hz	1–120 Hz	1–120 Hz	1–120 Hz
Service duty rating	Standard	Standard	Standard	Standard
Typical efficiency	97%	97%	97%	97%
Flying start capability	Yes	Yes	Yes	Yes

① Reflects conservative estimate. Actual amounts may vary.
② 24 IGBTs are required for motors above 5500 hp.

Frame Size VT/CT Reference Chart

Table 10.2-8. SC9000 EP Frame A
See **Page 10.2-3** and **Figure 10.2-10**

2400/60 Hz VT		3300/50 Hz VT		4160/60 Hz VT	
FLA	**hp**	**FLA**	**hp**	**FLA**	**hp**
69 80 91	300 350 400	48 56 64	300 350 400	38 44 51	300 350 400
103 114 —	450 500 —	72 80 96	450 500 600	57 63 76	450 500 600
— — —	— — —	112 — —	700 — —	89 101 114	700 800 900
— —	— —	— —	— —	124 132	1000 ① 1150 ①

2400/60 Hz CT		3300/50 Hz CT		4160/60 Hz CT	
FLA	**hp**	**FLA**	**hp**	**FLA**	**hp**
69 80 —	300 350 —	48 56 64	300 350 400	38 44 51	300 350 400
— — —	— — —	72 80 —	450 500 —	57 63 76	450 500 600

① Requires second blower configuration. Redundant blowers not available.

Table 10.2-9. SC9000 EP Frame B
See **Page 10.2-5** and **Figure 10.2-11**

2400/60 Hz VT		3300/50 Hz VT		4160/60 Hz VT	
FLA	**hp**	**FLA**	**hp**	**FLA**	**hp**
134 156 178	600 700 800	128 144 160	800 900 1000	124 155 186	1000 1250 1500
201 223	900 1000	200 240	1250 1500	217 248	1750 2000

2400/60 Hz CT		3300/50 Hz CT		4160/60 Hz CT	
FLA	**hp**	**FLA**	**hp**	**FLA**	**hp**
91 103 114	400 450 500	96 112 128	600 700 800	89 101 114	700 800 900
134 156	600 700	144 160	900 1000	124 155	1000 1250

Table 10.2-10. SC9000 EP Frame C
See **Page 10.2-7** and **Figure 10.2-12**

2400/60 Hz VT		3300/50 Hz VT		4160/60 Hz VT	
FLA	**hp**	**FLA**	**hp**	**FLA**	**hp**
279 335 390 —	1250 1500 1750 —	280 320 — —	1750 2000 — —	279 310 341 372	2250 2500 2750 ② 3000 ②

2400/60 Hz CT		3300/50 Hz CT		4160/60 Hz CT	
FLA	**hp**	**FLA**	**hp**	**FLA**	**hp**
178 201 223 279	800 900 1000 1250	200 — — —	1250 — — —	186 217 248 —	1500 1750 2000 —

② Requires second blower configuration. Redundant blowers not available.

Table 10.2-11. SC9000 EP Frame D
See **Pages 10.2-9** and **10.2-11** and **Figures 10.2-13** and **10.2-14**

2400/60 Hz VT		3300/50 Hz VT		4160/60 Hz VT	
FLA	**hp**	**FLA**	**hp**	**FLA**	**hp**
448 504 561	2000 2250 2500	360 400 440	2250 2500 2750	403 434 461	3250 3500 3750 ③
— — —	— — —	480 — —	3000 — —	493 527 558	4000 ③ 4250 ③ 4500 ③

2400/60 Hz CT		3300/50 Hz CT		4160/60 Hz CT	
FLA	**hp**	**FLA**	**hp**	**FLA**	**hp**
335 390 448	1500 1750 2000	240 280 320	1500 1750 2000	279 310 341	2250 2500 2750
— —	— —	— —	— —	372 403	3000 3250

③ Contact Eaton for single inverter configuration.

Table 10.2-12. SC9000 EP Frame E
See **Figure 10.2-15**

2400/60 Hz VT		3300/50 Hz VT		4160/60 Hz VT	
FLA	**hp**	**FLA**	**hp**	**FLA**	**hp**
— — —	— — —	— — —	— — —	589 620 651	4750 ④ 5000 ④ 5250
— — —	— — —	— — —	— — —	682 713 744	5500 5750 6000

2400/60 Hz CT		3300/50 Hz CT		4160/60 Hz CT	
FLA	**hp**	**FLA**	**hp**	**FLA**	**hp**
— — —	— — —	360 400 —	2250 2500 —	434 461 493	3500 3750 4000

④ Contact Eaton for single inverter configuration.

VT = Variable Torque (110% overload for 1 minute every 10 minutes)

CT = Constant Torque (150% overload for 1 minute every 10 minutes)

Table 10.2-13. SC9000 GP
See **Figure 10.2-29**

4160 V / 60 Hz VT														
FLA	13	19	26	32	38	44	51	57	53	76	89	101	114	124
hp	100	150	200	250	300	350	400	450	500	600	700	800	900	1000

Table 10.2-14. SC9000 EP Adjustable Frequency Drive Efficiency, Power Factor and Harmonics Typical Data

Description	Load (%)		
	50	75	100
Speed 50%			
Input PF (1)	0.96	0.98	0.98
Input THD (V)	3.13	3.64	3.43
Input THD (I)	7.59	6.40	6.73
Efficiency (%)	0.943	0.959	0.962
Speed: 75%			
Input PF (1)	0.98	0.99	0.99
Input THD (V)	1.34	2.32	3.15
Input THD (I)	6.76	4.44	3.85
Efficiency (%)	0.965	0.970	0.971
Speed: 100%			
Input PF (1)	0.98	0.99	0.99
Input THD (V)	2.16	2.20	2.30
Input THD (I)	5.95	4.38	3.13
Efficiency (%)	0.971	0.972	0.974

Table 10.2-15. SC9000 EP Adjustable Frequency Drive Heat Loss Data ①

Horsepower	Watts Loss as Heat	Horsepower	Watts Loss as Heat	Horsepower	Watts Loss as Heat
200	4600	900	20,700	3000	69,000
300	6900	1000	23,000	3500	80,500
350	8050	1250	28,750	3700	85,100
400	9200	1500	34,500	3750	86,250
450	10,350	1750	40,250	4000	92,000
500	11,500	2000	46,000	4500	103,500
600	13,800	2250	51,750	5500	126,500
700	16,100	2500	57,500	6000	138,000
800	18,400	2750	63,250	—	—

① Estimate additional 2 watt/hp heat loss for DVDT or sine filter (see IB20002EN for more details).

Table 10.2-16. SC9000 GP Adjustable Frequency Drive Heat Loss Data

hp	Watts Lost as Heat
4160 V / 60 Hz VT	
100 150 200	4600 6050 7500
250 300 350	8950 10,400 11,850
400 450 500	13,300 14,745 16,200
600 700 800	19,100 22,000 24,900
900 1000	27,785 30,685

Typical Schematic

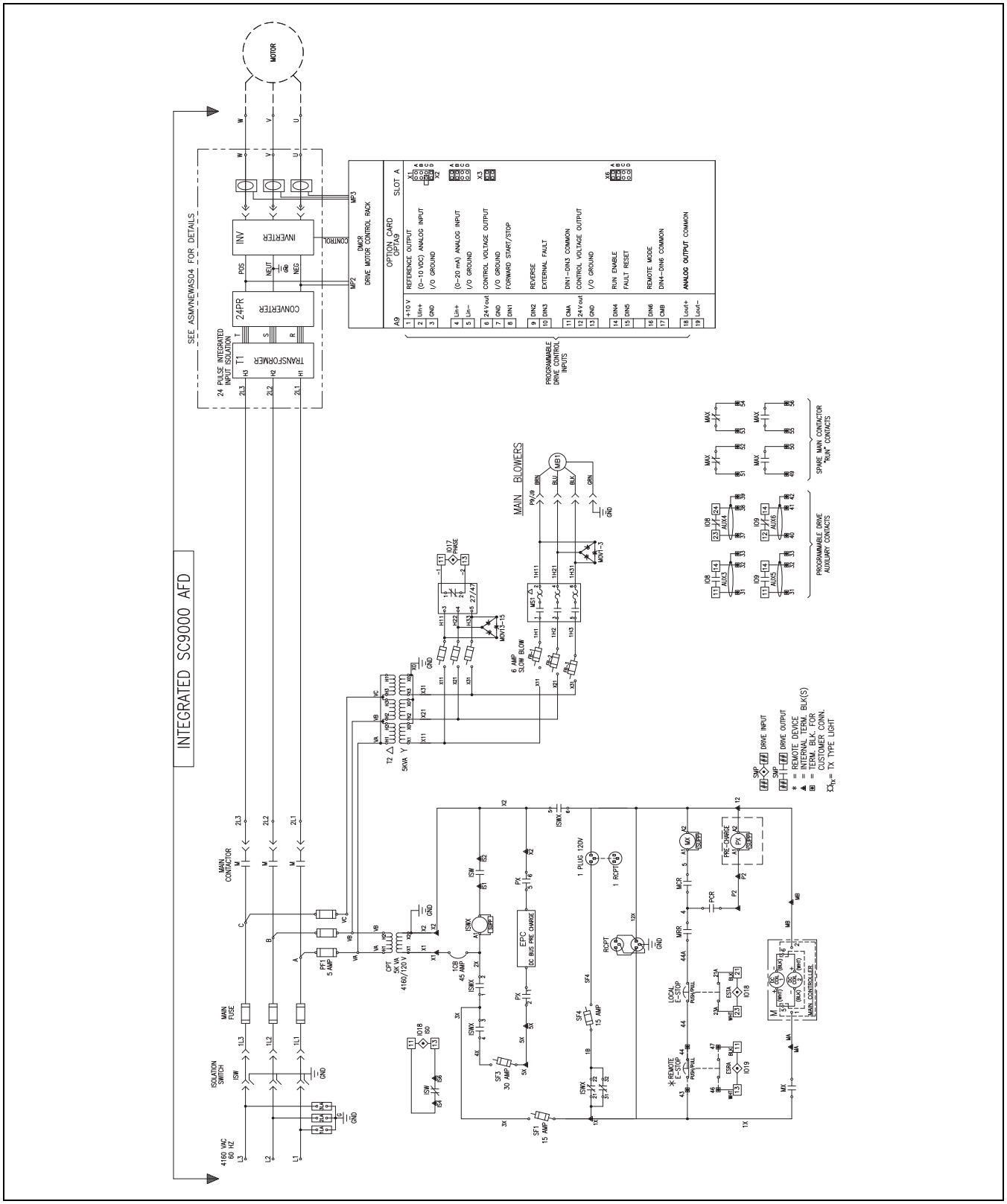


Figure 10.2-25. Typical Schematic for SC9000 EP AFD

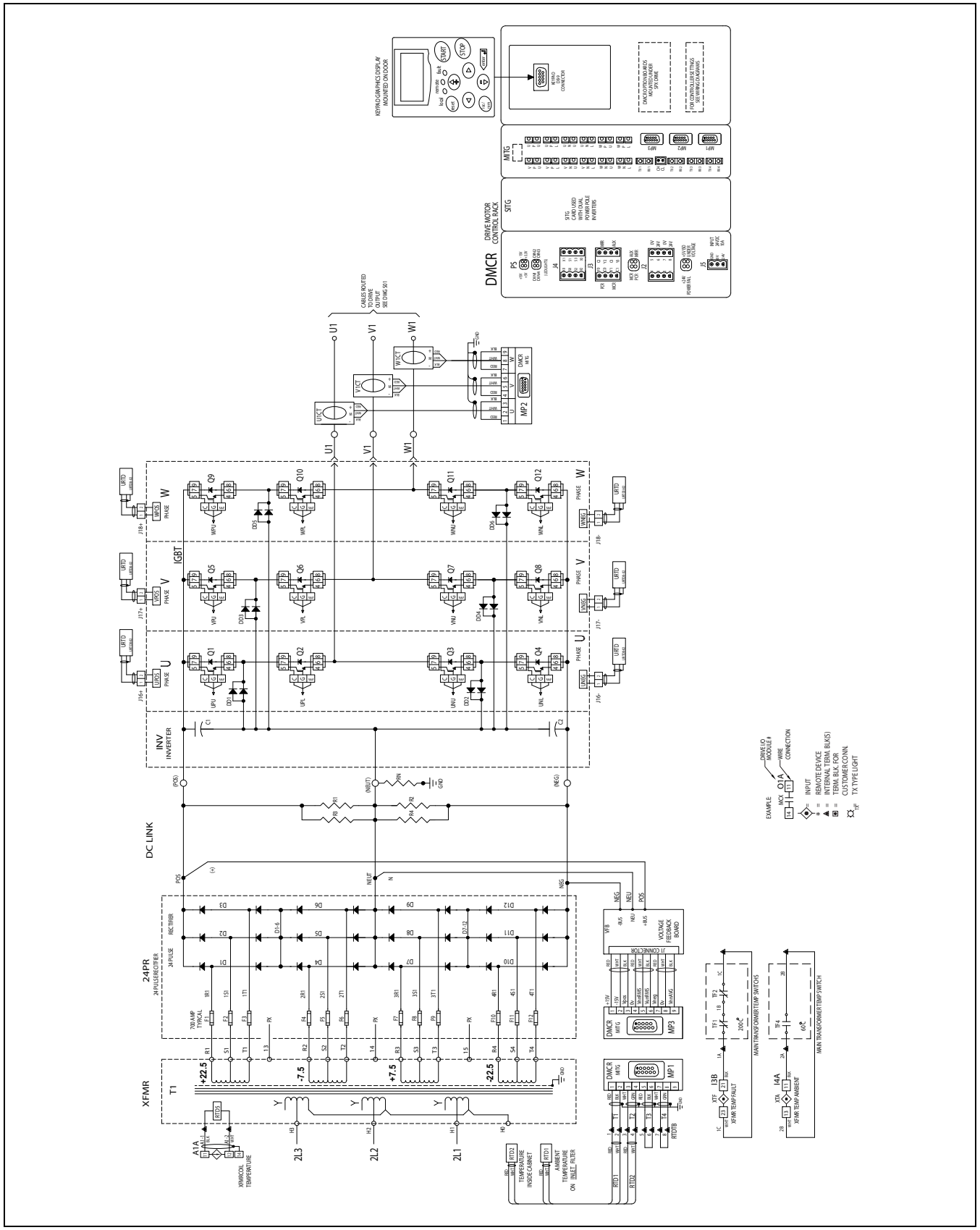


Figure 10.2-26. Typical Schematic for 24-Pulse Transformer, Rectifier and Inverter

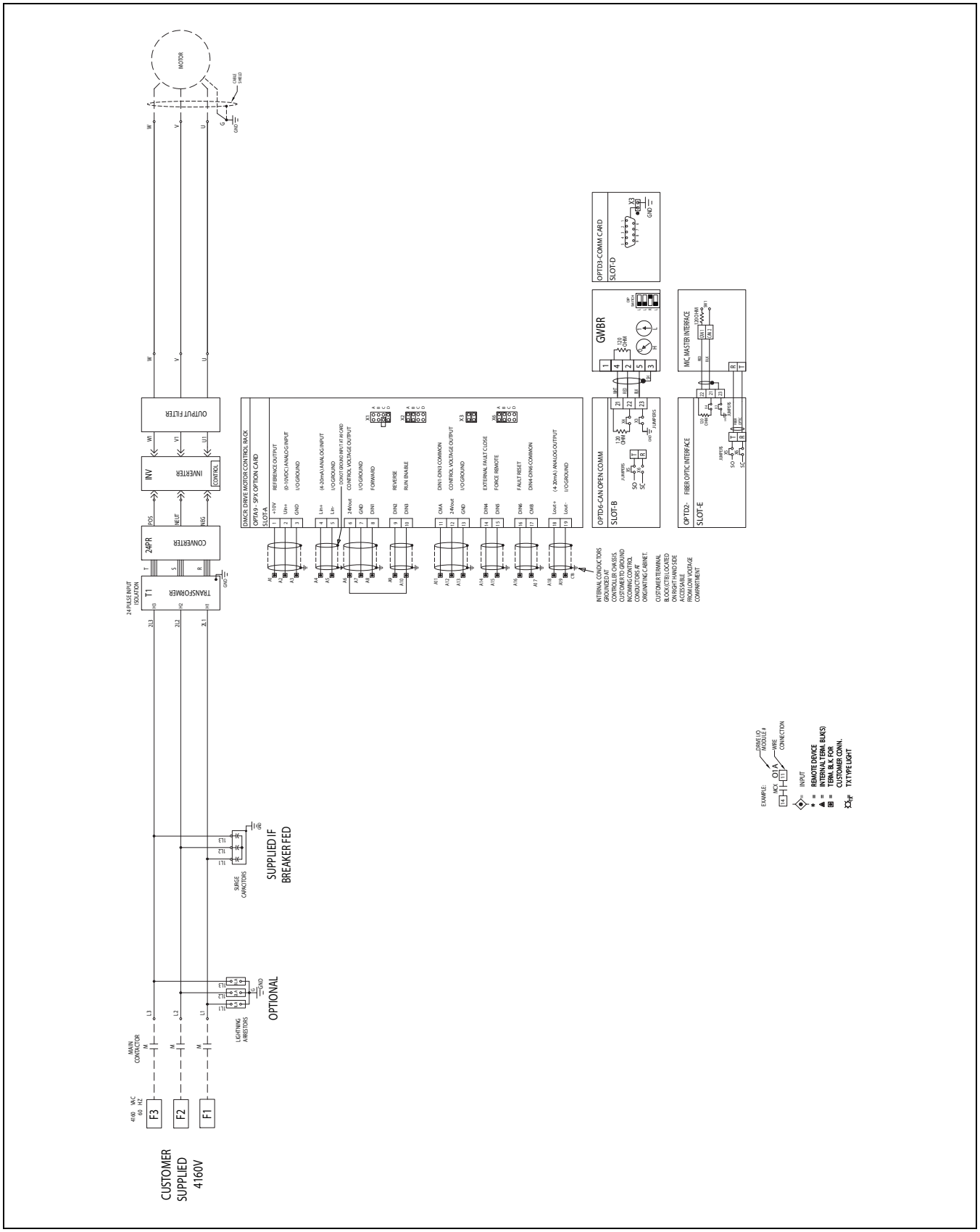


Figure 10.2-27. Typical GP Schematic

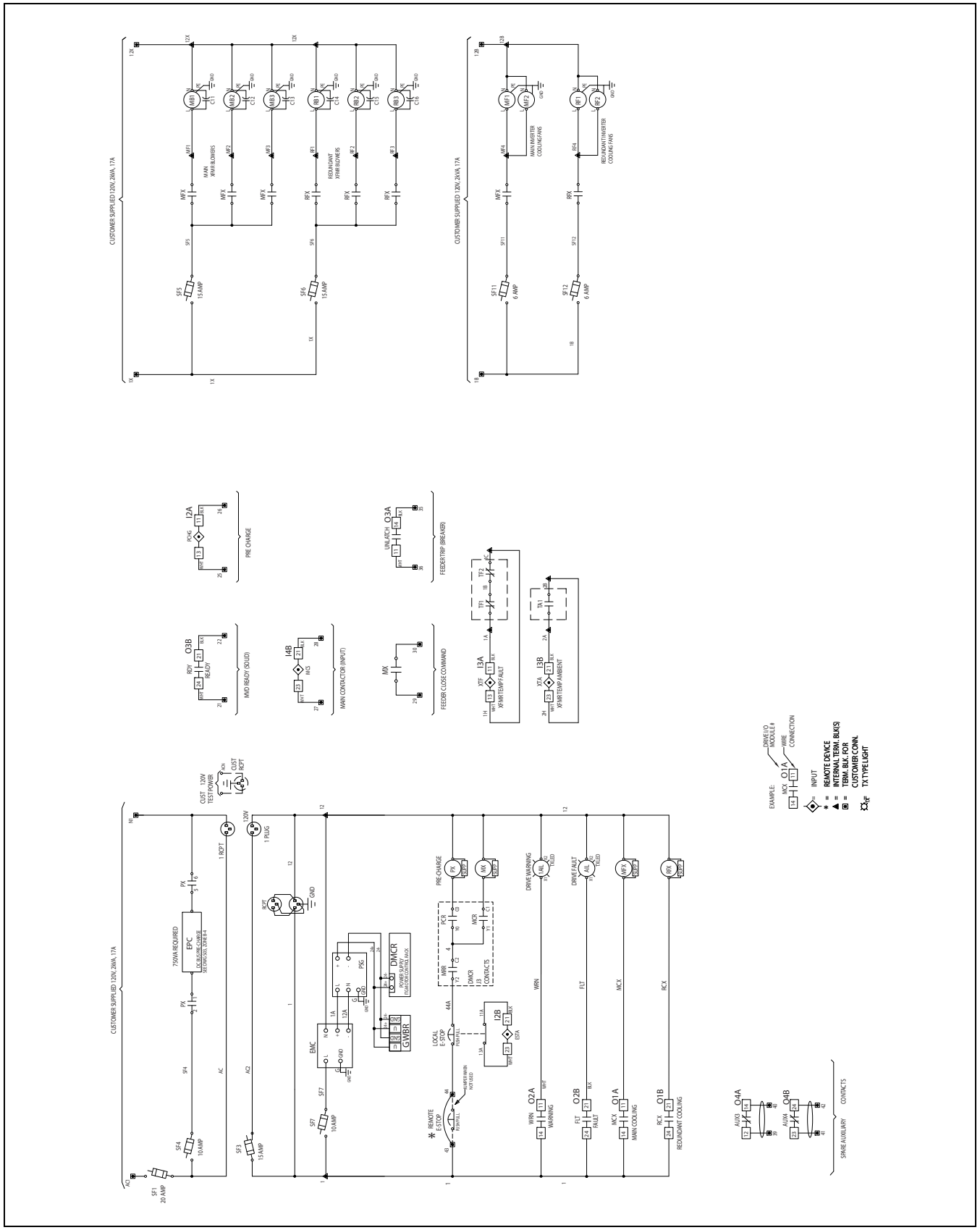


Figure 10.2-28. Typical GP Schematic

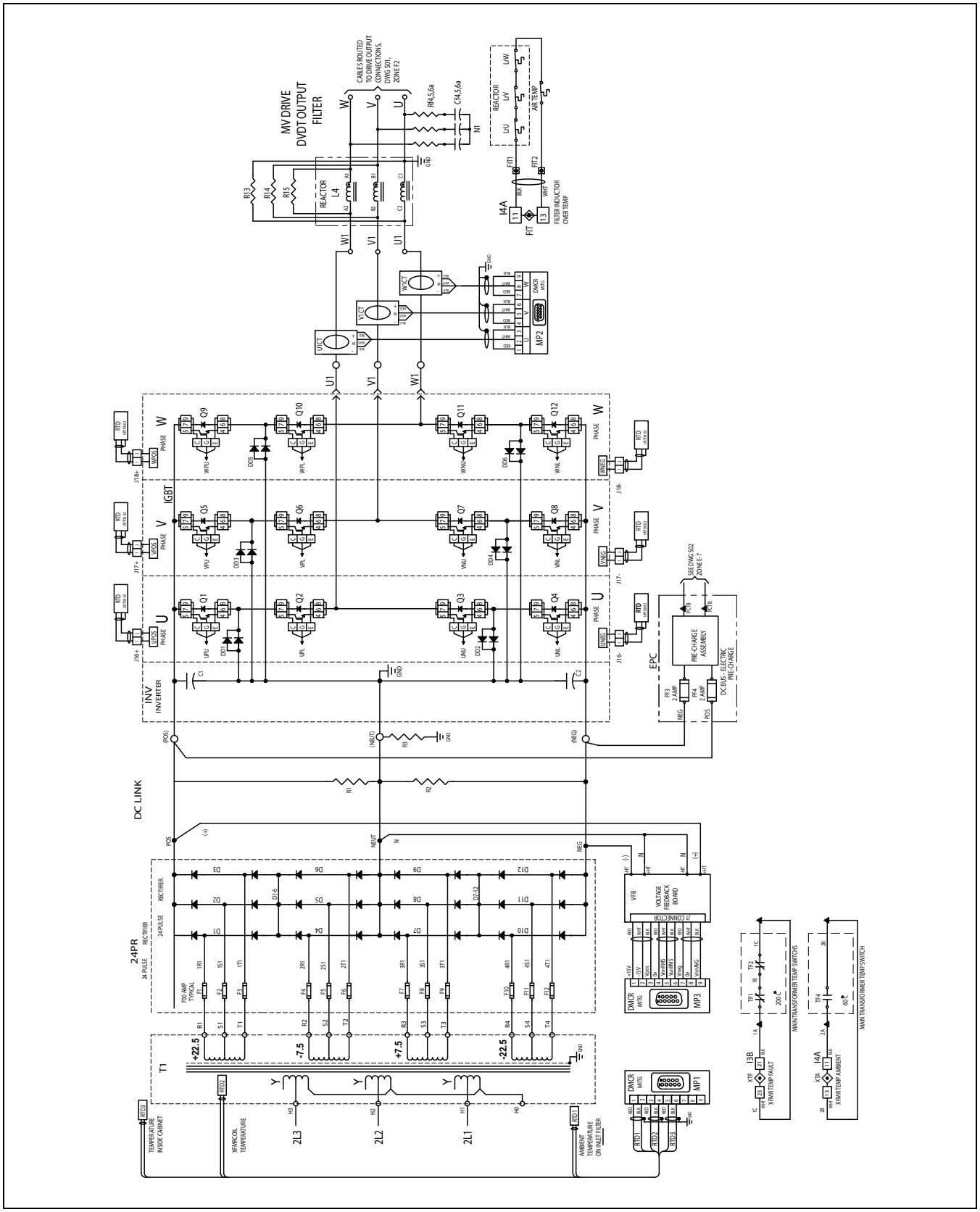


Figure 10.2-29. Typical Schematic for SC900 GP, Rectifier and Inverter

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