Power Factor Capacitors and Detuned Filters

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

| CSI Format: | 1995 | 2010 |
|---|---|---|
| Fixed Power Factor Correction Equipment—LV (UNIPAK) | **Section 16280A** | **Section 23 35 33.11** |
| Switched Power Factor Correction Equipment—LV (AUTOVAR) | **Section 16280B** | **Section 23 35 33.13** |
| Switched Detuned Filter Equipment—LV (AUTOVAR) | **Section 16280C** | **Section 26 35 26.11** |
| Switched Capacitor & Detuned Filter Equipment—MV (AUTOVAR) | **Section 16280E** | **Section 23 35 33.19** |
| Fixed Detuned Filter Power Factor Correction Equipment—LV (UNIPAK Detuned Filter) | **Section 16280F** | **Section 26 35 26.13** |

## Capacitor Selection

There are two basic types of capacitor installations: individual capacitors on linear or sinusoidal loads, and banks of fixed or automatically switched capacitors at the feeder or substation.

### Individual vs. Banked Installations

Advantages of individual capacitors at the load:

- Complete control. Capacitors cannot cause overcompensation on the line during light load conditions
- No need for separate switching. Motor always operates with capacitor
- Improved motor performance due to more efficient power utilization and reduced voltage drops
- Motors and capacitors can be easily relocated together
- Easier to select the right capacitor for the load
- Reduced line losses
- Increased system capacity

Advantages of bank installations at the feeder or substation:

- Lower cost per kvar
- Total plant power factor improved—reduces or eliminates all forms of kvar charges
- Automatic switching ensures exact amount of power factor correction, eliminates overcapacitance and resulting overvoltages

**Table 35.0-1. Summary of Advantages/Disadvantages of Individual, Fixed Banks, Automatic Banks, Combination**

| Method | Advantages | Disadvantages |
|---|---|---|
| Individual capacitors | Most technically efficient, most flexible | Higher installation and maintenance cost |
| Fixed bank | Most economical, fewer installations | Less flexible, requires switches and/or circuit breakers |
| Automatic bank | Best for variable loads, prevents overvoltages, low installation cost | Higher equipment cost |
| Combination | Most practical for larger numbers of motors | Least flexible |

### Selection Criteria

The selection of the type of capacitor installation will depend on advantages and disadvantages of each type and several plant variables, including load type, load size, load constancy, load capacity, motor starting methods and manner of utility billing.

### Load Type

If a facility has many large motors, 50 hp and above, it is usually economical to install one capacitor per motor and switch the capacitor and motor together. If there are many small motors, 1/2 to 25 hp, motors can be grouped with one capacitor at a central point in the distribution system. Often, the best solution for plants with large and small motors is to use both types of capacitor installations.

### Load Size

Facilities with large loads benefit from a combination of individual load, group load and banks of fixed and automatically-switched capacitor units. A small facility, on the other hand, may require only one capacitor at the service entrance.

Sometimes, only an isolated trouble spot requires power factor correction in applications such as welding machines, induction heaters or DC drives. If a particular feeder serving a low power factor load is corrected, it may raise overall plant power factor enough that additional capacitors are unnecessary.

### Load Constancy

If a facility operates around-the-clock and has a constant load demand, fixed capacitors offer the greatest economy. If load is determined by eight-hour shifts five days a week, use switched units to decrease capacitance during times of reduced load.

### Load Capacity

If the load on a transformer is approaching its maximum kVA rating and the load has a poor power factor, below 0.9 for example, capacitors may be added to supply reactive power to the load thereby reducing loading on the transformer. This will therefore add kVA capacity to the system. Similarly feeder cable load current can be reduced by the addition of capacitors, if the load requires a significant amount of reactive power.

### Utility Billing

The severity of the local electric utility tariff for power factor will affect payback and ROI. In many areas, an optimally designed power factor correction system will pay for itself in less than two years.

## National Electrical Code Requirements for Capacitors

**Nameplate kvar**: Tolerance +15, –0%.

**Discharge resistors**: Capacitors rated at 600 V and less must reduce the charge to less than 50 V within 1 minute of de-energization. Capacitors rated above 600 V must reduce the charge within 5 minutes.

**Continuous operation**: Up to 135% rated (nameplate) kvar, including the effects of 110% rated voltage (121% kvar), 15% capacitance tolerance and harmonic voltages over the fundamental frequency (60 Hz).

**Dielectric strength test**: Twice the rated AC voltage (or a DC voltage 4.3 times the AC rating for non-metallized systems).

**Overcurrent Protection**: Fusing between 1.65 and 2.5 times rated current to protect case from rupture. Does not preclude NEC® requirement for overcurrent protection in all three ungrounded conductors.

**Note:** When capacitor is connected to the load side of the motor overcurrent protection, fused disconnects or breaker protection is not required. Fuses are recommended for all other indoor applications.

# Capacitor Switching Devices

## Low Voltage Capacitor Switching

Circuit breakers and switches for use with a capacitor must have a current rating in excess of rated capacitor current to provide for overcurrent from overvoltages at fundamental frequency and harmonic currents. The following percent of the capacitor-rated current should be used as a general guideline:

Fused and unfused switches. . . . . 165%

Molded-case breaker or equivalent . . . . . 150%

Power circuit breakers . . . . . 135%

Insulated case circuit breakers. . . 135%

Contactors . . . . . 150%

The NEC, Section 460.8(c)(4), requires the disconnecting means to be rated not less than 135% of the rated capacitor current (for 600 V and below). See **Page 35.0-4** for more information on Low Voltage Capacitor Switching Devices.

## Medium Voltage Capacitor Switching

Capacitance switching constitutes severe operating duty for a circuit breaker. At the time the breaker opens at near current zero the capacitor is fully charged. After interruption, when the alternating voltage on the source side of the breaker reaches its opposite maximum, the voltage that appears across the contacts of the open breaker is at least twice the normal peak line-to-neutral voltage of the circuit. If a breakdown occurs across the open contact the arc is re-established. Due to the circuit constants on the supply side of the breaker, the voltage across the open contact can reach three times the normal line-to-neutral voltage. After it is interrupted and with subsequent alternation of the supply side voltage, the voltage across the open contact is even higher.

ANSI Standard C37.06 (indoor oilless circuit breakers) indicates the preferred ratings of Eaton's Type VCP-W vacuum breaker. For capacitor switching careful attention should be paid to the notes accompanying the table. The definition of the terms are in ANSI Standard C37.04 Article 5.13 (for the latest edition). The application guide ANSI/IEEE Standard C37.012 covers the method of calculation of the quantities covered by C37.06 Standard.

Note that the definitions in C37.04 make the switching of two capacitors banks in close proximity to the switchgear bus a back-to-back mode of switching. This classification requires a definite purpose circuit breaker (breakers specifically designed for capacitance switching).

We recommend that such application be referred to Eaton.

A breaker specified for capacitor switching should include as applicable:

1. Rated maximum voltage.
2. Rated frequency.
3. Rated open wire line charging switching current.
4. Rated isolated cable charging and shunt capacitor switching current.
5. Rated back-to-back cable charging and back-to-back capacitor switching current.
6. Rated transient overvoltage factor.
7. Rated transient inrush current and its frequency.
8. Rated interrupting time.
9. Rated capacitive current switching life.
10. Grounding of system and capacitor bank.

**Loadbreak interrupter switches** are permitted by ANSI/IEEE Standard C37.30 to switch capacitance but they must have tested ratings for the purpose. Refer to Eaton Type MVS ratings.

Projects that anticipate requiring capacitor bank switching or fault interrupting should identify the breakers that must have capacitive current switching ratings on the equipment schedules and contract drawings used for the project. Manufacturer's standard medium voltage breakers meeting ANSI C37.xx are not all rated for switching capacitive loads. Special breakers are usually available from vendors to comply with the ANSI C37.012 (Application Guide for Capacitor Current Switching) and other applicable ANSI standards. The use of capacitive current rated breakers can affect the medium voltage switchgear layout, thus early identification of these capacitive loads are critical to the design process.

For example, the standard 15 kV Eaton 150 VCP-W 500, 1200 A vacuum breaker does not have a capacitive current switching rating; however, the 15 kV Eaton 150 VCP-W 25C, 1200 A vacuum breaker does have the following general purpose ratings:

- 25 A rms cable charging current switching
- Isolated shunt capacitor bank switching current ratings of 25 A to 600 A
- Definite purpose back-to-back capacitor switch ratings required when two banks of capacitors are independently switched from the 15 kV switchgear bus

The special breakers with these capacitive current ratings do not have UL labels, thus UL assembly ratings are not available.

Contact Eaton for more details on vacuum breaker and fused load interrupter switch products with capacitive switching current ratings at medium voltages.

**Table 35.0-2. Recommended Wire Sizes, Switching Device Ratings and Overcurrent Protection Device Rating for Capacitor Banks Three-Phase 60 Hz AC System**

| Capacitor Rating | | Amperes | | | kcmil |
|---|---|---|---|---|---|
| kvar | Capacitor Rated Current | Fuse Rating ① | Safety Switch Rating | Circuit Breaker Trip Rating ② | Wire Size AWG (per phase) ③ |
| **240 V** | | | | | |
| 2.5 | 6 | 10 | 30 | 15 | 14 |
| 5 | 12 | 20 | 30 | 20 | 14 |
| 7.5 | 18 | 30 | 30 | 30 | 10 |
| 10 | 24 | 40 | 60 | 40 | 8 |
| 15 | 36 | 60 | 60 | 70 | 6 |
| 20 | 48 | 80 | 100 | 0 | 4 |
| 25 | 60 | 100 | 100 | 100 | 4 |
| 30 | 72 | 125 | 200 | 125 | 2 |
| 45 | 108 | 200 | 200 | 175 | 1/0 |
| 50 | 120 | 200 | 200 | 175 | 2/0 |
| 60 | 144 | 250 | 400 | 200 | 4/0 |
| 75 | 180 | 300 | 400 | 250 | 250 |
| 90 | 217 | 400 | 400 | 300 | 350 |
| 100 | 241 | 400 | 400 | 350 | 500 |
| 120 | 289 | 500 | 600 | 400 | 600 |
| 125 | 301 | 500 | 600 | 500 | 600 |
| 135 | 325 | 600 | 600 | 500 | (2) 4/0 |
| 150 | 361 | 600 | 600 | 500 | (2) 250 |
| 160 | 385 | 800 | 800 | 600 | (2) 350 |
| 200 | 481 | 800 | 800 | 700 | (2) 500 |
| 250 | 600 | 1000 | 1200 | 1000 | (2) 600 |
| 300 | 720 | 1200 | 1200 | 1000 | (4) 250 |
| 350 | 844 | 1400 | 1600 | 1200 | (4) 350 |
| 400 | 965 | 1600 | 1600 | 1600 | (4) 500 |
| **480 V** | | | | | |
| 2 | 2 | 15 | 30 | 15 | 14 |
| 5 | 6 | 15 | 30 | 15 | 14 |
| 7.5 | 9 | 15 | 30 | 15 | 14 |
| 10 | 12 | 20 | 30 | 20 | 14 |
| 15 | 18 | 30 | 30 | 30 | 10 |
| 20 | 24 | 40 | 60 | 40 | 10 |
| 25 | 30 | 50 | 60 | 50 | 6 |
| 30 | 36 | 60 | 60 | 50 | 6 |
| 35 | 42 | 70 | 100 | 70 | 6 |
| 40 | 48 | 100 | 100 | 70 | 4 |
| 45 | 54 | 100 | 100 | 100 | 4 |
| 50 | 60 | 100 | 100 | 100 | 2 |
| 60 | 72 | 125 | 200 | 100 | 2 |
| 75 | 90 | 150 | 200 | 125 | 1/0 |
| 80 | 96 | 175 | 200 | 150 | 1/0 |
| 90 | 108 | 200 | 200 | 150 | 2/0 |
| 100 | 120 | 200 | 200 | 175 | 2/0 |
| 120 | 144 | 250 | 400 | 200 | 4/0 |
| 125 | 150 | 250 | 400 | 225 | 4/0 |
| 150 | 180 | 300 | 400 | 250 | 250 |
| 160 | 192 | 350 | 400 | 300 | 350 |
| 180 | 217 | 400 | 400 | 300 | 350 |
| 200 | 241 | 400 | 400 | 350 | 500 |
| 225 | 271 | 500 | 600 | 400 | 500 |
| 250 | 301 | 500 | 600 | 500 | 600 |
| 300 | 361 | 600 | 600 | 500 | (2) 250 |
| 350 | 421 | 700 | 800 | 600 | (2) 350 |
| 400 | 481 | 800 | 800 | 700 | (2) 500 |
| 450 | 541 | 900 | 800 | 800 | (2) 500 |
| 500 | 601 | 1000 | 1200 | 1000 | (2) 600 |
| 550 | 662 | 1200 | 1200 | 1000 | (4) 250 |
| 600 | 722 | 1200 | 1200 | 1000 | (4) 250 |
| 660 | 794 | 1350 | 1600 | 1200 | (4) 350 |
| 700 | 842 | 1400 | 1600 | 1200 | (4) 350 |
| 720 | 866 | 1500 | 1600 | 1200 | (4) 350 |
| 800 | 962 | 1600 | 1600 | 1600 | (4) 500 |
| 900 | 1083 | 1800 | 1600 | 1600 | (4) 500 |
| 1000 | 1203 | 2000 | 2000 | 2000 | (4) 600 |
| 1100 | 1323 | 2500 | 2000 | 2000 | (4) 750 |
| 1200 | 1443 | 2500 | 2000 | 2000 | (4) 750 |

**Table 35.0-2. Recommended Wire Sizes, Switching Device Ratings and Overcurrent Protection Device Rating for Capacitor Banks Three-Phase 60 Hz AC System (Continued)**

| Capacitor Rating | | Amperes | | | kcmil |
|---|---|---|---|---|---|
| kvar | Capacitor Rated Current | Fuse Rating ① | Safety Switch Rating | Circuit Breaker Trip Rating ② | Wire Size AWG (per phase) ③ |
| **600 V** | | | | | |
| 5 | 5 | 15 | 30 | 15 | 14 |
| 7.5 | 7 | 15 | 30 | 15 | 14 |
| 10 | 10 | 20 | 30 | 15 | 14 |
| 15 | 14 | 25 | 30 | 30 | 10 |
| 20 | 19 | 35 | 60 | 30 | 10 |
| 25 | 24 | 40 | 60 | 40 | 8 |
| 30 | 29 | 50 | 60 | 40 | 8 |
| 35 | 34 | 60 | 60 | 50 | 8 |
| 40 | 38 | 70 | 100 | 70 | 6 |
| 45 | 43 | 80 | 100 | 70 | 6 |
| 50 | 48 | 80 | 100 | 70 | 4 |
| 60 | 58 | 100 | 100 | 100 | 4 |
| 75 | 72 | 125 | 200 | 100 | 4 |
| 80 | 77 | 150 | 200 | 125 | 2 |
| 100 | 96 | 175 | 200 | 150 | 1/0 |
| 120 | 115 | 200 | 200 | 175 | 2/0 |
| 125 | 120 | 200 | 200 | 175 | 2/0 |
| 150 | 144 | 250 | 400 | 200 | 4/0 |
| 160 | 154 | 300 | 400 | 225 | 4/0 |
| 180 | 173 | 300 | 400 | 250 | 250 |
| 200 | 192 | 350 | 400 | 300 | 350 |
| 225 | 217 | 400 | 400 | 300 | 350 |
| 250 | 241 | 400 | 400 | 260 | 500 |
| 300 | 289 | 500 | 600 | 400 | 600 |
| 350 | 337 | 600 | 600 | 500 | (2) 250 |
| 400 | 385 | 700 | 800 | 600 | (2) 350 |
| 450 | 433 | 900 | 800 | 800 | (2) 350 |
| 500 | 481 | 1000 | 1200 | 1000 | (2) 500 |
| 550 | 529 | 1200 | 1200 | 1000 | (2) 500 |
| 600 | 577 | 1200 | 1200 | 1000 | (2) 600 |
| 660 | 635 | 1350 | 1600 | 1200 | (4) 250 |
| 700 | 674 | 1400 | 1600 | 1200 | (4) 250 |
| 720 | 693 | 1500 | 1600 | 1200 | (4) 350 |
| 800 | 770 | 1600 | 1600 | 1600 | (4) 500 |
| 900 | 866 | 1800 | 1600 | 1600 | (4) 500 |
| 1000 | 962 | 2000 | 2000 | 2000 | (4) 500 |
| 1100 | 1059 | 2500 | 2000 | 2000 | (4) 500 |
| 1200 | 1155 | 2500 | 2000 | 2000 | (4) 750 |

① All feeder protection fuses are recommended to be time delay fuses and sized between 150–175% of the full load amperes of the capacitor current.

② All feeder protection breakers are recommended to be a minimum of 135% of the full load amperes of the capacitor current.

③ 80% rated circuit breakers should be derated for effective current rating shown above.

④ Recommended size based on 90 °C copper conductors applied at its 75 °C rating.

⑤ For conductor sizes involving multiple runs of 350 kcmil per phase or higher an external pull box may be required. Consult drawings for available space for termination.

## Installing Capacitors in a Plant Distribution System

### At the Load

Because capacitors act as kvar generators, the most efficient place to install them is directly at the motor, where kvar is consumed. Three options or other low power factor load exist for installing capacitors at the motor. Use **Figures 35.0-1–35.0-7**, and the information below to determine which option is best for each motor.

**Location A—Motor Side of Overload Relay**

- New motor installations in which overloads can be sized in accordance with reduced current draw
- Existing motors when no overload change is required

**Location B—Line Side of Overload Relay**

- Existing motors when overload rating surpasses code (see Appendix for NEC code requirements)

**Location C—Line Side of Starter**

- Motors that are jogged, plugged, reversed
- Multi-speed motors
- Starters with open transition and starters that disconnect/reconnect capacitor during cycle
- Motors that start frequently
- Motor loads with high inertia, where disconnecting the motor with the capacitor can turn the motor into a self-excited generator

### At the Service Feeder

When correcting entire plant loads, capacitor banks can be installed at the service entrance, if load conditions and transformer size permits. If the amount of correction is too large, some capacitors can be installed at individual motors or branch circuits.

When capacitors are connected to the bus, feeder, motor control center or switchboard, a disconnect and overcurrent protection must be provided.

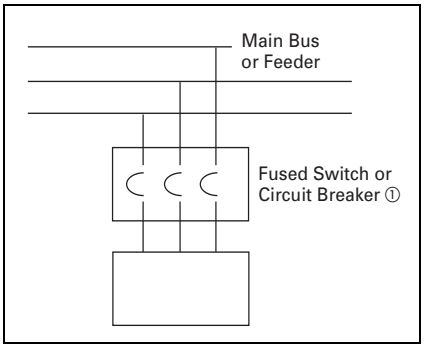


**Figure 35.0-2. Installing Capacitors Online**

① Refer to **Pages 35.0-3** and **35.0-14** for switching device considerations and conductor sizing.

## Locating Capacitors on Motor Circuits

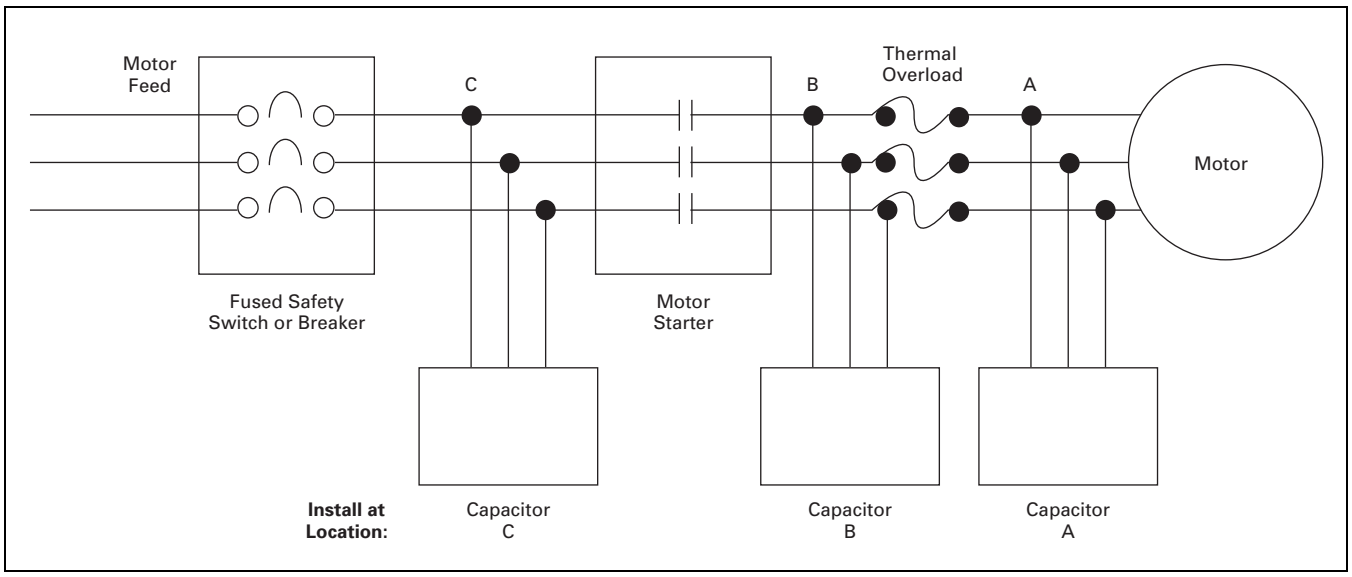


**Figure 35.0-1. Locating Capacitors on Motor Circuits**

35

## Application of Capacitors on Reduced Voltage and Multi-Speed Motor Starters

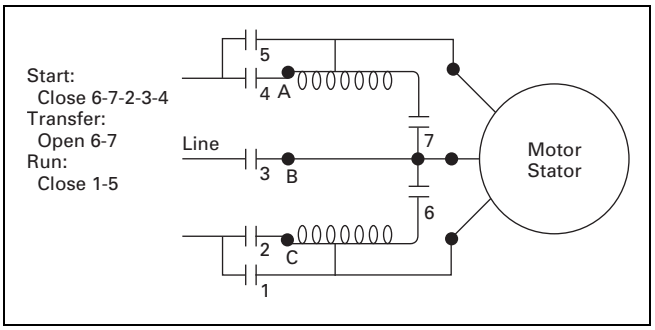


**Figure 35.0-3. Autotransformer—Closed Transition**

**Note:** Connect capacitor on motor side of starting contacts (2, 3, 4) at points A–B–C.

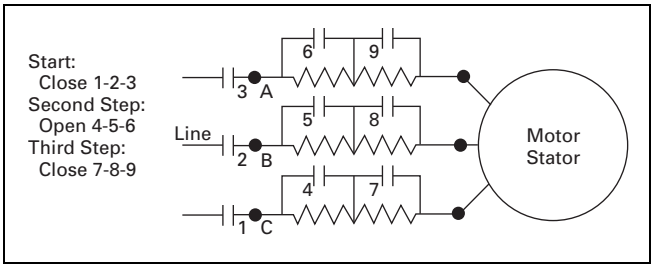


**Figure 35.0-4. Series Resistance Starting**

**Note:** Connect capacitor on motor side of starting contactor (1, 2, 3) at points A–B–C.

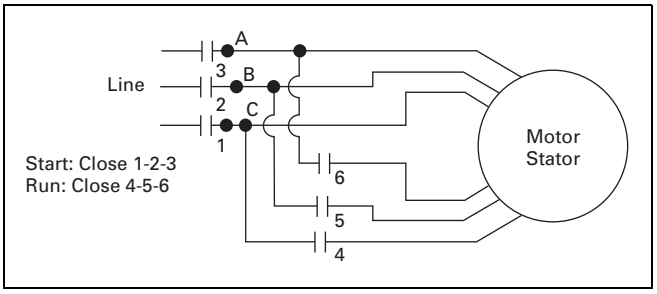


**Figure 35.0-5. Part-Winding Starting**

**Note:** Connect capacitor on motor side of starting contacts (1, 2, 3) at points A–B–C.

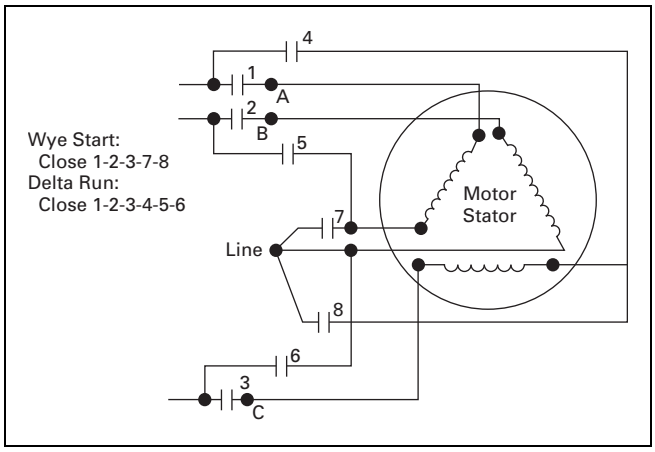


**Figure 35.0-6. Wye-Delta Starting**

**Note:** Connect capacitor on motor side of starting contacts (1, 2, 3) at points A–B–C.

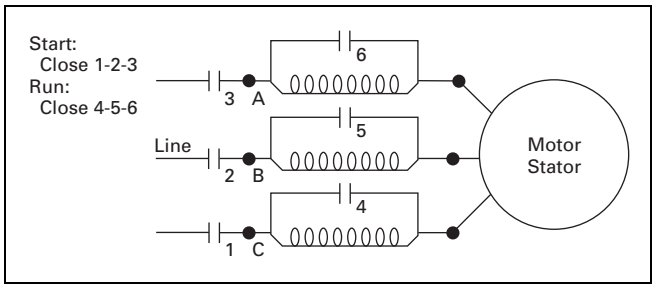


**Figure 35.0-7. Reactor Starting**

**Note:** Connect capacitor on motor side of starting contactor (1, 2, 3) at points A–B–C.

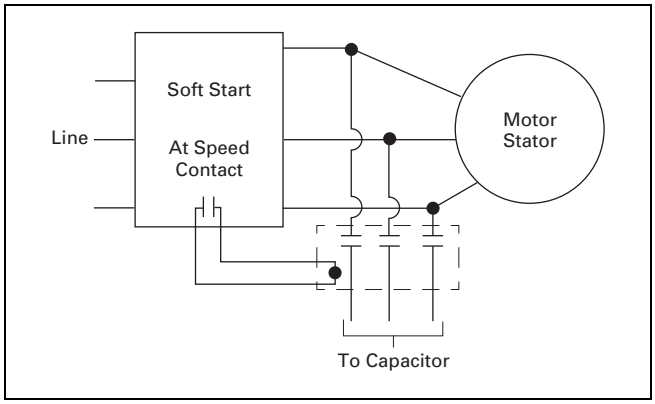


**Figure 35.0-8. Soft Start**

**Note:** Soft start application considerations. Capacitors should only be applied after the soft start is at full voltage and the bypass contactor is closed. An auxiliary contact on the bypass contactor is used to energize the capacitor contactor. When the bypass contactor in the soft start opens the capacitor contactor will drop out. For multiple motors on the same bus, as in a motor control center for example, it is desirable to take all the capacitors off line any time a soft starter is accelerating or decellearting (not in bypass).

## Harmonic Considerations

A discussion of power system harmonics is incomplete without discussing the effects of power factor correction capacitors. In an industrial plant containing power factor correction capacitors, harmonic currents and voltages can be magnified considerably due to the interaction of the capacitors with the service transformer. This is referred to as *harmonic resonance or parallel resonance*. For a typical plant containing power factor correction capacitors, the resonant frequency (frequency at which amplification occurs) normally falls in the vicinity of the 5th to the 13th harmonic. Because nonlinear loads typically inject currents at the 5th, 7th, 11th and 13th harmonics, a resonant or near-resonant condition will often result if drives and capacitors are installed on the same system, producing the symptoms and problems with blown fuses, damaged capacitors or failures in other portions of the electrical distribution system.

**Note:** Capacitors themselves do not cause harmonics, but only aggravate potential harmonic problems. Often, harmonic-related problems do not "show up" until capacitors are applied for power factor correction.

It is a common misconception that the problem of applying capacitors in harmonic environments is limited to problems caused for the capacitor itself—that the capacitor's lower impedance at higher frequencies causes a current overload into the capacitor and, therefore, must be removed. However, the capacitor/harmonics problem must be viewed from a power system standpoint. The capacitor-induced increase of harmonic voltages and currents on a plant's system may be causing problems while the capacitor itself remains within its acceptable current rating.

## Capacitor Banks and Transformers Can Cause Resonance

Capacitors and transformers can create dangerous resonance conditions when capacitor banks are installed at the service entrance. Under these conditions, harmonics produced by nonlinear devices can be amplified many fold.

Problematic amplification of harmonics becomes more likely as more kvar is added to a system which contains a significant amount of nonlinear load.

An estimate of the resonant harmonic frequency is found by using the following formula:

$$h = \sqrt{\frac{kVA_{sys}}{kvar}}$$

$kVA_{sys}$ = Short-Circuit Capacity of the System
kvar = Amount of Capacitor kvar on the Line
h = The Harmonic Number referred to a 60 Hz Base

If h is near the values of the major harmonics generated by a nonlinear device—i.e., 3, 5, 7, 11—then the resonance circuit will greatly increase harmonic distortion.

For example, if a plant has a 1500 kVA transformer with a 5-1/2% impedance and the short-circuit rating of the utility is 48,000 kVA, then $kVA_{sys}$ would equal 17,391 kVA.

If 350 kvar of capacitors were used to improve power factor, h would be:

$$h = \sqrt{\frac{17{,}391}{350}} = \sqrt{49.7} = 7.0$$

Because h falls right on the 7th harmonic, these capacitors could create a harmful resonance condition if nonlinear devices were present in the factory. In this case the capacitors should be applied only as detuned filter assemblies.

## Eliminating Harmonic Problems

When power factor correction is required in the presence of nonlinear loads, the most reliable, lowest cost solution is often realized with the use of detuned filters.

## Fixed and Switched Detuned Filters

A shunt detuned filter, sometimes called a harmonic filter, (see **Figure 35.0-9**) is, essentially, a power factor correction capacitor combined with a series iron core reactor. A detuned filter provides power factor correction at the fundamental frequency and becomes an inductance at frequencies higher than its "tuning point." Most filters are tuned below the 5th harmonic. Therefore, the filter provides an inductive impedance path to those currents at harmonic frequencies created by nearly all three-phase non-linear loads (5th, 7th, 11th, 13th, etc.). *Because the filter is not capacitive at these frequencies, the plant electrical system can no longer resonate at these frequencies and can not magnify the harmonic voltages and currents*.

A shunt detuned filter therefore accomplishes three things:

1. Provides power factor correction.
2. Prevents harmonic overvoltages due to resonance.
3. Reduces voltage harmonic distortion and transformer harmonic loading at frequencies above its tuning point.

In some circumstances, a harmonic resonance condition may accrue gradually over time as capacitors and nonlinear loads are installed in a plant. The replacement of such capacitors with harmonic filters in order to correct a problem may be prohibitively expensive. Custom-designed harmonic filters which are able to eliminate problems associated with resonance at any particular frequency while providing an extremely low amount of power factor correction capacitance. These low kvar filters are therefore able to provide the same amount of filtering capacity as a much larger conventional filter, but at a lower cost.

## Solutions for Systems with High Harmonics

If the plant loads vary, then a switched capacitor/filter bank is recommended. For systems with widely varying loads where harmonic cancellation is the primary goal, a Harmonic Correction Unit (HCU2) is recommended. Refer to **Page 35.3-1** for additional HCU2 information.

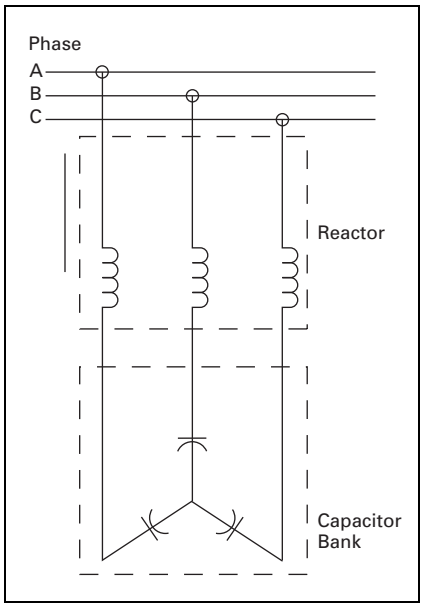


**Figure 35.0-9. Shunt Detuned Filter**

## Diagnosing a Potential Harmonics Related Problem

Negative symptoms of harmonics on plant equipment include blown fuses on capacitors, reduced motor life, false or spurious operations of fuses or circuit breakers, decreased life or increased noise in transformers or mis-operation of electronic or microprocessor controls. If one or more of these symptoms occurs with regularity, then the following steps should be taken.

1. If the plant contains power factor correction capacitors, the current into the capacitors should be measured using a 'true rms' current meter. If this value is higher than the capacitor's rated current at the system voltage (by >5% or so), the presence of harmonic voltage distortion is likely.
2. Conduct a paper audit of the plant's harmonic-producing loads and system configuration. This analysis starts with the gathering of kVA or horsepower data on all the major nonlinear devices in the plant, all capacitors, and rating information on service entrance transformer(s). This data is analyzed to determine whether the conditions are present to create unfavorable levels of harmonics.

If the electrical distribution system is complex—e.g., multiple service entrances, distributed capacitors—or if the paper audit is incomplete or considered to be too burdensome, the most definitive way to determine whether harmonics are causing a problem is through an on-site plant audit. This audit involves an inspection of the electrical system layout and connected loads, as well as harmonic measurements taken at strategic locations. This data can then be assembled and analyzed to obtain a clear and concise understanding of the power system.

## Motor Power Factor Correction

**Tables 35.0-3** and **35.0-4** contain **suggested maximum** capacitor ratings for induction motors switched with the capacitor. The data is general in nature and representative of general purpose induction motors of standard design. The preferable means to select capacitor ratings is based on the "maximum recommended kvar" information available from the motor manufacturer. If this is not possible or feasible, the tables can be used.

An important point to remember is that if the capacitor used with the motor is too large, self-excitation may cause a motor-damaging overvoltage when the motor and capacitor combination is disconnected from the line. In addition, high transient torques capable of damaging the motor shaft or coupling can occur if the motor is reconnected to the line while rotating and still generating a voltage of self-excitation.

### Definitions

kvar—rating of the capacitor in reactive kilovolt-amperes. This value is approximately equal to the motor no-load magnetizing kilovars.

% AR—percent reduction in line current due to the capacitor. A capacitor located on the motor side of the overload relay reduces line current through the relay. Therefore, a different overload relay and/or setting may be necessary. The reduction in line current may be determined by measuring line current with and without the capacitor or by calculation as follows:

$$\% \text{ AR} = 100 - 100 \times \frac{(\text{Original PF})}{(\text{Improved PF})}$$

If a capacitor is used with a lower kvar rating than listed in tables, the % AR can be calculated as follows:

$$\% \text{ AR} = \text{Listed \% AR} \times \frac{\text{Actual kvar}}{\text{kvar in Table}}$$

The tables can also be used for other motor ratings as follows:

A. For standard 60 Hz motors operating at 50 Hz:
   kvar = 1.7–1.4 of kvar listed
   % AR = 1.8–1.35 of % AR listed

B. For standard 50 Hz motors operating at 50 Hz:
   kvar = 1.4–1.1 of kvar listed
   % AR = 1.4–1.05 of % AR listed

C. For standard 60 Hz wound-rotor motors:
   kvar = 1.1 of kvar listed
   % AR = 1.05 of % AR listed

**Note:** For A, B, C, the larger multipliers apply for motors of higher speeds; i.e., 3600 rpm = 1.7 mult., 1800 rpm = 1.65 mult., etc.

To derate a capacitor used on a system voltage lower than the capacitor voltage rating, such as a 240 V capacitor used on a 208 V system, use the following formula:

$$\text{Actual kvar} = \text{Nameplate kvar} \times \frac{(\text{Applied Voltage})^2}{(\text{Nameplate Voltage})^2}$$

For the kVAC required to correct the power factor from a given value of COS $\phi 1$ to COS $\phi 2$, the formula is:

$$\text{kVAC} = \text{kW} (\tan \text{phase}_1 - \tan \text{phase}_2)$$

Capacitors cause a voltage rise. At light load periods the capacitive voltage rise can raise the voltage at the location of the capacitors to an unacceptable level. This voltage rise can be calculated approximately by the formula

$$\% \text{ VR} = \frac{\text{MVA}_r}{\text{MVA}_{SC}}$$

$\text{MVA}_R$ is the capacitor rating and $\text{MVA}_{SC}$ is the system short-circuit capacity.

With the introduction of variable speed drives and other harmonic current generating loads, the capacitor impedance value determined must not be resonant with the inductive reactances of the system. This matter is discussed further under the heading "Harmonics and Nonlinear Loads."

## Useful Capacitor Formulas

**Nomenclature:** C = Capacitance in μF
V = Voltage
A = Current
K = 1000

### A. Additional Data

1. Simplified Voltage Rise:

$$\% \text{ L.R.} = \frac{\text{kvar (Cap.)} \times \% \text{ Transformer Reactance}}{\text{kVA(Transformer)}}$$

2. Losses Reduction:

$$\% \text{ L.R.} = 100 - 100\left(\frac{\text{Original PF}}{\text{Improved PF}}\right)^2$$

3. Operation at other than rated voltage and frequency
**Note:** Use of voltages and frequencies above the rated values can be dangerous. Consult the factory for any unusual operating conditions.

a. Reduced Voltage:

$$\text{Actual kvar (Output)} = \text{Rated kvar}\left(\frac{\text{Actual Voltage}}{\text{Rated Voltage}}\right)^2$$

b. Reduced Frequency:

$$\text{Actual kvar} = \text{Rated kvar}\left(\frac{\text{Actual Freq.}}{\text{Rated Freq.}}\right)^2$$

c. Examples:

(a) Voltage Reduction:

$$\text{kvar (208)} = \text{kvar (240)}\left(\frac{208}{240}\right)^2 = 0.75$$

(10 kvar @ 240 V = 7.5 kvar @ 208 V)

$$\text{kvar (120)} = \text{kvar (240)}\left(\frac{120}{240}\right)^2 = 0.25$$

(10 kvar @ 240 V = 2.5 kvar @ 120 V)

(b) Frequency Reduction:

$$\text{kvar (50 Hz)} = \text{kvar (60 Hz)}\left(\frac{50}{60}\right) = 0.83$$

(60 kvar @ 480 V 60 Hz = 50 kvar, 480 V, 50 Hz)

### B. Miscellaneous

1. Power Factor = $\cos\theta = \frac{kW}{kVA}$

$\tan\theta = \frac{kW}{kVA}$

| | Single-Phase | Three-Phase |
|---|---|---|
| 2. kW = | $\frac{V \times A \times PF}{10^3}$ | $\frac{\sqrt{3} \times V \times A \times PF}{10^3}$ |
| 3. kVA = | $\frac{V \times A}{10^3}$ | $\frac{\sqrt{3} \times V \times A}{10^3}$ |
| 4. Line Current Amperes = | $\frac{kVA \times 10^3}{V}$ | $\frac{kVA \times 10^3}{\sqrt{3} \times V}$ |

5. Capacitor Current (Amperes) = $(2\pi f)CV \times 10^{-6}$

also: $\frac{kvar \times 10^3}{V}$ $\frac{kvar \times 10^3}{\sqrt{3} \times V}$

6. kVA = $\frac{kW}{PF}$ (kW Motor Input)

7. kW (Motor Input) = $\frac{hp \times 0.746}{efficiency}$

8. Approx. Motor kVA = Motor hp (at full load)

**Table 35.0-3. Suggested Maximum Capacitor Ratings**

| Induction Motor hp Rating | Number of Poles and Nominal Motor Speed in RPM | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2—3600 RPM | | 4—1800 RPM | | 6—1200 RPM | | 8—900 RPM | | 10—720 RPM | | 12—600 RPM | |
| | Capacitor kvar | Current Reduction % | Capacitor kvar | Current Reduction % | Capacitor kvar | Current Reduction % | Capacitor kvar | Current Reduction % | Capacitor kvar | Current Reduction % | Capacitor kvar | Current Reduction % |
| **Used for High Efficiency Motors and Older Design (Pre "T-Frame") Motors** ① | | | | | | | | | | | | |
| 3 | 1.5 | 14 | 1.5 | 15 | 1.5 | 20 | 2 | 27 | 2.5 | 35 | 3 | 41 |
| 5 | 2 | 12 | 2 | 13 | 2 | 17 | 3 | 25 | 4 | 32 | 4 | 37 |
| 7.5 | 2.5 | 11 | 2.5 | 12 | 3 | 15 | 4 | 22 | 5 | 30 | 6 | 34 |
| 10 | 3 | 10 | 3 | 11 | 3 | 14 | 5 | 21 | 6 | 27 | 7.5 | 31 |
| 15 | 4 | 9 | 4 | 10 | 5 | 13 | 6 | 18 | 8 | 23 | 9 | 27 |
| 20 | 5 | 9 | 5 | 10 | 6 | 12 | 7.5 | 16 | 9 | 21 | 12.5 | 25 |
| 25 | 6 | 9 | 6 | 10 | 7.5 | 11 | 9 | 15 | 10 | 20 | 15 | 23 |
| 30 | 7 | 8 | 7 | 9 | 9 | 11 | 10 | 14 | 12.5 | 18 | 17.5 | 22 |
| 40 | 9 | 8 | 9 | 9 | 10 | 10 | 12.5 | 13 | 15 | 16 | 20 | 20 |
| 50 | 12.5 | 8 | 10 | 9 | 12.5 | 10 | 15 | 12 | 20 | 15 | 25 | 19 |
| 60 | 15 | 8 | 15 | 8 | 15 | 10 | 17.5 | 11 | 22.5 | 15 | 27.5 | 19 |
| 75 | 17.5 | 8 | 17.5 | 8 | 17.5 | 10 | 20 | 10 | 25 | 14 | 35 | 18 |
| 100 | 22.5 | 8 | 20 | 8 | 25 | 9 | 27.5 | 10 | 35 | 13 | 40 | 17 |
| 125 | 27.5 | 8 | 25 | 8 | 30 | 9 | 30 | 10 | 40 | 13 | 50 | 16 |
| 150 | 30 | 8 | 30 | 8 | 35 | 9 | 37.5 | 10 | 50 | 12 | 50 | 15 |
| 200 | 40 | 8 | 37.5 | 8 | 40 | 9 | 50 | 10 | 60 | 12 | 60 | 14 |
| 250 | 50 | 8 | 45 | 7 | 50 | 8 | 60 | 9 | 70 | 11 | 75 | 13 |
| 300 | 60 | 8 | 50 | 7 | 60 | 8 | 60 | 9 | 80 | 11 | 90 | 12 |
| 350 | 60 | 8 | 60 | 7 | 75 | 8 | 75 | 9 | 90 | 10 | 95 | 11 |
| 400 | 75 | 8 | 60 | 6 | 75 | 8 | 85 | 9 | 95 | 10 | 100 | 11 |
| 450 | 75 | 8 | 75 | 6 | 80 | 8 | 90 | 9 | 100 | 9 | 110 | 11 |
| 500 | 75 | 8 | 75 | 6 | 85 | 8 | 100 | 9 | 100 | 9 | 120 | 10 |
| **T-Frame NEMA® "Design B" Motors** ① | | | | | | | | | | | | |
| 2 | 1 | 14 | 1 | 24 | 1.5 | 30 | 2 | 42 | 2 | 40 | 3 | 50 |
| 3 | 1.5 | 14 | 1.5 | 23 | 2 | 28 | 3 | 38 | 3 | 40 | 4 | 49 |
| 5 | 2 | 14 | 2.5 | 22 | 3 | 26 | 4 | 31 | 4 | 40 | 5 | 49 |
| 7.5 | 2.5 | 14 | 3 | 20 | 4 | 21 | 5 | 28 | 5 | 38 | 6 | 45 |
| 10 | 4 | 14 | 4 | 18 | 5 | 21 | 6 | 27 | 7.5 | 36 | 8 | 38 |
| 15 | 5 | 12 | 5 | 18 | 6 | 20 | 7.5 | 24 | 8 | 32 | 10 | 34 |
| 20 | 6 | 12 | 6 | 17 | 7.5 | 19 | 9 | 23 | 10 | 29 | 12.5 | 30 |
| 25 | 7.5 | 12 | 7.5 | 17 | 8 | 19 | 10 | 23 | 12.5 | 25 | 17.5 | 30 |
| 30 | 8 | 11 | 8 | 16 | 10 | 19 | 15 | 22 | 15 | 24 | 20 | 30 |
| 40 | 12.5 | 12 | 15 | 16 | 15 | 19 | 17.5 | 21 | 20 | 24 | 25 | 30 |
| 50 | 15 | 12 | 17.5 | 15 | 20 | 19 | 22.5 | 21 | 22.5 | 24 | 30 | 30 |
| 60 | 17.5 | 12 | 20 | 15 | 22.5 | 17 | 25 | 20 | 30 | 22 | 35 | 28 |
| 75 | 20 | 12 | 25 | 14 | 25 | 15 | 30 | 17 | 35 | 21 | 40 | 19 |
| 100 | 22.5 | 11 | 30 | 14 | 30 | 12 | 35 | 16 | 40 | 15 | 45 | 17 |
| 125 | 25 | 10 | 35 | 12 | 35 | 12 | 40 | 14 | 45 | 15 | 50 | 17 |
| 150 | 30 | 10 | 40 | 12 | 40 | 12 | 50 | 14 | 50 | 13 | 60 | 17 |
| 200 | 35 | 10 | 50 | 11 | 50 | 11 | 70 | 14 | 70 | 13 | 90 | 17 |
| 250 | 40 | 11 | 60 | 10 | 60 | 10 | 80 | 13 | 90 | 13 | 100 | 17 |
| 300 | 45 | 11 | 70 | 10 | 75 | 12 | 100 | 14 | 100 | 13 | 120 | 17 |
| 350 | 50 | 12 | 75 | 8 | 90 | 12 | 120 | 13 | 120 | 13 | 135 | 15 |
| 400 | 75 | 10 | 80 | 8 | 100 | 12 | 130 | 13 | 140 | 13 | 150 | 15 |
| 450 | 80 | 8 | 90 | 8 | 120 | 10 | 140 | 12 | 160 | 14 | 160 | 15 |
| 500 | 100 | 8 | 120 | 9 | 150 | 12 | 160 | 12 | 180 | 13 | 180 | 15 |

① For use with three-phase, 60 Hz NEMA Classification B motors to raise full load power factor to approximately 95%.

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**Table 35.0-4. Suggested Capacitor Ratings, in kvars, for NEMA Design C, D and Wound-Rotor Motors**

| Induction Motor Rating (hp) | Design C Motor | | Design D Motor 1200 r/Minimum | Wound-Rotor Motor |
|---|---|---|---|---|
| | 1800 and 1200 r/Minimum | 900 r/Minimum | | |
| 15 | 5 | 5 | 5 | 5.5 |
| 20 | 5 | 6 | 6 | 7 |
| 25 | 6 | 6 | 6 | 7 |
| 30 | 7.5 | 9 | 10 | 11 |
| 40 | 10 | 12 | 12 | 13 |
| 50 | 12 | 15 | 15 | 17.5 |
| 60 | 17.5 | 18 | 18 | 20 |
| 75 | 19 | 22.5 | 22.5 | 25 |
| 100 | 27 | 27 | 30 | 33 |
| 125 | 35 | 37.5 | 37.5 | 40 |
| 150 | 37.5 | 45 | 45 | 50 |
| 200 | 45 | 60 | 60 | 65 |
| 250 | 54 | 70 | 70 | 75 |
| 300 | 65 | 90 | 75 | 85 |

**Note:** Applies to three-phase, 60 Hz motors when switched with capacitors as single unit.
**Note:** Use motor manufacturer's recommended kvar as published in the performance data sheets for specific motor types: drip-proof, TEFC, severe duty, high efficiency and NEMA design.

**Table 35.0-5. 2400 Volts and 4160 Volt Motors NEMA Design B**

| Nominal Motor Speed in RPM and Number of Poles | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Induction Motor Rating (hp) | 3600 RPM 2 | | 1800 RPM 4 | | 1200 RPM 6 | | 900 RPM 8 | | 720 RPM 10 | | 600 RPM 12 | |
| | kvar | Current Reduction % | kvar | Current Reduction % | kvar | Current Reduction % | kvar | Current Reduction % | kvar | Current Reduction % | kvar | Current Reduction % |
| 100 | 25 | 8 | 25 | 10 | 25 | 11 | 25 | 11 | 25 | 12 | 25 | 16 |
| 120 | 25 | 7 | 25 | 9 | 25 | 10 | 25 | 10 | 25 | 11 | 50 | 15 |
| 150 | 25 | 7 | 25 | 8 | 25 | 9 | 25 | 9 | 25 | 11 | 50 | 14 |
| 200 | 50 | 7 | 50 | 8 | 50 | 9 | 50 | 9 | 50 | 10 | 75 | 14 |
| 250 | 50 | 7 | 50 | 7 | 50 | 8 | 75 | 9 | 75 | 10 | 75 | 14 |
| 300 | 50 | 7 | 50 | 7 | 75 | 8 | 75 | 9 | 75 | 9 | 100 | 13 |
| 350 | 50 | 6 | 50 | 6 | 75 | 8 | 75 | 9 | 75 | 9 | 100 | 12 |
| 400 | 75 | 6 | 75 | 6 | 75 | 7 | 100 | 9 | 100 | 9 | 100 | 11 |
| 450 | 75 | 6 | 75 | 6 | 75 | 6 | 100 | 9 | 100 | 9 | 125 | 10 |
| 500 | 75 | 5 | 75 | 6 | 100 | 6 | 125 | 9 | 125 | 9 | 125 | 9 |
| 600 | 75 | 5 | 100 | 6 | 100 | 6 | 125 | 8 | 150 | 9 | 150 | 9 |
| 700 | 100 | 5 | 100 | 6 | 125 | 6 | 150 | 8 | 150 | 8 | 150 | 8 |
| 800 | 100 | 5 | 150 | 6 | 150 | 6 | 150 | 7 | 200 | 8 | 200 | 8 |
| 900 | 125 | 5 | 150 | 6 | 200 | 6 | 200 | 7 | 250 | 8 | 250 | 8 |
| 1000 | 150 | 5 | 200 | 6 | 250 | 5 | 250 | 6 | 250 | 7 | 250 | 7 |
| 1250 | 200 | 5 | 200 | 6 | 250 | 5 | 300 | 6 | 300 | 6 | 300 | 6 |

**Table 35.0-6. NEMA Design B and C 2300 and 4000 V Motors (after 1956)**

| Nominal Motor Speed in RPM and Number of Poles | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Induction Motor Rating (hp) | 3600 RPM 2 | | 1800 RPM 4 | | 1200 RPM 6 | | 900 RPM 8 | | 720 RPM 10 | | 600 RPM 12 | |
| | kvar | Current Reduction % | kvar | Current Reduction % | kvar | Current Reduction % | kvar | Current Reduction % | kvar | Current Reduction % | kvar | Current Reduction % |
| **NEMA Design B 2300 and 4000 V Motors (after 1956)** | | | | | | | | | | | | |
| 100 | 25 | 7 | 25 | 10 | 25 | 11 | 25 | 11 | 25 | 12 | 25 | 17 |
| 120 | 25 | 7 | 25 | 9 | 25 | 10 | 25 | 10 | 25 | 11 | 50 | 15 |
| 150 | 25 | 7 | 25 | 8 | 25 | 8 | 25 | 9 | 50 | 11 | 50 | 15 |
| 200 | 25 | 7 | 25 | 6 | 50 | 8 | 50 | 9 | 50 | 10 | 75 | 14 |
| 250 | 30 | 7 | 30 | 5 | 50 | 8 | 50 | 9 | 75 | 10 | 100 | 14 |
| 300 | 50 | 7 | 50 | 5 | 75 | 8 | 75 | 9 | 75 | 9 | 100 | 12 |
| 350 | 50 | 6 | 50 | 5 | 75 | 8 | 75 | 9 | 75 | 9 | 100 | 11 |
| 400 | 50 | 5 | 50 | 5 | 75 | 6 | 100 | 9 | 100 | 9 | 100 | 10 |
| 450 | 75 | 5 | 50 | 5 | 75 | 6 | 100 | 8 | 100 | 8 | 100 | 8 |
| 500 | 75 | 5 | 75 | 5 | 100 | 6 | 125 | 8 | 125 | 8 | 125 | 8 |
| 600 | 75 | 5 | 100 | 5 | 100 | 5 | 125 | 7 | 125 | 8 | 125 | 8 |
| 700 | 100 | 5 | 100 | 5 | 100 | 5 | 125 | 7 | 150 | 8 | 150 | 8 |
| 800 | 100 | 5 | 125 | 5 | 125 | 5 | 150 | 7 | 150 | 8 | 150 | 8 |
| 900 | 125 | 5 | 150 | 5 | 200 | 5 | 200 | 6 | 250 | 7 | 250 | 7 |
| 1000 | 150 | 5 | 200 | 5 | 250 | 5 | 250 | 6 | 250 | 7 | 250 | 7 |
| 1250 | 200 | 5 | 200 | 5 | 250 | 5 | 300 | 6 | 300 | 6 | 300 | 6 |
| **NEMA Design C 2300 and 4000 V Motors (after 1956)** | | | | | | | | | | | | |
| 100 | — | — | 25 | 11 | 25 | 11 | 25 | 11 | 25 | 11 | — | — |
| 125 | — | — | 25 | 11 | 25 | 11 | 25 | 11 | 25 | 11 | — | — |
| 150 | — | — | 25 | 9 | 25 | 9 | 50 | 9 | — | — | — | — |
| 200 | — | — | 50 | 9 | 50 | 9 | 50 | 9 | — | — | — | — |
| 250 | — | — | 50 | 8 | 50 | 9 | 50 | 9 | — | — | — | — |
| 300 | — | — | 50 | 6 | 75 | 9 | 75 | 9 | — | — | — | — |
| 350 | — | — | 50 | 6 | 75 | 8 | 75 | 9 | — | — | — | — |

**Table 35.0-7. Multipliers to Determine Capacitor Kilovars Required for Power Factor Correction**

| Original Power Factor | Corrected Power Factor | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.80 | 0.81 | 0.82 | 0.83 | 0.84 | 0.85 | 0.86 | 0.87 | 0.88 | 0.89 | 0.90 | 0.91 | 0.92 | 0.93 | 0.94 | 0.95 | 0.96 | 0.97 | 0.98 | 0.99 | 1.0 |
| 0.50 | 0.982 | 1.008 | 1.034 | 1.060 | 1.086 | 1.112 | 1.139 | 1.165 | 1.192 | 1.220 | 1.248 | 1.276 | 1.306 | 1.337 | 1.369 | 1.403 | 1.440 | 1.481 | 1.529 | 1.589 | 1.732 |
| 0.51 | 0.937 | 0.962 | 0.989 | 1.015 | 1.041 | 1.067 | 1.094 | 1.120 | 1.147 | 1.175 | 1.203 | 1.231 | 1.261 | 1.292 | 1.324 | 1.358 | 1.395 | 1.436 | 1.484 | 1.544 | 1.687 |
| 0.52 | 0.893 | 0.919 | 0.945 | 0.971 | 0.997 | 1.023 | 1.050 | 1.076 | 1.103 | 1.131 | 1.159 | 1.187 | 1.217 | 1.248 | 1.280 | 1.314 | 1.351 | 1.392 | 1.440 | 1.500 | 1.643 |
| 0.53 | 0.850 | 0.876 | 0.902 | 0.928 | 0.954 | 0.980 | 1.007 | 1.033 | 1.060 | 1.088 | 1.116 | 1.144 | 1.174 | 1.205 | 1.237 | 1.271 | 1.308 | 1.349 | 1.397 | 1.457 | 1.600 |
| 0.54 | 0.809 | 0.835 | 0.861 | 0.887 | 0.913 | 0.939 | 0.966 | 0.992 | 1.019 | 1.047 | 1.075 | 1.103 | 1.133 | 1.164 | 1.196 | 1.230 | 1.267 | 1.308 | 1.356 | 1.416 | 1.559 |
| 0.55 | 0.769 | 0.795 | 0.821 | 0.847 | 0.873 | 0.899 | 0.926 | 0.952 | 0.979 | 1.007 | 1.035 | 1.063 | 1.093 | 1.124 | 1.156 | 1.190 | 1.227 | 1.268 | 1.316 | 1.376 | 1.519 |
| 0.56 | 0.730 | 0.756 | 0.782 | 0.808 | 0.834 | 0.860 | 0.887 | 0.913 | 0.940 | 0.968 | 0.996 | 1.024 | 1.054 | 1.085 | 1.117 | 1.151 | 1.188 | 1.229 | 1.277 | 1.337 | 1.480 |
| 0.57 | 0.692 | 0.718 | 0.744 | 0.770 | 0.796 | 0.822 | 0.849 | 0.875 | 0.902 | 0.930 | 0.958 | 0.986 | 1.016 | 1.047 | 1.079 | 1.113 | 1.150 | 1.191 | 1.239 | 1.299 | 1.442 |
| 0.58 | 0.655 | 0.681 | 0.707 | 0.733 | 0.759 | 0.785 | 0.812 | 0.838 | 0.865 | 0.893 | 0.921 | 0.949 | 0.979 | 1.010 | 1.042 | 1.076 | 1.113 | 1.154 | 1.202 | 1.262 | 1.405 |
| 0.59 | 0.619 | 0.645 | 0.671 | 0.697 | 0.723 | 0.749 | 0.776 | 0.802 | 0.829 | 0.857 | 0.885 | 0.913 | 0.943 | 0.974 | 1.006 | 1.040 | 1.077 | 1.118 | 1.166 | 1.226 | 1.369 |
| 0.60 | 0.583 | 0.609 | 0.635 | 0.661 | 0.687 | 0.713 | 0.740 | 0.766 | 0.793 | 0.821 | 0.849 | 0.877 | 0.907 | 0.938 | 0.970 | 1.004 | 1.041 | 1.082 | 1.130 | 1.190 | 1.333 |
| 0.61 | 0.549 | 0.575 | 0.601 | 0.627 | 0.653 | 0.679 | 0.706 | 0.732 | 0.759 | 0.787 | 0.815 | 0.843 | 0.873 | 0.904 | 0.936 | 0.970 | 1.007 | 1.048 | 1.096 | 1.156 | 1.299 |
| 0.62 | 0.516 | 0.542 | 0.568 | 0.594 | 0.620 | 0.646 | 0.673 | 0.699 | 0.726 | 0.754 | 0.782 | 0.810 | 0.840 | 0.871 | 0.903 | 0.937 | 0.974 | 1.015 | 1.063 | 1.123 | 1.266 |
| 0.63 | 0.483 | 0.509 | 0.535 | 0.561 | 0.587 | 0.613 | 0.640 | 0.666 | 0.693 | 0.721 | 0.749 | 0.777 | 0.807 | 0.838 | 0.870 | 0.904 | 0.941 | 0.982 | 1.030 | 1.090 | 1.233 |
| 0.64 | 0.451 | 0.474 | 0.503 | 0.529 | 0.555 | 0.581 | 0.608 | 0.634 | 0.661 | 0.689 | 0.717 | 0.745 | 0.775 | 0.806 | 0.838 | 0.872 | 0.909 | 0.950 | 0.998 | 1.068 | 1.201 |
| 0.65 | 0.419 | 0.445 | 0.471 | 0.497 | 0.523 | 0.549 | 0.576 | 0.602 | 0.629 | 0.657 | 0.685 | 0.713 | 0.743 | 0.774 | 0.806 | 0.840 | 0.877 | 0.918 | 0.966 | 1.026 | 1.169 |
| 0.66 | 0.388 | 0.414 | 0.440 | 0.466 | 0.492 | 0.518 | 0.545 | 0.571 | 0.598 | 0.626 | 0.654 | 0.682 | 0.712 | 0.743 | 0.775 | 0.809 | 0.846 | 0.887 | 0.935 | 0.995 | 1.138 |
| 0.67 | 0.358 | 0.384 | 0.410 | 0.436 | 0.462 | 0.488 | 0.515 | 0.541 | 0.568 | 0.596 | 0.624 | 0.652 | 0.682 | 0.713 | 0.745 | 0.779 | 0.816 | 0.857 | 0.905 | 0.965 | 1.108 |
| 0.68 | 0.328 | 0.354 | 0.380 | 0.406 | 0.432 | 0.458 | 0.485 | 0.511 | 0.538 | 0.566 | 0.594 | 0.622 | 0.652 | 0.683 | 0.715 | 0.749 | 0.786 | 0.827 | 0.875 | 0.935 | 1.078 |
| 0.69 | 0.299 | 0.325 | 0.351 | 0.377 | 0.403 | 0.429 | 0.456 | 0.482 | 0.509 | 0.537 | 0.565 | 0.593 | 0.623 | 0.654 | 0.686 | 0.720 | 0.757 | 0.798 | 0.846 | 0.906 | 1.049 |
| 0.70 | 0.270 | 0.296 | 0.322 | 0.348 | 0.374 | 0.400 | 0.427 | 0.453 | 0.480 | 0.508 | 0.536 | 0.564 | 0.594 | 0.625 | 0.657 | 0.691 | 0.728 | 0.769 | 0.817 | 0.877 | 1.020 |
| 0.71 | 0.242 | 0.268 | 0.294 | 0.320 | 0.346 | 0.372 | 0.399 | 0.425 | 0.452 | 0.480 | 0.508 | 0.536 | 0.566 | 0.597 | 0.629 | 0.663 | 0.700 | 0.741 | 0.789 | 0.849 | 0.992 |
| 0.72 | 0.214 | 0.240 | 0.266 | 0.292 | 0.318 | 0.344 | 0.371 | 0.397 | 0.424 | 0.452 | 0.480 | 0.508 | 0.538 | 0.569 | 0.601 | 0.635 | 0.672 | 0.713 | 0.761 | 0.821 | 0.964 |
| 0.73 | 0.186 | 0.212 | 0.238 | 0.264 | 0.290 | 0.316 | 0.343 | 0.369 | 0.396 | 0.424 | 0.452 | 0.480 | 0.510 | 0.541 | 0.573 | 0.607 | 0.644 | 0.685 | 0.733 | 0.793 | 0.936 |
| 0.74 | 0.159 | 0.185 | 0.211 | 0.237 | 0.263 | 0.289 | 0.316 | 0.342 | 0.369 | 0.397 | 0.425 | 0.453 | 0.483 | 0.514 | 0.546 | 0.580 | 0.617 | 0.658 | 0.706 | 0.766 | 0.909 |
| 0.75 | 0.132 | 0.158 | 0.184 | 0.210 | 0.236 | 0.262 | 0.289 | 0.315 | 0.342 | 0.370 | 0.398 | 0.426 | 0.456 | 0.487 | 0.519 | 0.553 | 0.590 | 0.631 | 0.679 | 0.739 | 0.882 |
| 0.76 | 0.105 | 0.131 | 0.157 | 0.183 | 0.209 | 0.235 | 0.262 | 0.288 | 0.315 | 0.343 | 0.371 | 0.399 | 0.429 | 0.460 | 0.492 | 0.526 | 0.563 | 0.604 | 0.652 | 0.712 | 0.855 |
| 0.77 | 0.079 | 0.105 | 0.131 | 0.157 | 0.183 | 0.209 | 0.236 | 0.262 | 0.289 | 0.317 | 0.345 | 0.373 | 0.403 | 0.434 | 0.466 | 0.500 | 0.537 | 0.578 | 0.626 | 0.685 | 0.829 |
| 0.78 | 0.052 | 0.078 | 0.104 | 0.130 | 0.156 | 0.182 | 0.209 | 0.235 | 0.262 | 0.290 | 0.318 | 0.346 | 0.376 | 0.407 | 0.439 | 0.473 | 0.510 | 0.551 | 0.599 | 0.659 | 0.802 |
| 0.79 | 0.026 | 0.052 | 0.078 | 0.104 | 0.130 | 0.156 | 0.183 | 0.209 | 0.236 | 0.264 | 0.292 | 0.320 | 0.350 | 0.381 | 0.413 | 0.447 | 0.484 | 0.525 | 0.573 | 0.633 | 0.776 |
| 0.80 | 0.000 | 0.026 | 0.052 | 0.078 | 0.104 | 0.130 | 0.157 | 0.183 | 0.210 | 0.238 | 0.266 | 0.294 | 0.324 | 0.355 | 0.387 | 0.421 | 0.458 | 0.499 | 0.547 | 0.609 | 0.750 |
| 0.81 | | 0.000 | 0.026 | 0.052 | 0.078 | 0.104 | 0.131 | 0.157 | 0.184 | 0.212 | 0.240 | 0.268 | 0.298 | 0.329 | 0.361 | 0.395 | 0.432 | 0.473 | 0.521 | 0.581 | 0.724 |
| 0.82 | | | 0.000 | 0.026 | 0.052 | 0.078 | 0.105 | 0.131 | 0.158 | 0.186 | 0.214 | 0.242 | 0.272 | 0.303 | 0.335 | 0.369 | 0.406 | 0.447 | 0.495 | 0.555 | 0.698 |
| 0.83 | | | | 0.000 | 0.026 | 0.052 | 0.079 | 0.105 | 0.132 | 0.160 | 0.188 | 0.216 | 0.246 | 0.277 | 0.309 | 0.343 | 0.380 | 0.421 | 0.469 | 0.529 | 0.672 |
| 0.84 | | | | | 0.000 | 0.026 | 0.053 | 0.079 | 0.106 | 0.134 | 0.162 | 0.190 | 0.220 | 0.251 | 0.283 | 0.317 | 0.354 | 0.395 | 0.443 | 0.503 | 0.646 |
| 0.85 | | | | | | 0.000 | 0.027 | 0.053 | 0.080 | 0.108 | 0.136 | 0.164 | 0.194 | 0.225 | 0.257 | 0.291 | 0.328 | 0.369 | 0.417 | 0.477 | 0.620 |
| 0.86 | | | | | | | 0.000 | 0.026 | 0.053 | 0.081 | 0.109 | 0.137 | 0.167 | 0.198 | 0.230 | 0.264 | 0.301 | 0.342 | 0.390 | 0.450 | 0.593 |
| 0.87 | | | | | | | | 0.000 | 0.027 | 0.055 | 0.083 | 0.111 | 0.141 | 0.172 | 0.204 | 0.238 | 0.275 | 0.316 | 0.364 | 0.424 | 0.567 |
| 0.88 | | | | | | | | | 0.000 | 0.028 | 0.056 | 0.084 | 0.114 | 0.145 | 0.177 | 0.211 | 0.248 | 0.289 | 0.337 | 0.397 | 0.540 |
| 0.89 | | | | | | | | | | 0.000 | 0.028 | 0.056 | 0.086 | 0.117 | 0.149 | 0.183 | 0.220 | 0.261 | 0.309 | 0.369 | 0.512 |
| 0.90 | | | | | | | | | | | 0.000 | 0.028 | 0.058 | 0.089 | 0.121 | 0.155 | 0.192 | 0.233 | 0.281 | 0.341 | 0.484 |
| 0.91 | | | | | | | | | | | | 0.000 | 0.030 | 0.061 | 0.093 | 0.127 | 0.164 | 0.205 | 0.253 | 0.313 | 0.456 |
| 0.92 | | | | | | | | | | | | | 0.000 | 0.031 | 0.063 | 0.097 | 0.134 | 0.175 | 0.223 | 0.283 | 0.426 |
| 0.93 | | | | | | | | | | | | | | 0.000 | 0.032 | 0.066 | 0.103 | 0.144 | 0.192 | 0.252 | 0.395 |
| 0.94 | | | | | | | | | | | | | | | 0.000 | 0.034 | 0.071 | 0.112 | 0.160 | 0.220 | 0.363 |
| 0.95 | | | | | | | | | | | | | | | | 0.000 | 0.037 | 0.079 | 0.126 | 0.186 | 0.329 |
| 0.96 | | | | | | | | | | | | | | | | | 0.000 | 0.041 | 0.089 | 0.149 | 0.292 |
| 0.97 | | | | | | | | | | | | | | | | | | 0.000 | 0.048 | 0.108 | 0.251 |
| 0.98 | | | | | | | | | | | | | | | | | | | 0.000 | 0.060 | 0.203 |
| 0.99 | | | | | | | | | | | | | | | | | | | | 0.000 | 0.143 |

**Note:** To obtain required capacitor kvar:
1. Get PF correction factor from **Table 35.0-7** above.
2. Required capacitor kvar = kW load x factor.

## How Much kvar Do I Need?

The unit for rating power factor capacitors is kvar, equal to 1000 volt-amperes of reactive power. The kvar rating signifies how much reactive power the capacitor will provide.

Instructions:

1. Find the present power factor in column 1.
2. Read across to optimum power factor column.
3. Multiply that number by kW demand.

Example:

If your plant consumed 410 kW, was currently operating at 73% power factor and you wanted to correct power factor to 95%, you would:

1. Find 0.73 in column 1.
2. Read across to 0.95 column.
3. Multiply 0.607 by 410 = 249 (round to 250).
4. You need 250 kvar to bring your plant to 95% power factor.

If you don't know the existing power factor level of your plant, you will have to calculate it before using the table above. To calculate existing power factor:
kW divided by kVA = Power Factor.

A power factor sizing and ROI calculator is available on-line at www.eaton.com/pfc.

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# UNIPUMP Power Factor Correction Capacitors

*UNIPUMP*

## General Description

Non-fused capacitors for outdoor irrigation and oil field installations.

- Designed expressly for outdoor pumping applications
- Pole or wall mounting
- Small, light-weight enclosure for easy installation
- SO-WA type flexible cable facilitates installation (4-conductor)
- Gland-type weatherproof bushings
- Robust enclosure

## Application Description

Outdoor irrigation and oil and gas field pumping.

## Features

### Configuration

- **Enclosure**: Heavy, No. 14 gauge steel finished with durable baked powder coat finish. Integral strap mounting bracket with keyhole at top for pole or wall installation. No knockouts

### Capacitor Cells

- **Terminals**: Insulated finger-safe terminals rated for 3 kVAC withstand
- **Dielectric fill**: Cells use soft organic polymer resin—Resinol
  - Eliminates potential for corona/ partial discharge/electrochemical oxidation
  - Excellent heat dissipation
  - Flash point: +444 °F (+229 °C)
  - Fire point: +840 °F (+449 °C)
- **Design**: Self-healing metallized high crystalline polypropylene with ramp metallization film. Total losses less than 0.45 watt per kvar. (Dielectric losses less than 0.2 watt per kvar)
- **Pressure-sensitive interrupter**: Built-in UL recognized three-phase pressure-sensitive interrupter and thermally or mechanically activated disconnecting link removes capacitor from the supply before dangerous pressure buildup or excessive fault current. Bulged capacitor cell top provides easy visual indication of interrupter operation
- **Ceramic discharge resistors**: Reduce residual voltage to less than 50 V within one minute of de-energization. Selected for 20-year nominal life. Exceeds NEC requirements
- **Capacitor operating temperature**: –40 °F to +115 °F (–40 °C to +46 °C)
- **Warranty**: Two full years of warranty on capacitor cells

## Standards and Certifications

- UL 810 and CSA C22.2 No. 190 listed

## Product Selection

**Table 35.1-1. UNIPUMP Selection Chart**

| kvar | Rated Current (Amperes) | Enclosure Size | Cable Size ① | Shipping Weight in Lb (kg) | Catalog Number |
|---|---|---|---|---|---|
| **240 Vac** | | | | | |
| 2 | 4.8 | AA | 14 | 10.0 (4.7) | **223JMR** |
| 2.5 | 6.0 | AA | 14 | 10.0 (4.7) | **2X23JMR** |
| 3 | 7.2 | AA | 14 | 10.0 (4.7) | **323JMR** |
| 4 | 9.6 | AA | 14 | 11.0 (4.8) | **423JMR** |
| 5 | 12.0 | BB | 12 | 11.0 (4.8) | **523JMR** |
| 6 | 14.4 | BB | 12 | 15.0 (6.6) | **623JMR** |
| 7.5 | 18.0 | BB | 12 | 15.0 (6.6) | **7X23JMR** |
| **480 Vac** | | | | | |
| 2 | 2.4 | AA | 14 | 10.4 (4.7) | **243JMR** |
| 2.5 | 3.0 | AA | 14 | 10.4 (4.7) | **2X43JMR** |
| 3 | 3.6 | AA | 14 | 10.4 (4.7) | **343JMR** |
| 4 | 4.8 | AA | 14 | 10.4 (4.7) | **443JMR** |
| 5 | 6.0 | AA | 14 | 10.4 (4.7) | **543JMR** |
| 6 | 7.2 | AA | 14 | 10.6 (4.8) | **643JMR** |
| 7.5 | 9.0 | AA | 14 | 10.6 (4.8) | **7X43JMR** |
| 10 | 12.0 | AA | 14 | 10.8 (4.9) | **1043JMR** |
| 12.5 | 15.0 | BB | 12 | 15.0 (6.8) | **12X43JMR** |
| 15 | 18.0 | BB | 12 | 15.0 (6.8) | **1543JMR** |
| 17.5 | 21.0 | BB | 8 | 15.8 (7.2) | **17X43JMR** |
| 20 | 24.0 | BB | 8 | 16.8 (7.7) | **2043JMR** |
| 25 | 30.0 | BB | 8 | 16.8 (7.7) | **2543JMR** |
| **600 Vac** | | | | | |
| 5 | 4.9 | AA | 14 | 10.8 (4.9) | **563JMR** |
| 7.5 | 7.4 | AA | 14 | 10.8 (4.9) | **7X63JMR** |
| 10 | 9.8 | AA | 14 | 10.8 (4.9) | **1063JMR** |
| 12.5 | 12.3 | BB | 12 | 15.0 (6.8) | **12X63JMR** |
| 15 | 14.7 | BB | 12 | 15.8 (7.2) | **1563JMR** |
| 17.5 | 17.2 | BB | 8 | 16.8 (7.7) | **17X63JMR** |
| 20 | 19.6 | BB | 8 | 16.8 (7.7) | **2063JMR** |

① Ratings based on 60 Hz operation.

**Note:** Refer to **Figure 35.1-1** for enclosure size.

## Dimensions

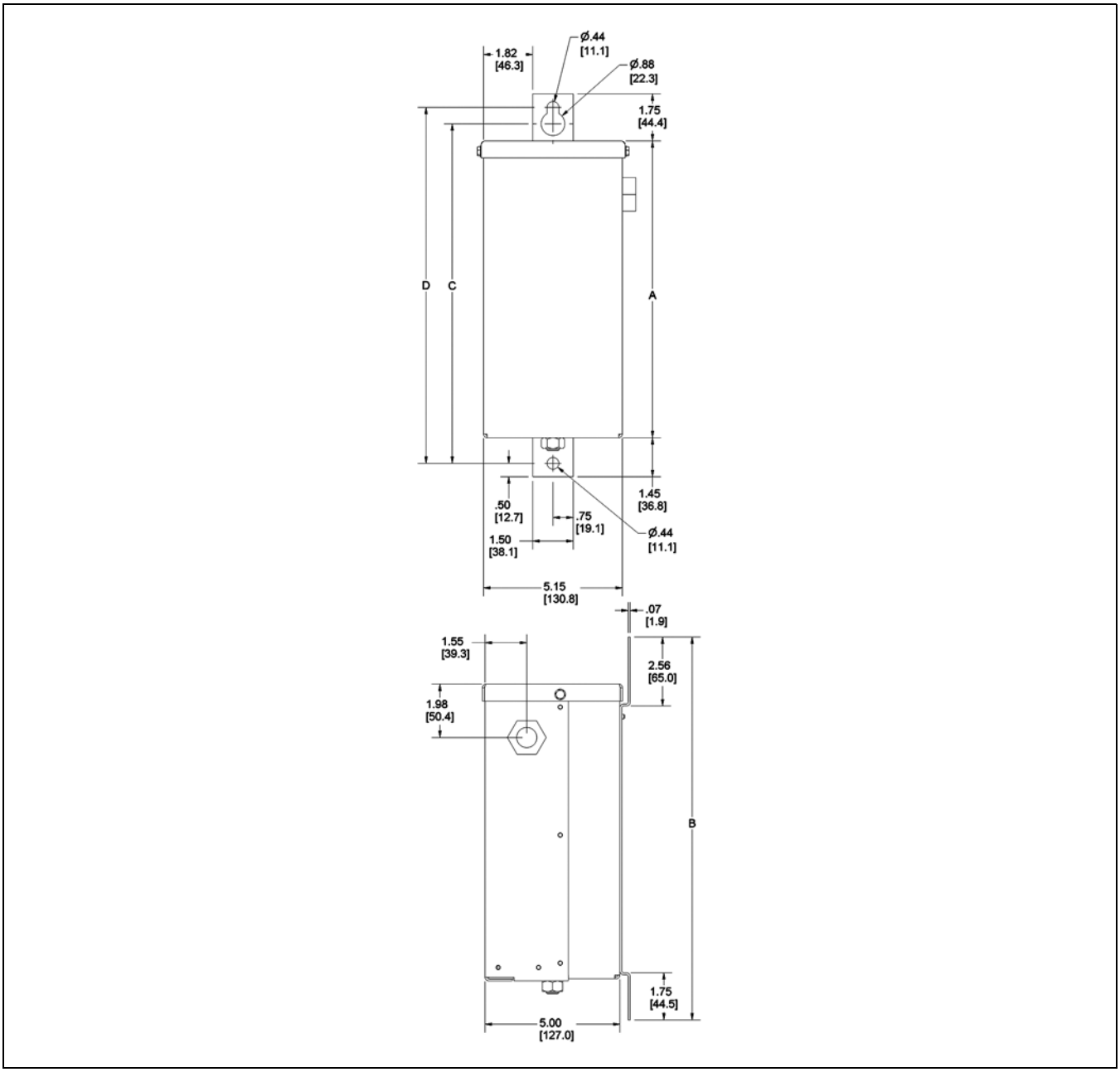


**Figure 35.1-1. UNIPUMP—Dimensions in Inches (mm)**

**Table 35.1-2. UNIPUMP Dimension Chart**

| Case Size | Dimensions in Inches (mm) | | | |
|---|---|---|---|---|
| | A | B | C | D |
| AA | 11.00 (279.7) | 14.20 (360.9) | 12.60 (320.0) | 13.20 (335.5) |
| BB | 14.00 (354.5) | 17.10 (435.6) | 15.50 (394.7) | 16.10 (410.2) |

# Low Voltage Power Factor Correction Capacitor Banks and Detuned Filters

*Low Voltage Power Factor Correction Capacitor Banks and Detuned Filters*

## General Description

### Power Factor Correction Capacitors

Eaton Power factor correction capacitors and detuned filters are an essential part of modern electric power systems. Power factor correction capacitors are the simplest and most economical means of increasing the capacity of any power system, minimizing energy losses and correcting load power factor. In addition, power factor penalties can be reduced and power quality can be greatly enhanced.

There are several reasons to correct poor power factor. The first is to reduce or eliminate a power factor penalty charged by the utility. Another reason is that your existing transformer is, or shortly will be, at full capacity and installing power factor correction capacitors can be a very cost-effective solution compared to installing a brand new service. Depending on the amount of power factor correction (kvar that needs to be injected into the electrical system to improve the power factor) and the dynamic nature of the load, a fixed or switched capacitor bank may be the best solution. When capacity becomes a problem, the choice of a solution will be dependent upon the size of the increase needed. Like all power quality solutions, there are many factors that need to be considered when determining which solution will be best to solve your power factor problem.

**Note:** Images contained in this document may be shown with optional components and features not included as part of the base offering.

### Harmonic Filtering

As the world becomes more dependent on electric and electronic equipment, the likelihood that the negative impact of harmonic distortion increases dramatically. The efficiency and productivity gains from these increasingly sophisticated pieces of equipment have a negative side effect…increased harmonic distortion in the power lines. The difficult thing about harmonic distortion is determining the cause. Once this has been determined, the solution can be easy. Active harmonic filtering equipment will mitigate specific harmonic issues, and correct poor power factor as well.

## Standard UNIPAK Capacitor Banks

## Features, Benefits and Functions

- Five-year warranty on capacitor cells (units with heavy-duty cells)
- Two-year warranty on capacitor cells (units with standard-duty cells)
- Designed for heavy-duty applications
- Indoor/outdoor service
- Wall (up to C2 enclosure size) and floor-mounted units available
- Individual cells are internally protected through the use of an overpressure disconnector and thermal element
- Quick lead times
- Detuned filters available
- Slim profile allows reduced footprint, conserving valuable floor space
- Main incoming lugs for copper cable standard

### Configuration

- **Outer case**: Heavy, No. 14 gauge steel finished with durable baked powder coat finish. Wall-mounting flanges and floor-mounting feet. Elimination of knockouts permits indoor/outdoor use. Manufactured to NEMA requirements 1 and 3R
- Elevated floor-mounting feet allow access for easy maintenance
- **Cover**: "L" shaped gasketed cover with multiple fasteners provides front opening for ease of installation and service
- **Ground terminal**: Furnished inside case
- **Power terminal lugs**: Large size provided for easy connection
- **Options**:
  - Non-fused units available, selected sizes
  - Heavy-duty capacitor cells, selected sizes
- **Standard fusing**:
  - **Size Code A1**: Three midget-type fuses with 100,000 ampere interrupting capacity
  - **Size Code A2 and larger**: Slotted-blade type fuses with 200,000 A interrupting capacity; fuses mounted on stand-off bushings; solderless connectors for easy hookup of incoming line conductors
  - **Fuse indicating lights**: Red, neon blown-fuse indicating lights are protected by transparent weather-proof guard

### Capacitor Cells

- **Terminals**: Insulated finger-safe terminals rated for 3 kVAC withstand
- **Dielectric fill**: Cells use soft organic polymer resin—Resinol
  - Eliminates potential for corona/partial discharge/electrochemical oxidation
  - Excellent heat dissipation
  - Flash point: +444 °F (+229 °C)
  - Fire point: +840 °F (+449 °C)
- **Design**: Self-healing metallized high crystalline polypropylene with metallization film. Dielectric losses less than 0.2 watt per kvar
- **Total capacitor cell heat loss**: Total losses less than 0.45 watt per kvar including discharge resistor
- **Pressure-sensitive interrupter**: Built-in UL recognized three-phase pressure-sensitive interrupter and thermally or mechanically activated disconnecting link removes capacitor from the supply before dangerous pressure buildup or excessive fault current. Bulged capacitor cell top provides easy visual indication of interrupter operation
- **Ceramic discharge resistors**: Reduce residual voltage to less than 50 V within one minute of de-energization. Selected for 20-year nominal life. Exceeds NEC requirements
- **Capacitor operating temperature**: –40 °F to +115 °F (–40 °C to +46 °C)
- **Capacitor cell case**: Weatherproof aluminum housing
- **Warranty**: The longest in the industry—five full years of warranty on capacitor cells (units with heavy-duty cells); units with standard-duty cells have a two-year warranty on capacitor cells

### Heavy-duty capacitor cells

- For use in moderate harmonic environments where engineering evaluation allows in place of detuned filter designs
- Provides future conversion capability into a detuned filter system when required by facility growth of increased nonlinear load levels

*UNIPAK Capacitor Bank Interior*

## Standards and Certifications

- UL 810 and CSA C22.2 No. 190 listed

## UNIPAK Detuned Filter

*Reactor Enclosure* *Capacitor Enclosure*

# General Description

### UNIPAK Low Voltage Fixed Detuned Filters

- Detuned filter systems for low voltage, heavy-duty applications
- Correct power factor in high harmonic environments
- Two-enclosure design isolates capacitors from high-temperature operating reactors and allows for flexible installation
- Five-year cell warranty / one-year reactor warranty
- Three-phase cell capacitor construction

### Application Description

Designed for power factor correction in plants with high amounts of nonlinear loads.

### Standard Features

- Enclosures: Standard NEMA 1 enclosures have durable baked powder coat finish
- UNIPAK detuned filter operating temperature: –40 °F to +115 °F (–40 °C to +46 °C)
- UNIPAK detuned filter storage temperature: –40 °F to +131 °F (–40 °C to +55 °C)
- Power and ground terminal lugs: Furnished inside enclosures

### Reactors

- **Detuning**: Standard reactor designs are detuned to the 4.2nd harmonic and recommended to protect capacitors against harmonic resonance. Detuning to other harmonics is available as an option. The harmonic spectrum should be evaluated for applications involving reactors tuned above the 4.2nd harmonic to ensure optimal equipment life, specifically when used in conjunction with six-pulse motor drives
- **Construction**: 100% copper windings for cool operating temperatures; designed operating temperature rise less than 80 °C. Open frame construction with 220 °C insulation system
- **Thermal sensors**: One per phase, self-resetting thermal switches provide reactor overtemperature protection and indication
- **Reactor indicating light**: Thermal overload indicating light activates when reactor temperature reaches 180 °C
- **Fuses**: Standard fusing with cleared fuse indication

### Standards and Certifications

- UL 508A and CSA C22.2 No. 190 Listed

## UNIPAK Low Voltage Fixed Capacitor Banks

**Table 35.1-3. 240 Vac UNIPAK Selection Chart**

| kvar | Rated Current | Enclosure Size | Shipping Weight in Lb (kg) | Catalog Number |
|---|---|---|---|---|
| 1 | 2.4 | A1 | 18 (8) | **123PMURF** |
| 1.5 | 3.6 | A1 | 18 (8) | **1X23PMURF** |
| 2 | 4.8 | A1 | 19 (9) | **223PMURF** |
| 2.5 | 6 | A1 | 19 (9) | **2X23PMURF** |
| 3 | 7.2 | A1 | 19 (9) | **323PMURF** |
| 4 | 9.6 | A1 | 20 (9) | **423PMURF** |
| 5 | 12 | A2 | 29 (13) | **523PMURF** |
| 6 | 14.4 | A2 | 29 (13) | **623PMURF** |
| 7.5 | 18 | A2 | 30 (14) | **7X23PMURF** |
| 8 | 19.2 | A2 | 31 (14) | **823PMURF** |
| 10 | 24 | A2 | 31 (14) | **1023PMURF** |
| 12.5 | 30 | A2 | 32 (14) | **12X23PMURF** |
| 15 | 36 | A2 | 33 (15) | **1523PMURF** |
| 17.5 | 42 | B1 | 44 (20) | **17X23PMURF** |
| 20 | 48 | B1 | 45 (20) | **2023PMURF** |
| 22.5 | 54 | B1 | 46 (21) | **22X23PMURF** |
| 25 | 60 | B1 | 46 (21) | **2523PMURF** |
| 27.5 | 66 | B1 | 47 (21) | **27X23PMURF** |
| 30 | 72 | B1 | 47 (21) | **3023PMURF** |
| 32.5 | 78 | C1 | 47 (22) | **32X23PMURF** |
| 35 | 84 | C1 | 48 (22) | **3523PMURF** |
| 37.5 | 90 | C1 | 60 (27) | **37X23PMURF** |
| 40 | 96 | C1 | 64 (29) | **4023PMURF** |
| 42.5 | 102 | C1 | 65 (30) | **42X23PMURF** |
| 45 | 108 | C1 | 66 (30) | **4523PMURF** |
| 50 | 120 | C1 | 68 (31) | **5023PMURF** |
| 60 | 144 | C1 | 69 (31) | **6023PMURF** |
| 70 | 168 | C2 | 99 (45) | **7023PMURF** |
| 75 | 180 | C2 | 100 (46) | **7523PMURF** |
| 80 | 192 | C2 | 101 (46) | **8023PMURF** |
| 90 | 216 | C2 | 103 (47) | **9023PMURF** |
| 100 | 240 | D1 | 104 (47) | **10023PMURF** |
| 120 | 288 | D1 | 133 (60) | **12023PMURF** |
| 140 | 336 | E1 | 137 (62) | **14023PMURF** |
| 150 | 360 | E1 | 140 (64) | **15023PMURF** |
| 160 | 384 | E1 | 175 (80) | **16023PMURF** |
| 180 | 432 | E1 | 182 (83) | **18023PMURF** |
| 200 | 480 | E1 | 189 (86) | **20023PMURF** |

**Notes:**

- Replaceable fuses and indicator lights standard
- Internally fused only also available for some ratings—please consult the factory
- Ratings based on 60 Hz operation

**Table 35.1-4. 480 Vac UNIPAK Selection Chart**

| kvar | Rated Current | Enclosure Size | Shipping Weight in Lb (kg) | Catalog Number |
|---|---|---|---|---|
| 1.5 | 1.8 | A1 | 17 (8) | **1X43PMURF** |
| 2 | 2.4 | A1 | 18 (8) | **243PMURF** |
| 2.5 | 3 | A1 | 18 (8) | **2X43PMURF** |
| 3 | 3.6 | A1 | 19 (9) | **343PMURF** |
| 4 | 4.8 | A1 | 19 (9) | **443PMURF** |
| 5 | 6 | A1 | 19 (9) | **543PMURF** |
| 6 | 7.2 | A1 | 19 (9) | **643PMURF** |
| 7.5 | 9 | A1 | 20 (9) | **7X43PMURF** |
| 8 | 9.6 | A1 | 20 (9) | **843PMURF** |
| 9 | 10.8 | A1 | 20 (9) | **943PMURF** |
| 10 | 12 | A1 | 20 (9) | **1043PMURF** |
| 12.5 | 15 | A2 | 29 (13) | **12X43PMURF** |
| 15 | 18 | A2 | 29 (13) | **1543PMURF** |
| 17.5 | 21 | A2 | 30 (14) | **17X43PMURF** |
| 20 | 24 | A2 | 31 (14) | **2043PMURF** |
| 22.5 | 27 | B1 | 44 (20) | **22X43PMURF** |
| 25 | 30 | A2 | 32 (15) | **2543PMURF** |
| 27.5 | 33 | B1 | 44 (20) | **27X43PMURF** |
| 30 | 36 | B1 | 44 (20) | **3043PMURF** |
| 32.5 | 39 | B1 | 45 (20) | **32X43PMURF** |
| 35 | 42 | B1 | 45 (20) | **3543PMURF** |
| 37.5 | 45 | B1 | 46 (21) | **37X43PMURF** |
| 40 | 48 | B1 | 46 (21) | **4043PMURF** |
| 42.5 | 51 | B1 | 47 (21) | **42X43PMURF** |
| 45 | 54 | B1 | 47 (22) | **4543PMURF** |
| 50 | 60 | B1 | 48 (22) | **5043PMURF** |
| 55 | 66 | C1 | 48 (22) | **5543PMURF** |
| 60 | 72 | C1 | 48 (22) | **6043PMURF** |
| 65 | 78 | C1 | 64 (29) | **6543PMURF** |
| 70 | 84 | C1 | 65 (30) | **7043PMURF** |
| 75 | 90 | C1 | 65 (30) | **7543PMURF** |
| 80 | 96 | C1 | 66 (30) | **8043PMURF** |
| 85 | 102 | C1 | 68 (31) | **8543PMURF** |
| 90 | 108 | C1 | 68 (31) | **9043PMURF** |
| 100 | 120 | C1 | 69 (31) | **10043PMURF** |
| 120 | 144 | C2 | 69 (31) | **12043PMURF** |
| 125 | 150 | C2 | 99 (45) | **12543PMURF** |
| 140 | 168 | C2 | 100 (46) | **14043PMURF** |
| 150 | 180 | C2 | 101 (46) | **15043PMURF** |
| 160 | 192 | D1 | 103 (47) | **16043PMURF** |
| 180 | 216 | D1 | 104 (47) | **18043PMURF** |
| 200 | 240 | D1 | 137 (62) | **20043PMURF** |
| 225 | 270 | D1 | 140 (64) | **22543PMURF** |
| 250 | 300 | E1 | 170 (77) | **25043PMURF** |
| 300 | 360 | E1 | 175 (80) | **30043PMURF** |
| 350 | 420 | E1 | 182 (83) | **35043PMURF** |
| 400 | 480 | E1 | 189 (86) | **40043PMURF** |

**Notes:**

- Unfused units available up to 100 kvar at 480 V
- 480 V units above 50 kvar have 525 V capacitor cells
- Ratings based on 60 Hz operation

## UNIPAK Low Voltage Fixed Capacitor Banks

**Table 35.1-5. 600 Vac UNIPAK Selection Chart**

| kvar | Rated Current | Enclosure Size | Shipping Weight in Lb (kg) | Catalog Number |
|---|---|---|---|---|
| 5 | 4.9 | A1 | 19 (9) | **563PMURF** |
| 7.5 | 7.4 | A1 | 19 (9) | **7X63PMURF** |
| 10 | 9.8 | A1 | 20 (9) | **1063PMURF** |
| 12.5 | 12.3 | A1 | 20 (9) | **12X63PMURF** |
| 15 | 14.7 | A2 | 29 (13) | **1563PMURF** |
| 17.5 | 17.2 | A2 | 29 (13) | **17X63PMURF** |
| 20 | 19.6 | A2 | 30 (14) | **2063PMURF** |
| 22.5 | 22.1 | B1 | 44 (20) | **22X63PMURF** |
| 25 | 24.5 | B1 | 31 (14) | **2563PMURF** |
| 27.5 | 27 | B1 | 44 (20) | **27X63PMURF** |
| 30 | 29.4 | B1 | 45 (20) | **3063PMURF** |
| 32.5 | 31.9 | B1 | 45 (20) | **32X63PMURF** |
| 35 | 34.3 | B1 | 46 (21) | **3563PMURF** |
| 37.5 | 36.8 | B1 | 46 (21) | **37X63PMURF** |
| 40 | 39.2 | B1 | 47 (21) | **4063PMURF** |
| 42.5 | 41.7 | B1 | 47 (22) | **42X63PMURF** |
| 45 | 44.1 | B1 | 48 (22) | **4563PMURF** |
| 50 | 49 | B1 | 48 (22) | **5063PMURF** |
| 55 | 53.9 | C1 | 64 (29) | **5563PMURF** |
| 60 | 58.8 | C1 | 64 (29) | **6063PMURF** |
| 65 | 63.7 | C1 | 65 (30) | **6563PMURF** |
| 70 | 68.6 | C1 | 65 (30) | **7063PMURF** |
| 75 | 73.5 | C1 | 66 (30) | **7563PMURF** |
| 80 | 78.4 | C1 | 68 (31) | **8063PMURF** |
| 85 | 83.3 | C1 | 68 (31) | **8563PMURF** |
| 90 | 88.2 | C1 | 69 (31) | **9063PMURF** |
| 100 | 98 | C1 | 69 (31) | **10063PMURF** |
| 120 | 117.6 | C2 | 99 (45) | **12063PMURF** |
| 125 | 122.5 | C2 | 100 (46) | **12563PMURF** |
| 140 | 137.2 | C2 | 101 (46) | **14063PMURF** |
| 150 | 147 | C2 | 103 (47) | **15063PMURF** |
| 160 | 156.8 | D1 | 135 (61) | **16063PMURF** |
| 180 | 176.4 | D1 | 137 (62) | **18063PMURF** |
| 200 | 196 | D1 | 140 (64) | **20063PMURF** |
| 225 | 220.5 | D1 | 143 (65) | **22563PMURF** |
| 250 | 245 | E1 | 170 (77) | **25063PMURF** |
| 300 | 294 | E1 | 175 (80) | **30063PMURF** |
| 350 | 343 | E1 | 182 (83) | **35063PMURF** |
| 400 | 392 | E1 | 189 (86) | **40063PMURF** |

**Notes:**

- Unfused units available up to 100 kvar at 600 V
- Ratings based on 60 Hz operation

## UNIPAK—With Heavy Duty Cells

**Table 35.1-6. Low Voltage Fixed Capacitor Systems with Heavy Duty Cells**

| kvar | Rated Current (Amperes) | Enclosure Size | Shipping Weight in Lb (kg) | Catalog Number |
|---|---|---|---|---|
| **240 V** | | | | |
| 15 | 36 | B1 | 38.4 (17) | **1523HURF** |
| 25 | 60 | B1 | 38.4 (17) | **2523HURF** |
| 30 | 72 | C1 | 55.2 (25) | **3023HURF** |
| 50 | 120 | C1 | 57.6 (26) | **5023HURF** |
| 60 | 144 | C2 | 100.8 (46) | **6023HURF** |
| 75 | 180 | C2 | 104.4 (47) | **7523HURF** |
| 100 | 240 | D1 | 136.8 (62) | **10023HURF** |
| 125 | 300 | E1 | 189.6 (86) | **12523HURF** |
| **480 V** | | | | |
| 15 | 18 | B1 | 25.2 (11) | **1543HURF** |
| 25 | 30 | B1 | 37.2 (17) | **2543HURF** |
| 30 | 36 | B1 | 38.4 (17) | **3043HURF** |
| 50 | 60 | C1 | 39.6 (18) | **5043HURF** |
| 60 | 72 | C1 | 52.8 (24) | **6043HURF** |
| 75 | 90 | C2 | 55.2 (25) | **7543HURF** |
| 100 | 120 | C2 | 57.6 (26) | **10043HURF** |
| 125 | 150 | D1 | 100.8 (46) | **12543HURF** |
| 150 | 180 | D1 | 104.4 (47) | **15043HURF** |
| 200 | 240 | E1 | 136.8 (62) | **20043HURF** |
| 250 | 300 | E1 | 186.0 (84) | **25043HURF** |
| **600 V** | | | | |
| 15 | 15 | B1 | 37.2 (17) | **1563HURF** |
| 25 | 24.5 | B1 | 38.4 (17) | **2563HURF** |
| 30 | 29.4 | B1 | 39.6 (18) | **3063HURF** |
| 50 | 49 | C1 | 55.2 (25) | **5063HURF** |
| 60 | 58.8 | C1 | 57.6 (26) | **6063HURF** |
| 75 | 73.5 | C2 | 100.8 (46) | **7563HURF** |
| 100 | 98 | C2 | 104.4 (47) | **10063HURF** |
| 125 | 122.5 | D1 | 136.8 (62) | **12563HURF** |
| 150 | 147 | D1 | 136.8 (62) | **15063HURF** |
| 200 | 196 | E1 | 186.0 (84) | **20063HURF** |
| 250 | 245 | E1 | 189.6 (86) | **25063HURF** |

**Notes:**

- Replaceable fuses and indicator lights standard
- Internally fused only also available for some ratings—please consult the factory
- Ratings based on 60 Hz operation

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## UNIPAK Detuned Filters—Fixed Capacitor Banks with Integral Anti-Resonance Reactor

**Table 35.1-7. Fixed UNIPAK Detuned Filters**

| kvar | Rated Current (Amperes) | Capacitor Enclosure Size | Shipping Weight in Lb (kg) | Reactor Enclosure Case Size | Reactor Shipping Weight in Lb (kg) | Combined Shipping Weight in Lb (kg) | Catalog Number |
|---|---|---|---|---|---|---|---|
| **240 V** | | | | | | | |
| 15 | 36 | B1 | 48.4 (22.0) | R | 90.0 (40.9) | 138.4 (62.8) | **15232HMURFY** |
| 25 | 60 | B1 | 48.4 (22.0) | R | 105.0 (47.7) | 153.4 (69.6) | **25232HMURFY** |
| 30 | 72 | C1 | 65.2 (29.6) | R | 110.0 (49.9) | 175.2 (79.5) | **30232HMURFY** |
| 50 | 120 | C1 | 67.6 (30.7) | R | 130.0 (59.0) | 197.6 (89.7) | **50232HMURFY** |
| 60 | 144 | C2 | 110.8 (50.3) | R | 160.0 (72.6) | 270.8 (122.9) | **60232HMURFY** |
| 75 | 180 | C2 | 114.4 (51.9) | R | 185.0 (84.0) | 299.4 (135.9) | **75232HMURFY** |
| 100 | 240 | D1 | 146.8 (66.6) | R | 240.0 (109.0) | 386.8 (175.6) | **100232HMURFY** |
| 125 | 300 | E1 | 199.6 (90.6) | S | 280.0 (127.1) | 479.6 (217.7) | **125232HMURFY** |
| 150 | 360 | E1 | 220.0 (99.9) | S | 280.0 (127.1) | 500.0 (227.0) | **150232HMURFY** |
| **480 V** | | | | | | | |
| 15 | 18 | B1 | 35.2 (16.0) | R | 90.0 (40.9) | 125.2 (56.8) | **15432HMURFY** |
| 25 | 30 | B1 | 47.2 (21.4) | R | 105.0 (47.7) | 152.2 (69.1) | **25432HMURFY** |
| 30 | 36 | B1 | 48.4 (22.0) | R | 110.0 (49.9) | 158.4 (71.9) | **30432HMURFY** |
| 50 | 60 | C1 | 49.6 (22.5) | R | 130.0 (59.0) | 179.6 (81.5) | **50432HMURFY** |
| 60 | 72 | C1 | 62.8 (28.5) | R | 160.0 (72.6) | 222.8 (101.2) | **60432HMURFY** |
| 75 | 90 | C2 | 65.2 (29.6) | R | 185.0 (84.0) | 250.2 (113.6) | **75432HMURFY** |
| 100 | 120 | C2 | 67.6 (30.7) | R | 240.0 (109.0) | 307.6 (139.7) | **100432HMURFY** |
| 125 | 150 | D1 | 110.8 (50.3) | R | 280.0 (127.1) | 390.8 (177.4) | **125432HMURFY** |
| 150 | 180 | D1 | 114.4 (51.9) | S | 280.0 (127.1) | 394.4 (179.1) | **150432HMURFY** |
| 200 | 240 | E1 | 146.8 (66.6) | S | 330.0 (149.8) | 476.8 (216.5) | **200432HMURFY** |
| 250 | 300 | E1 | 196.0 (89.0) | T | 570.0 (258.8) | 766.0 (347.8) | **250432HMURFY** |
| **600 V** | | | | | | | |
| 15 | 15 | B1 | 47.2 (21.4) | R | 90.0 (40.9) | 137.2 (62.3) | **15632HMURFY** |
| 25 | 24.5 | B1 | 48.4 (22.0) | R | 90.0 (47.7) | 153.4 (69.6) | **25632HMURFY** |
| 30 | 29.4 | B1 | 49.6 (22.5) | R | 105.0 (49.9) | 159.6 (72.5) | **30632HMURFY** |
| 50 | 49 | C1 | 65.2 (29.6) | R | 110.0 (59.0) | 195.2 (88.6) | **50632HMURFY** |
| 60 | 58.8 | C1 | 67.6 (30.7) | R | 130.0 (72.6) | 227.6 (103.3) | **60632HMURFY** |
| 75 | 73.5 | C2 | 110.8 (50.3) | R | 160.0 (84.0) | 295.8 (134.3) | **75632HMURFY** |
| 100 | 98 | C2 | 114.4 (51.9) | R | 185.0 (109.0) | 354.4 (160.9) | **100632HMURFY** |
| 150 | 147 | D1 | 146.8 (66.6) | S | 280.0 (127.1) | 426.8 (193.8) | **150632HMURFY** |
| 200 | 196 | E1 | 196.0 (89.0) | T | 330.0 (149.8) | 526.0 (238.8) | **200632HMURFY** |
| 250 | 245 | E1 | 199.6 (90.6) | T | 570.0 (258.8) | 769.6 (349.4) | **250632HMURFY** |

**Notes:**

- Other ratings available, please consult factory
- Units in table above are 60 Hz

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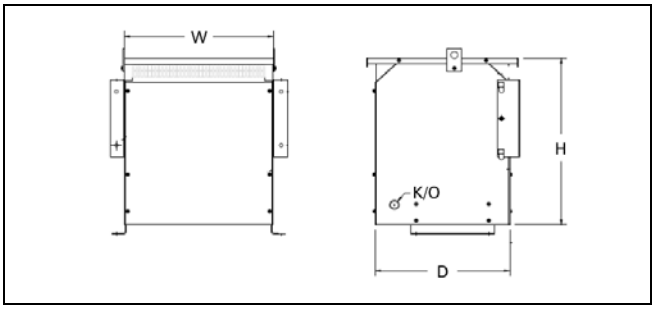


**Figure 35.1-2. Reactor Cabinet**

**Table 35.1-8. Reactor Cabinet—Dimensions in Inches (mm)**

| Case Size | Height | Width | Depth |
|---|---|---|---|
| R | 20.50 (520.7) | 20.50 (520.7) | 20.75 (527.1) |
| S | 24.50 (622.3) | 24.50 (622.3) | 22.00 (558.8) |
| T | 32.00 (812.8) | 30.75 (781.1) | 27.75 (704.9) |

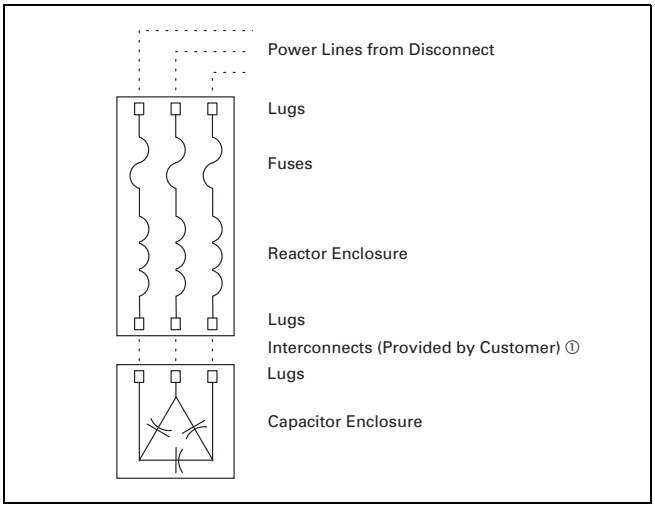


**Figure 35.1-3. Filter Schematic with Wiring Interconnects**

① Refer to NEC.

## Low Voltage Fixed Capacitor Banks and Fixed Harmonic Filters—Dimensions in Inches (mm)

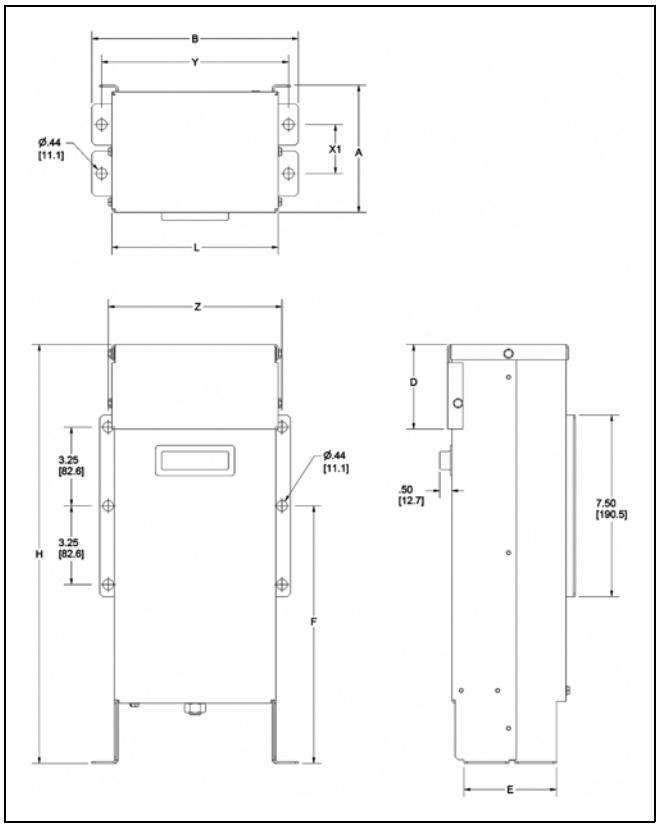


Figure 35.1-4. Case A1, A2

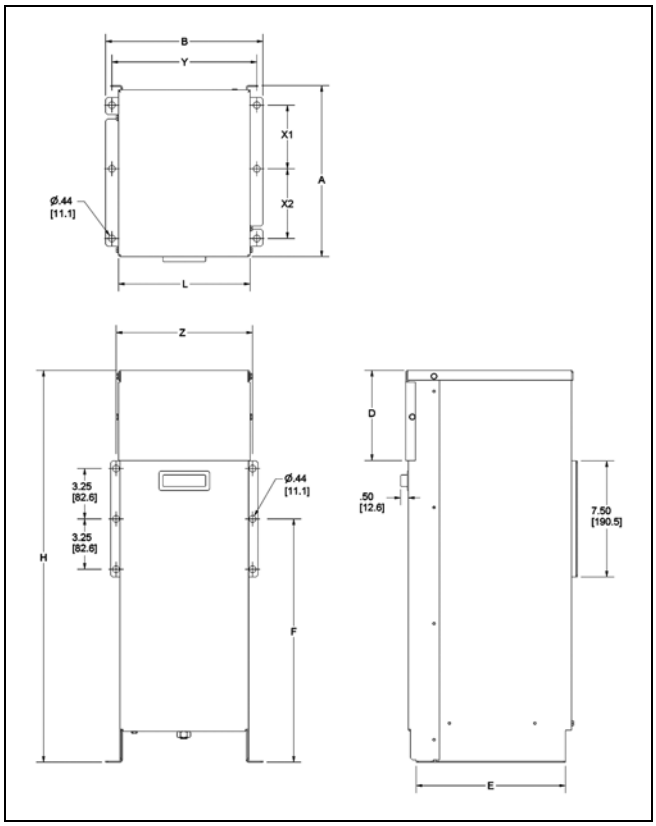


Figure 35.1-5. Case B1

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## Low Voltage Fixed Capacitor Banks and Fixed Harmonic Filters—Dimensions in Inches (mm)

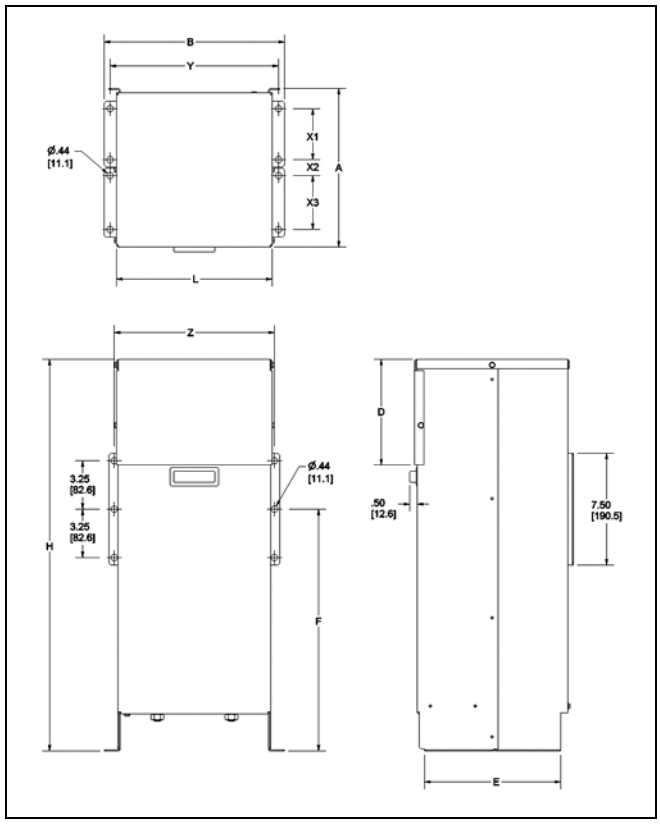



Figure 35.1-6. Case C1, C2

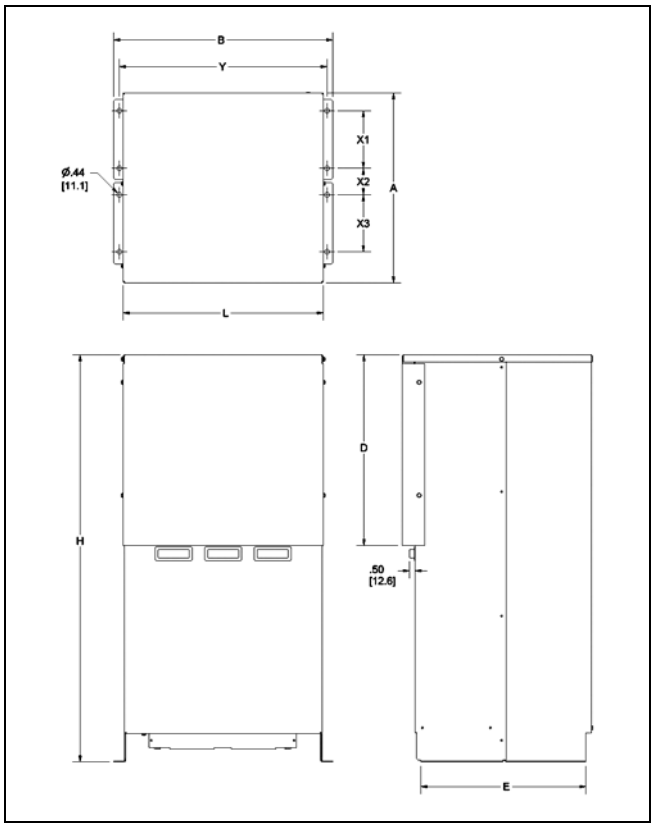



Figure 35.1-7. Case D1, E1

**Table 35.1-9. UNIPAK Enclosures**

| Case Size | Dimensions in Inches (mm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | D | E | F | H | L | X1 | X2 | X3 | Y | Z |
| A1 | 5.30 (133.5) | 8.50 (215.9) | 3.50 (88.7) | 3.80 (96.8) | 10.60 (270.2) | 17.30 (439.4) | 6.80 (173.9) | 2.00 (51.5) | N/A | N/A | 7.70 (195.6) | 7.20 (181.7) |
| A2 | 6.00 (151.2) | 8.50 (215.9) | 5.60 (141.9) | 4.50 (114.6) | 13.30 (336.7) | 22.30 (567.6) | 6.80 (173.9) | 2.30 (58.3) | N/A | N/A | 7.70 (195.6) | 7.20 (181.7) |
| B1 | 11.10 (280.8) | 10.10 (257.3) | 5.80 (148.0) | 9.60 (244.1) | 15.70 (399.0) | 25.30 (642.6) | 8.50 (215.3) | 4.10 (104.4) | 4.50 (114.3) | N/A | 9.30 (237.0) | 8.80 (223.1) |
| C1 | 10.60 (270.4) | 12.10 (306.8) | 7.10 (180.0) | 9.10 (231.5) | 16.20 (412.5) | 26.30 (668.0) | 10.40 (264.8) | 3.40 (86.9) | 1.10 (27.3) | 3.6 (92.0) | 11.30 (286.5) | 10.70 (272.6) |
| C2 | 12.00 (304.2) | 19.30 (490.7) | 16.90 (428.3) | 9.50 (240.5) | 16.30 (413.0) | 36.00 (914.4) | 17.70 (448.8) | 3.00 (75.3) | 1.50 (38.1) | 3.8 (95.3) | 18.30 (465.3) | 18.00 (456.5) |
| D1 | 16.80 (426.6) | 19.30 (490.7) | 16.90 (428.3) | 14.60 (370.1) | N/A | 36.00 (914.4) | 17.70 (448.8) | 5.10 (129.1) | 2.40 (59.7) | 5.0 (127.9) | 18.30 (465.3) | N/A |
| E1 | 22.30 (566.4) | 24.40 (618.7) | 16.80 (425.5) | 19.50 (494.1) | N/A | 36.00 (914.4) | 22.70 (576.7) | 6.50 (165.1) | 4.40 (111.9) | 5.0 (127.0) | 22.40 (567.9) | N/A |

**Legend:**

A = Total depth

B = Total width

D = Height of removable front cover

E = Depth of feet

F = Height of middle mounting hole in wall bracket

H = Total height

L = Width without feet and brackets

X = Depth between front and rear mounting holes in inches

Y = Width between floor mounting holes

Z = Width between wall bracket mounting holes

# AUTOVAR® 300 Automatic Power Factor Correction Capacitor Systems

*AUTOVAR 300*

## General Description

Automatically switched power factor correction systems for low voltage applications.

- Wallmount design is ideal for minimum space requirements
- Programmable to automatically add/subtract capacitor stages to maintain preset target power factor
- Heavy-duty, three-phase capacitor construction
- Five-year warranty of cells against manufacturing defects

## Application Description

AUTOVAR 300 is an ideal capacitor bank to automatically regulate power factor where floor space is limited and expansion of the facility's electrical load is not expected.

## Features

### Configuration

- **Cabinet**: Wallmounting 12 gauge steel with ANSI 61 gray, NEMA 1 (gasketed)
- **Power line interconnect**: Rugged, power distribution block connection. Typical power distribution block can accommodate phase wire sizes from 4 AWG to 500 kcmil; typical ground lug can accommodate wire sizes from 14 AWG to 2/0 AWG. Consult equipment approval drawings for actual lug size
- **Control wiring**: UL type MTW/AWM, CSA TEW 105 °C copper wire is standard
- **Fusing**: 200,000 A interrupting capacity provided on all three phases of each stage. Blade-type fuses mounted on insulator stand-offs with cleared-fuse indicating lights
- **Cleared-fuse lights**: Cleared-fuse neon indicating lights for each phase and stage located on the door
- **Door interlock**: Door interlock automatically disengages capacitors. Power continues to be provided to the unit until the disconnect is open
- **Exhaust fan**: Provides ventilation; dust filtering included
- **Safety**: Ground fault interruption provides protection in case of accidental contact with control power and ground
- **Conduit/cable entry**: Available in top/side cable entry
- **Thermal sensing**: Built-in thermal sensing, alarming, and protection feature allows the unit to operate in optimal temperature while alerting the user of ambient temperature exceeding the nominal operating range. Stages will be automatically switched off if temperature exceeds the maximum specified temperature
- **Temperature range**: The operating temperature range is –20 °C to +46 °C, and the storage temperature range is –40 °C to +55 °C. For optimal equipment life, the temperature should not exceed 35 °C annual average, and the environment should not exceed Pollution Degree 2 as defined in UL 61010-1

### Controller

- Visual indication of incorrect CT polarity
- Digital display of power factor and number of energized stages
- Automatic setting of c/k value (sensitivity based on CT ratio and kvar available)
- Visual indication of insufficient kvar to reach target power factor
- Automatic sensing of kvar values per step
- Optional communications capable controller (RS-485/Modbus®)
- Standard metering capability:
  - ❑ Voltage
  - ❑ Current (sensed phase only)
  - ❑ Frequency
  - ❑ Active power (kW)
  - ❑ Reactive power (kvar
  - ❑ Apparent power (kVA)
  - ❑ Total voltage harmonic distortion (VTHD)
  - ❑ Individual harmonic voltage distortion (odd orders up to the 19th harmonic)
- Built-in manual mode allows for testing and manual operation of stages
- Multiple user-friendly alarm displays. Controller provides easy-to-understand alarms for various conditions, such as:
  - ❑ Undervoltage or overvoltage
  - ❑ Undercurrent or overcurrent
  - ❑ Target power factor not met
  - ❑ Harmonic overload
  - ❑ Faulty step/stages
  - ❑ Overtemperature alarm

### Contactor

- Fully rated for capacitor switching
- Integral pre-charge/pre-insertion module standard. The contactor reduces damaging switching transients, providing safety and durability for the system
  - ❑ Lessens the chance of disrupting sensitive electronic equipment
  - ❑ Reduced inrush current extends the life of the capacitor cells

### Options

- Optional main molded-case circuit breaker
- NEMA 3R weather-resistant enclosure
- Hand-Off-Auto switches
- Remote alarm relay terminal block
- Communications capable controller

### Support and Service

- Renewal parts are available through local Eaton distributors
- Factory trained service personnel are available through Eaton's Electrical Services & Systems

## Standards and Certifications

- Entire cabinet assembly is UL 508A and CSA C22.2 No. 190 Listed
- Capacitors are UL 810 recognized
- Contactor—UL/CSA recognized; IEC 6b rated

## Product Selection

**Table 35.2-1. Wall-Mounted AUTOVAR 300 Switched Capacitor Banks—Low Voltage Applications**

| kvar | Step x kvar | Rated Current (Amperes) | Base Shipping Weight in Lb (kg) ① | Base Catalog Number |
|---|---|---|---|---|
| **240 V** | | | | |
| 25 | 5 x 5 | 60 | 217 (98.5) | **25MCSR2313** |
| 50 | 5 x 10 | 120 | 255 (115.8) | **50MCSR2313** |
| 75 | 5 x 15 | 180 | 260 (118.0) | **75MCSR2313** |
| 100 | 5 x 20 | 240 | 270 (122.6) | **100MCSR231** |
| 125 | 5 x 25 | 300 | 292 (132.6) | **125MCSR231** |
| **480 V** | | | | |
| 50 | 5 x 10 | 60 | 200 (90.8) | **50MCSR4313** |
| 75 | 5 x 15 | 90 | 210 (95.3) | **75MCSR4313** |
| 100 | 5 x 20 | 120 | 210 (95.3) | **100MCSR4313** |
| 125 | 5 x 25 | 150 | 240 (109.0) | **125MCSR4313** |
| 150 | 5 x 30 | 180 | 240 (109.0) | **150MCSR4313** |
| 175 | 5 x 35 | 210 | 260 (118.0) | **175MCSR431** |
| 200 | 5 x 40 | 241 | 270 (122.6) | **200MCSR431** |
| 225 | 5 x 45 | 270 | 290 (131.7) | **225MCSR431** |
| 250 | 5 x 50 | 300 | 292 (132.6) | **250MCSR431** |
| **600 V** | | | | |
| 50 | 5 x 10 | 48 | 200 (90.8) | **50MCSR6313** |
| 75 | 5 x 15 | 72 | 210 (95.3) | **75MCSR6313** |
| 100 | 5 x 20 | 96 | 210 (95.3) | **100MCSR6313** |
| 125 | 5 x 25 | 120 | 240 (109.0) | **125MCSR6313** |
| 150 | 5 x 30 | 144 | 240 (109.0) | **150MCSR6313** |
| 175 | 5 x 35 | 168 | 260 (118.0) | **175MCSR631** |
| 200 | 5 x 40 | 192 | 270 (122.6) | **200MCSR631** |
| 225 | 5 x 45 | 216 | 290 (131.7) | **225MCSR631** |
| 250 | 5 x 50 | 240 | 292 (132.6) | **250MCSR631** |

① Weight without options.

**Table 35.2-2. Options**

| Description | Option Code |
|---|---|
| Current transformer—multi-tap, split core current transformer (3000:5 A) ② | TX2 |
| Hand-Off-Auto switch—provides manual control to connect or disconnect capacitor stages regardless of controller output **Note:** Standard controller includes manual operation of each stage. | H |
| Remote alarm relay—relay for a remote alarm to indicate inability to reach target power factor | A |
| Molded-case circuit breaker (65 kAIC at 480 V) **Note:** This option increases enclosure height 24 inches | M |
| Weatherproofing (NEMA 3R) | W |
| Communicating controller (RS-485/Modbus) | C |

② A current transformer with a 5 A secondary is required to operate an automatic capacitor bank. Rating based on service entrance ampacity. For other ratios, please consult factory.

**Table 35.2-3. Enclosure J—Dimensions in Inches (mm)**

| Description | Height A | Depth B |
|---|---|---|
| Without MCCB | 36.00 (914.4) | 13.67 (347.2) |
| With MCCB | 60.00 (1524.0) | 13.67 (347.2) |

## Enclosure J—Dimensions in Inches (mm)

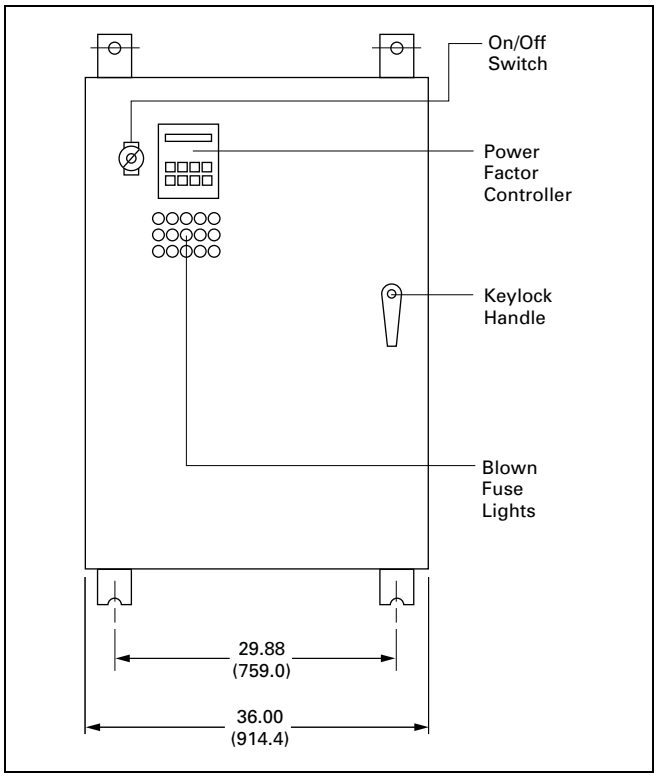



**Figure 35.2-1. Front View of Enclosure J**

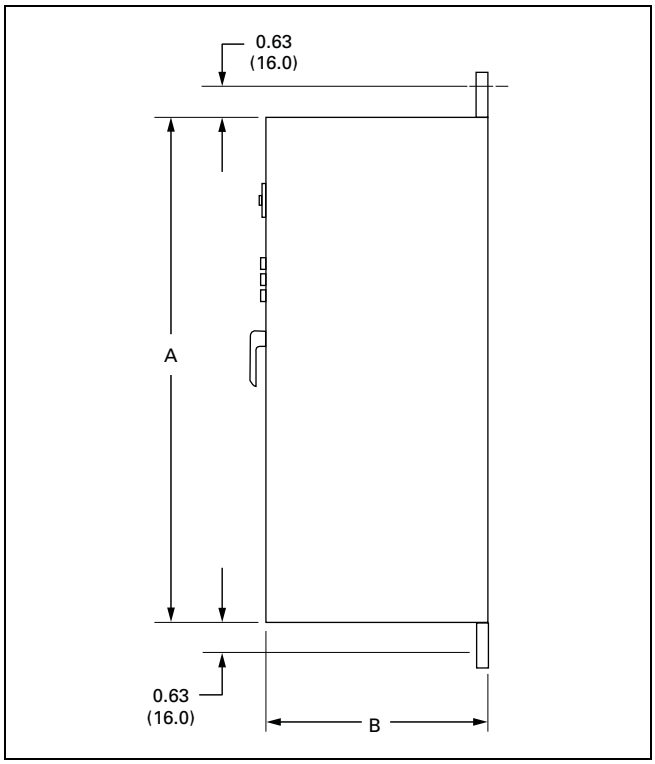



**Figure 35.2-2. Side View of Enclosure J**

# AUTOVAR 600 Automatic Power Factor Correction Capacitor Systems

*AUTOVAR 600*

## General Description

- Programmable to automatically add/subtract capacitor stages to maintain preset target power factor
- Three-phase capacitor cell construction
- Cool operating, 100% copper wound, thermal-protected reactors are sized up to 150% of rated capacitor current (AUTOVAR detuned filter only)

## Application Description

- Service entrance or substation power factor correction installations requiring precise maintenance of target power factor (AUTOVAR 600)
- Service entrance or substation power factor correction installations requiring precise maintenance of target power factor in three-phase, nonlinear, high harmonic environments (AUTOVAR detuned filter)
- Typically connected at main low voltage switchgear

## Features

### Configuration

- **Cabinet**: 12 gauge steel with ANSI 61 gray, baked finish. Removable lift bolts standard, NEMA 1 (gasketed)
- **Power line interconnect**: Rugged, copper busbar connection with access provided for top entry. Contact factory for availability of bottom entry. Busbars are braced for 65 kA (optional 100 kA rating available). All internal power wiring connections from bus are laid out on a most direct basis with minimum bends for ease of trouble-shooting. Clear barrier limiting access to live parts included standard
- **Modular tray design**: Capacitor stages arranged in modular trays with capacitors, fuses, cleared-fuse indicating lights, and contactors grouped in a logical, easily understood layout. This permits easy access, quick identification of operating problems, and ease of expandability
- **Fusing**: UL recognized, 200,000 A interrupting capacity provided on all three phases of each stage. Blade-type fuses mounted on insulator stand-offs
- **Cleared-fuse indicating lights**: LEDs located door-mounted and neon at individual fuses to facilitate tracing of cleared fuses
- **Push-to-test**: Allows testing of door-mounted LED cleared fuse indicating lights
- **AutoLocate**: When door is open and bus is energized, fuse circuit automatically checks for cleared fuses. If a fuse has cleared, the light at the fuse turns on for easy troubleshooting
- **Door interlock**: Door interlock automatically turns off control circuit when engaged. Power continues to be provided to the unit until disconnect is open
- **Exhaust fans**: Two side louver fans per cabinet provide cooling and reduce operator exposure to discharge. Replaceable dust filtering provided. Dust filters can be replaced without opening cabinet
- **Ease of expansion**: Capacitor stage nests are self-contained and can be added in the field. Two bolts mount the nest in the field. Control wire plugs connect to factory standard wire harness on the left side of the cabinet
- **Ease of replacement**: Cells can be easily replaced individually by removing the mounting bolt and lifting out of the nest without removal of any other components
- **Thermal sensing**: Built-in thermal sensing, alarming, and protection feature allows the unit to operate in optimal temperature while alerting the user of ambient temperature exceeding the nominal operating range. Stages will be automatically switched off if temperature exceeds the maximum specified temperature
- **Temperature range**: The operating temperature range is –20 °C to +46 °C, and the storage temperature range is –40 °C to +55 °C. For optimal equipment life, the temperature should not exceed 35 °C annual average, and the environment should not exceed Pollution Degree 2 as defined in UL 61010-1

### Controller

- Visual indication of incorrect CT polarity
- Digital display of power factor and number of energized stages
- Automatic setting of c/k value (sensitivity based on CT ratio and kvar available)
- Visual indication of insufficient kvar to reach target power factor
- Automatic sensing of kvar values per step
- Optional communications capable controller (RS-485/Modbus)
- Standard metering capability:
  - Voltage
  - Current (sensed phase only)
  - Frequency
  - Active power (kW)
  - Reactive power (kvar)
  - Apparent power (kVA)
  - Total voltage harmonic distortion (VTHD)
  - Individual harmonic voltage distortion (odd orders up to the 19th harmonic)
- Built-in manual mode allows for testing and manual operation of stages
- Multiple user-friendly alarm displays. Controller provides easy-to-understand alarms for various conditions, such as:
  - Undervoltage or overvoltage
  - Undercurrent or overcurrent
  - Target power factor not met
  - Harmonic overload
  - Faulty step/stages
  - Overtemperature alarm

## Contactor

- Fully rated for capacitor switching
- Integral pre-charge/pre-insertion module standard. The contactor reduces damaging switching transients, providing safety and durability for the system
  - Lessens the chance of disrupting sensitive electronic equipment
  - Reduced inrush current extends the life of the capacitor cells

## Additional Features

- Optional molded-case main circuit breaker
- Ground fault interruption provides protection in case of accidental contact with control power and ground
- Control wiring—standard NEC color-coded modular bundles with quick disconnect feature for ease of trouble-shooting or ease of expendability. UL type MTW/AWM, CSA TEW 105 °C copper wire is standard
- Optional digital metering—IQ 250
- Mechanical wire lugs are included as standard equipment. Typical phase lugs range from (2) 6 AWG–350 kcmil to (4) 3 AWG–750 kcmil. Typical ground lug can accept wire from 6 AWG to 350 kcmil. Lugs are compatible with copper wire 90 °C
- Heavy-duty capacitor cells are standard on AUTOVAR detuned filter and optional on AUTOVAR 600. For 480 V units, standard-duty cells are 525 V rated, and heavy-duty cells are 600 V rated

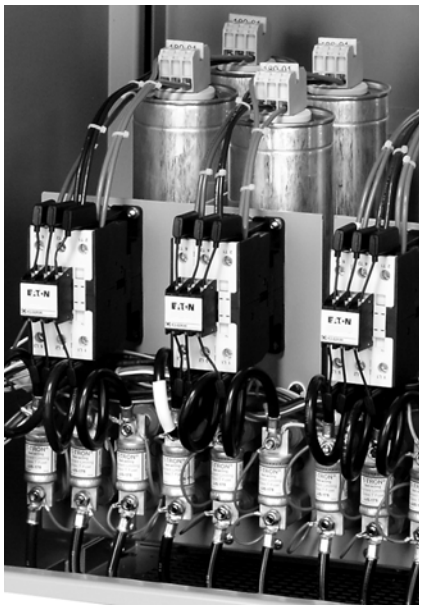
## Support and Service

- Renewal parts are available through local Eaton distributors
- Factory trained service personnel are available through Eaton's Electrical Services & Systems

*AUTOVAR 600—Interior View*

## Standards and Certifications

- AUTOVAR 600—UL and CSA listed
- Contactor—UL/CSA recognized; IEC 6b rated
- Entire cabinet assembly is UL 508A and CSA C22.2 No. 190 Listed
- Capacitors are UL 810 recognized



*Modular Step Nest Assembly*

*Bottom Entry Location*

*Factory Pre-Wired for Future Expansion*

# Technical Data and Specifications

**Table 35.2-4. AUTOVAR 600 Floor-Mounted Switched Capacitor Bank—Low Voltage Applications**

| kvar | Step x kvar | Rated Current (Amperes) | Enclosure Size ① | | Base Shipping Weight in Lb (kg) | Base Catalog Number |
|---|---|---|---|---|---|---|
| | | | NEMA 1, without Main Breaker, No Suffix | NEMA 1, with Main Breaker, M Suffix | | |
| **240 Vac** | | | | | | |
| 75 | 3 x 25 | 180 | L | L | 644 (292.4) | **75TPCSR231** |
| 100 | 4 x 25 | 240 | L | L | 692 (314.2) | **100TPCSR231** |
| 125 | 5 x 25 | 300 | L | L | 740 (336.0) | **125TPCSR231** |
| 150 | 6 x 25 | 361 | L | L | 788 (357.8) | **150TPCSR231** |
| 200 | 8 x 25 | 481 | L | L | 884 (401.3) | **200TPCSR231** |
| 250 | 10 x 25 | 600 | L | L | 944 (428.6) | **250TPCSR231** |
| 300 | 12 x 25 | 720 | L | L | 1022 (464.0) | **300TPCSR231** |
| 350 | 7 x 50 | 844 | KK | KK | 1616 (734.0) | **350TPCSR231** |
| 400 | 8 x 50 | 965 | KK | C/F | 1704 (774.0) | **400TPCSR231** |
| **480 Vac** | | | | | | |
| 100 | 2 x 50 | 120 | L | L | 588 (266.7) | **100TPCSR431** |
| 150 | 3 x 50 | 180 | L | L | 632 (287.0) | **150TPCSR431** |
| 200 | 4 x 50 | 240 | L | L | 676 (306.9) | **200TPCSR431** |
| 250 | 5 x 50 | 300 | L | L | 720 (326.9) | **250TPCSR431** |
| 300 | 6 x 50 | 360 | L | L | 764 (346.9) | **300TPCSR431** |
| 350 | 7 x 50 | 420 | L | L | 808 (366.8) | **350TPCSR431** |
| 400 | 8 x 50 | 480 | L | L | 852 (386.8) | **400TPCSR431** |
| 450 | 9 x 50 | 540 | L | L | 896 (406.8) | **450TPCSR431** |
| 500 | 10 x 50 | 600 | L | L | 944 (428.6) | **500TPCSR431** |
| 550 | 11 x 50 | 660 | L | L | 984 (446.7) | **550TPCSR431** |
| 600 | 12 x 50 | 720 | L | L | 1022 (464.0) | **600TPCSR431** |
| 660 | 11 x 60 | 792 | L | L | 1010 (458.5) | **660TPCSR431** |
| 700 | 7 x 100 | 840 | L | KK | 1616 (734.0) | **700TPCSR431** |
| 720 | 12 x 60 | 864 | L | L | 1050 (476.7) | **720TPCSR431** |
| 800 | 8 x 100 | 960 | KK | C/F | 1704 (774.0) | **800TPCSR431** |
| 900 | 9 x 100 | 1080 | KK | C/F | 1792 (814.0) | **900TPCSR431** |
| 1000 | 10 x 100 | 1200 | KK | C/F | 1888 (857.0) | **1000TPCSR431** |
| 1100 | 11 x 100 | 1320 | KK | C/F | 1966 (893.0) | **1100TPCSR431** |
| 1200 | 12 x 100 | 1440 | KK | C/F | 2044 (928.0) | **1200TPCSR431** |
| **600 Vac** | | | | | | |
| 100 | 2 x 50 | 46 | L | L | 588 (266.7) | **100TPCSR631** |
| 150 | 3 x 50 | 144 | L | L | 632 (287.0) | **150TPCSR631** |
| 200 | 4 x 50 | 192 | L | L | 676 (306.9) | **200TPCSR631** |
| 250 | 5 x 50 | 240 | L | L | 720 (326.9) | **250TPCSR631** |
| 300 | 6 x 50 | 288 | L | L | 764 (346.9) | **300TPCSR631** |
| 350 | 7 x 50 | 336 | L | L | 808 (366.8) | **350TPCSR631** |
| 400 | 8 x 50 | 384 | L | L | 852 (386.8) | **400TPCSR631** |
| 450 | 9 x 50 | 432 | L | L | 896 (406.8) | **450TPCSR631** |
| 500 | 10 x 50 | 480 | L | L | 944 (428.6) | **500TPCSR631** |
| 550 | 11 x 60 | 528 | L | L | 984 (446.7) | **550TPCSR631** |
| 600 | 12 x 50 | 576 | L | L | 1022 (464.0) | **600TPCSR631** |
| 660 | 11 x 60 | 634 | L | L | 1010 (458.5) | **660TPCSR631** |
| 700 | 7 x 100 | 672 | L | KK | 1616 (734.0) | **700TPCSR631** |
| 720 | 12 x 60 | 692 | L | L | 1050 (476.7) | **720TPCSR631** |
| 800 | 8 x 100 | 768 | KK | KK | 1704 (774.0) | **800TPCSR631** |
| 900 | 9 x 100 | 864 | KK | KK | 1792 (814.0) | **900TPCSR631** |
| 1000 | 10 x 100 | 960 | KK | C/F | 1888 (857.0) | **1000TPCSR631** |
| 1100 | 11 x 100 | 1056 | KK | C/F | 1966 (893.0) | **1100TPCSR631** |
| 1200 | 12 x 100 | 1152 | KK | C/F | 2044 (928.0) | **1200TPCSR631** |

① Enclosure sizing for units with integrated surge protection or bottom entry can vary and may not be available on all kvar sizes. Contact Eaton's Technical Resource Center at 1-800-809-2772, choose option #4, then option #2.
C/F = Consult factory

**Table 35.2-5. AUTOVAR 600 Floor-Mounted Switched Capacitor Banks Units with Heavy-Duty Cells—Low Voltage Applications**

| kvar | Step x kvar | Rated Current Amperes | Enclosure Size ① | | | | Base Shipping Weight in Lb (kg) | Base Catalog Number (NEMA 1, no options) |
|---|---|---|---|---|---|---|---|---|
| | | | NEMA 1, without Main Breaker, No Suffix | NEMA 1, with Main Breaker, M Suffix | NEMA 3R, without Main Breaker, W Suffix | NEMA 1, with Main Breaker, MW Suffix | | |
| **240 Vac** | | | | | | | | |
| 75 | 3 x 25 | 180 | L | L | L | L | 659 (298.9) | **75TPHSR231** |
| 100 | 4 x 25 | 240 | L | L | L | L | 712 (323.0) | **100TPHSR231** |
| 125 | 5 x 25 | 300 | L | L | L | L | 765 (347.0) | **125TPHSR231** |
| 150 | 6 x 25 | 361 | L | L | L | L | 818 (371.0) | **150TPHSR231** |
| 200 | 8 x 25 | 481 | L | L | L | L | 924 (419.1) | **200TPHSR231** |
| 250 | 10 x 25 | 601 | L | L | L | L | 994 (450.9) | **250TPHSR231** |
| 300 | 12 x 25 | 720 | L | L | L | L | 1082 (490.8) | **300TPHSR231** |
| 350 | 7 x 50 | 844 | L | KK | KK | KK | 1686 (764.8) | **350TPHSR231** |
| 400 | 8 x 50 | 965 | KK | C/F | KK | C/F | 1784 (809.2) | **400TPHSR231** |
| **480 Vac** | | | | | | | | |
| 100 | 2 x 50 | 120 | L | L | L | L | 617 (279.9) | **100TPHSR431** |
| 150 | 3 x 50 | 180 | L | L | L | L | 677 (307.1) | **150TPHSR431** |
| 200 | 4 x 50 | 240 | L | L | L | L | 736 (333.8) | **200TPHSR431** |
| 250 | 5 x 50 | 300 | L | L | L | L | 795 (360.6) | **250TPHSR431** |
| 300 | 6 x 50 | 360 | L | L | L | L | 854 (387.4) | **300TPHSR431** |
| 350 | 7 x 50 | 420 | L | L | L | L | 913 (414.1) | **350TPHSR431** |
| 400 | 8 x 50 | 480 | L | L | L | L | 972 (440.9) | **400TPHSR431** |
| 450 | 9 x 50 | 540 | L | L | L | L | 1031 (467.7) | **450TPHSR431** |
| 500 | 10 x 50 | 600 | L | L | L | L | 1094 (496.2) | **500TPHSR431** |
| 550 | 11 x 50 | 660 | L | L | L | L | 1149 (521.2) | **550TPHSR431** |
| 600 | 12 x 50 | 720 | L | L | L | L | 1202 (545.2) | **600TPHSR431** |
| 700 | 14 x 50 | 792 | L | KK | KK | KK | 1826 (828.3) | **700TPHSR431** |
| 800 | 8 x 100 | 462 | KK | C/F | KK | C/F | 1944 (881.8) | **800TPHSR431** |
| 900 | 9 x 100 | 1083 | KK | C/F | KK | C/F | 2062 (935.3) | **900TPHSR431** |
| 1000 | 10 x 100 | 1203 | KK | C/F | KK | C/F | 2198 (997.0) | **1000TPHSR431** |
| 1100 | 11 x 100 | 1323 | KK | C/F | KK | C/F | 2296 (1041.4) | **1100TPHSR431** |
| 1200 | 12 x 100 | 1443 | KK | C/F | KK | C/F | 2404 (1090.4) | **1200TPHSR431** |
| **600 Vac** | | | | | | | | |
| 100 | 2 x 50 | 96 | L | L | L | L | 617 (279.9) | **100TPHSR631** |
| 150 | 3 x 50 | 144 | L | L | L | L | 677 (307.1) | **150TPHSR631** |
| 200 | 4 x 50 | 192 | L | L | L | L | 736 (333.8) | **200TPHSR631** |
| 250 | 5 x 50 | 240 | L | L | L | L | 795 (360.6) | **250TPHSR631** |
| 300 | 6 x 50 | 288 | L | L | L | L | 854 (387.4) | **300TPHSR631** |
| 350 | 7 x 50 | 336 | L | L | L | L | 913 (414.1) | **350TPHSR631** |
| 400 | 8 x 50 | 384 | L | L | L | L | 972 (440.9) | **400TPHSR631** |
| 450 | 9 x 50 | 432 | L | L | L | L | 1031 (467.7) | **450TPHSR631** |
| 500 | 10 x 50 | 480 | L | L | L | L | 1094 (496.2) | **500TPHSR631** |
| 550 | 11 x 60 | 529 | L | L | L | L | 1149 (521.2) | **550TPHSR631** |
| 600 | 12 x 50 | 576 | L | L | L | L | 1202 (545.2) | **600TPHSR631** |
| 700 | 7 x 100 | 672 | L | KK | KK | KK | 1826 (828.3) | **700TPHSR631** |
| 800 | 8 x 100 | 768 | KK | KK | KK | KK | 1944 (881.8) | **800TPHSR631** |
| 900 | 9 x 100 | 864 | KK | KK | KK | KK | 2062 (935.3) | **900TPHSR631** |
| 1000 | 10 x 100 | 962 | KK | C/F | KK | C/F | 2198 (997.0) | **1000TPHSR631** |
| 1100 | 11 x 100 | 1058 | KK | C/F | KK | C/F | 2296 (1041.4) | **1100TPHSR631** |
| 1200 | 12 x 100 | 1155 | KK | C/F | KK | C/F | 2404 (1090.4) | **1200TPHSR631** |

① Enclosure sizing for units with integrated surge protection or bottom entry can vary and may not be available on all kvar sizes. Contact Eaton's Technical Resource Center at 1-800-809-2772, choose option #4, then option #2.
C/F = Consult factory

**Table 35.2-6. Options—AUTOVAR 600 and AUTOVAR Detuned Filters**

| Description | Option Code |
|---|---|
| Remote alarm relay terminal block—relay terminal block for a remote alarm to indicate controller alarm status | **A** |
| Fully insulated main bus | **B** |
| Communicating PF controller (Modbus RS-485) | **C** |
| Hand-off-auto switch provides manual control to connect or disconnect capacitor stages regardless of controller output ① | **H** |
| Integrated main breaker | **M** |
| Integrated main breaker with high interrupting rating (see breaker table for more information), includes 100 kA busbar bracing | **M1** |
| 100 kA busbar bracing | **N1** |
| Integrated CVX series surge protection, without sine wave tracking | **T1** |
| Integrated SPD series surge protection, 160 kA per phase, with sine wave tracking | **T2** |
| IQ 250 electronic meter ② | **Q** |
| Weather-resistant enclosure (NEMA 3R gasketed) ③ | **W** |
| Standard filter detuned to the 4.2nd harmonic ④ | **Y** |

① Manual control is always available through menu controller on system, even if the H option is not selected.

② Not available on NEMA 3R units (W option).

③ Only available on AUTOVAR 600 with heavy-duty cells and AUTOVAR detuned filters using 'L + L', 'L + KK', and 'KK + KK' enclosures.

④ Tuning to the 4.2nd harmonic is the preferred option. Other tunings available. Contact Eaton's Technical Resource Center (TRC) power factor application engineers at 1-800-809-2772, choose option #4, then option #2.

**Note:** Current transformers required for operation of AUTOVAR units. Please see IL157001EN for more information on current transformers.

## Dimensions in Inches (mm)

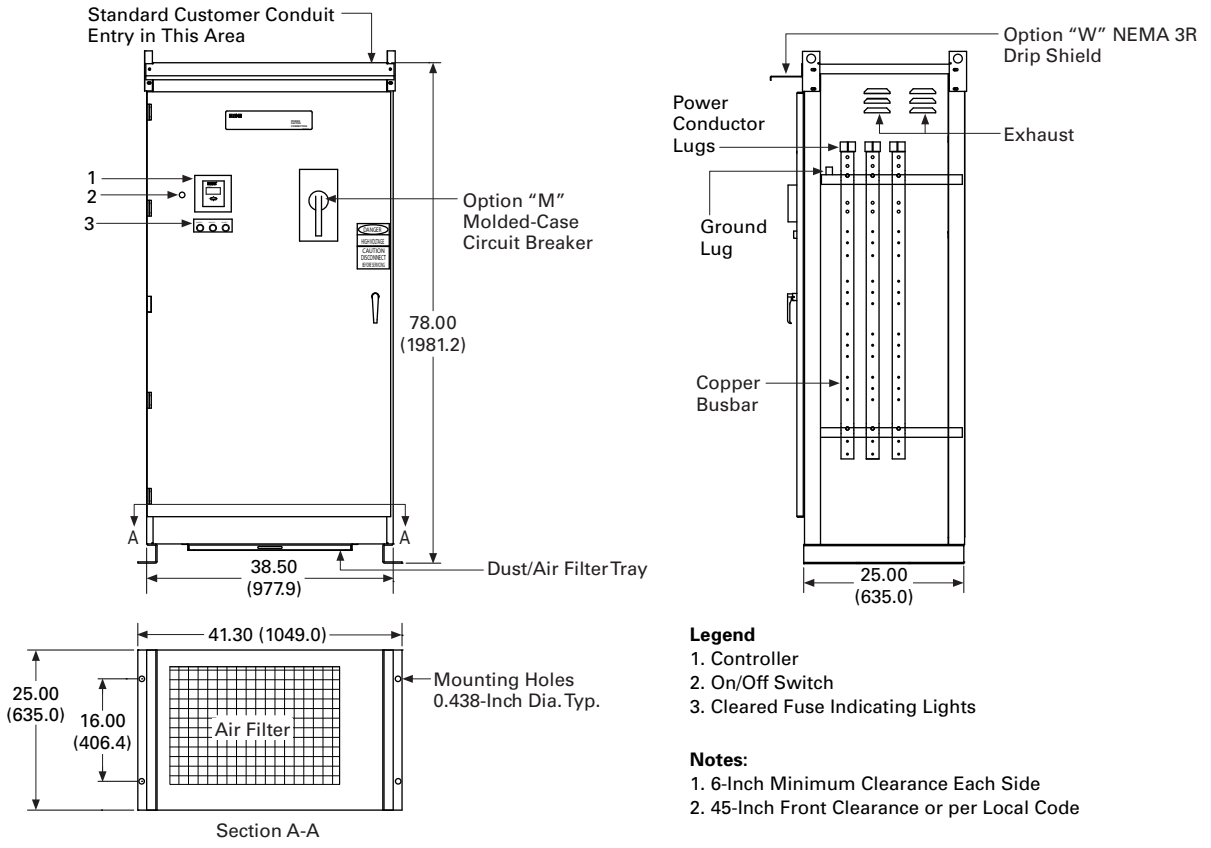



**Figure 35.2-3. AUTOVAR "L" (Single Door) Enclosure**

## Dimensions in Inches (mm)

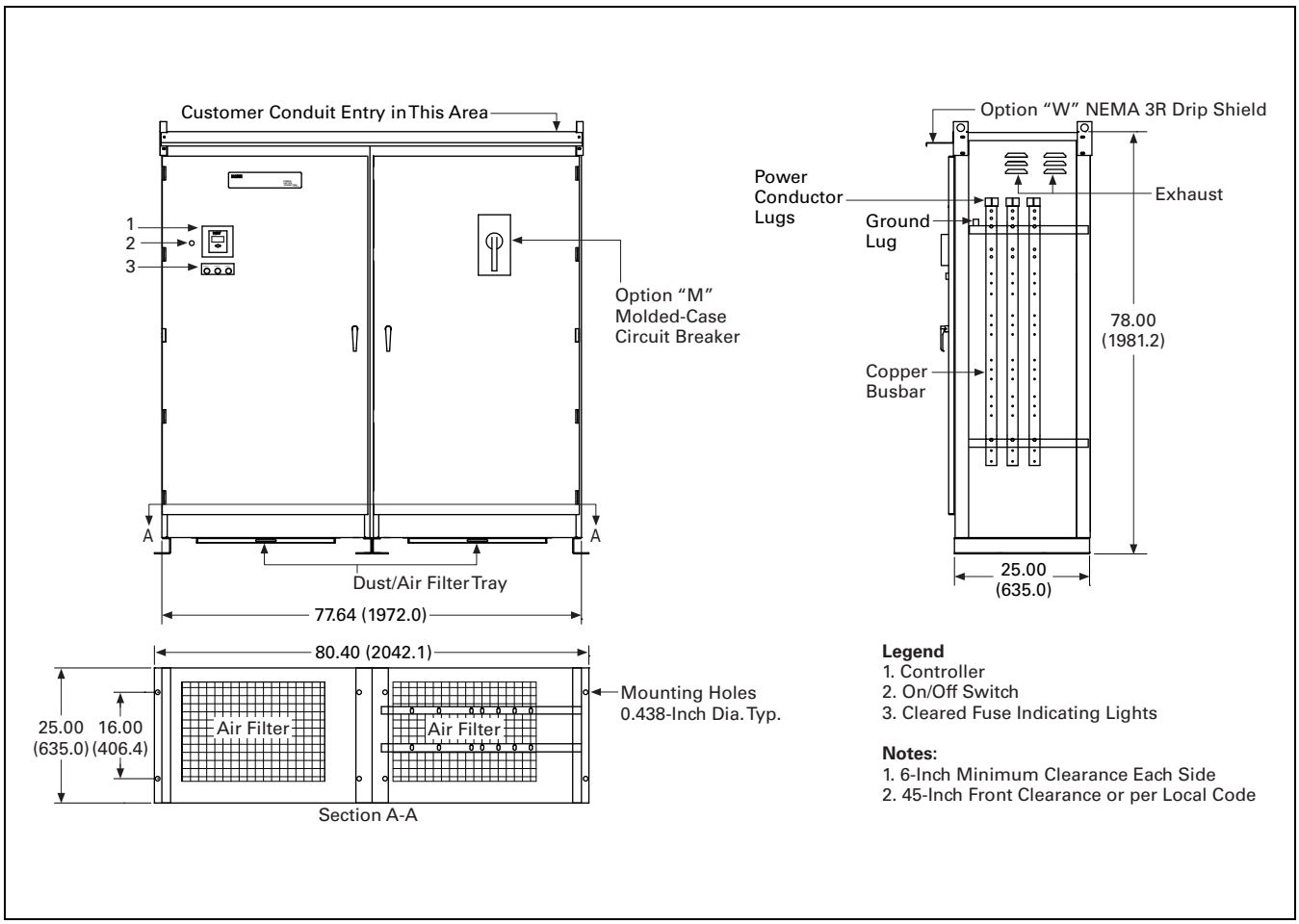



**Figure 35.2-4. AUTOVAR "KK" (One Double Door) Enclosure**

# AUTOVAR Filter—LV Automatic Detuned Filter

*AUTOVAR Filter*

*AUTOVAR Filter—Interior View*

## General Description

- Programmable to automatically add/subtract capacitor stages to maintain preset target power factor
- Three-phase capacitor cell construction
- Five-year warranty of cells against manufacturing defects
- Cool operating, 100% copper wound, thermal-protected reactors are sized up to 150% of rated capacitor current (AUTOVAR detuned filter only)

## Application Description

- Service entrance or substation power factor correction installations requiring precise maintenance of target power factor (AUTOVAR 600)
- Service entrance or substation power factor correction installations requiring precise maintenance of target power factor in three-phase, nonlinear, high harmonic environments (AUTOVAR detuned filter)
- Typically connected at main low voltage switchgear

## Features

### Configuration

- **Cabinet**: 12 gauge steel with ANSI 61 gray, baked finish. Removable lift bolts standard, NEMA 1 (gasketed)
- **Power line interconnect**: Rugged, copper busbar connection with access provided for top entry. Contact factory for availability of bottom entry. Busbars are braced for 65 kA (optional 100 kA rating available). All internal power wiring connections from bus are laid out on a most direct basis with minimum bends for ease of troubleshooting. Clear barrier limiting access to live parts included standard
- **Modular tray design**: Capacitor stages arranged in modular trays with capacitors, fuses, cleared-fuse indicating lights, and contactors grouped in a logical, easily understood layout. This permits easy access, quick identification of operating problems, and ease of expandability
- **Fusing**: UL recognized, 200,000 A interrupting capacity provided on all three phases of each stage. Blade-type fuses mounted on insulator stand-offs
- **Cleared-fuse indicating lights**: LEDs located door-mounted and neon at individual fuses to facilitate tracing of cleared fuses
- **Push-to-test**: Allows testing of door-mounted LED cleared fuse indicating lights
- **AutoLocate**: When door is open and bus is energized, fuse circuit automatically checks for cleared fuses. If a fuse has cleared, the light at the fuse turns on for easy troubleshooting
- **Door interlock**: Door interlock automatically turns off control circuit when engaged. Power continues to be provided to the unit until disconnect is open
- **Exhaust fans**: Two side louver fans per cabinet provide cooling and reduce operator exposure to discharge. Replaceable dust filtering provided. Dust filters can be replaced without opening cabinet
- **Ease of expansion**: Capacitor stage nests are self-contained and can be added in the field. Two bolts mount the nest in the field. Control wire plugs connect to factory standard wire harness on the left side of the cabinet

- **Ease of replacement**: Cells can be easily replaced individually by removing the mounting bolt and lifting out of the nest without removal of any other components
- **Thermal sensing**: Built-in thermal sensing, alarming, and protection feature allows the unit to operate in optimal temperature while alerting the user of ambient temperature exceeding the nominal operating range. Stages will be automatically switched off if temperature exceeds the maximum specified temperature
- **Temperature range**: The operating temperature range is –20 °C to +46 °C, and the storage temperature range is –40 °C to +55 °C. For optimal equipment life, the temperature should not exceed 35 °C annual average, and the environment should not exceed Pollution Degree 2 as defined in UL 61010-1

## Controller

- Visual indication of incorrect CT polarity
- Digital display of power factor and number of energized stages
- Automatic setting of c/k value (sensitivity based on CT ratio and kvar available)
- Visual indication of insufficient kvar to reach target power factor
- Automatic sensing of kvar values per step
- Optional communications capable controller (RS-485/Modbus)
- Standard metering capability:
  - Voltage
  - Current (sensed phase only)
  - Frequency
  - Active power (kW)
  - Reactive power (kvar)
  - Apparent power (kVA)
  - Total voltage harmonic distortion (VTHD)
  - Individual harmonic voltage distortion (odd orders up to the 19th harmonic)
- Built-in manual mode allows for testing and manual operation of stages
- Multiple user-friendly alarm displays. Controller provides easy-to-understand alarms for various conditions, such as:
  - Undervoltage or overvoltage
  - Undercurrent or overcurrent
  - Target power factor not met
  - Harmonic overload
  - Faulty step/stages
  - Overtemperature alarm

## Contactor

- Fully rated for capacitor switching
- Integral pre-charge/pre-insertion module standard. The contactor reduces damaging switching transients, providing safety and durability for the system
  - Lessens the chance of disrupting sensitive electronic equipment
  - Reduced inrush current extends the life of the capacitor cells

## Reactors

- **Tuning**: Standard reactor designs are detuned to the 4.2nd harmonic and recommended to protect capacitors against harmonic resonance. Detuning to the 4.7th harmonic is available as an option. The harmonic spectrum should be evaluated for applications involving reactors detuned to the 4.7th harmonic to ensure optimal equipment life, specifically when used in conjunction with six-pulse motor drives
- **Windings**: 80 °C temperature rise design 100% copper windings for minimal losses
- **Thermal overload protection**: Each reactor includes three normally closed, auto reset thermostats that open at 180 °C. When thermostats engage, the contactor opens
- **Insulation**: 220 °C insulation system
- **Warranty**: One-year replacement of reactors

## Additional Features

- Optional molded-case main circuit breaker
- Ground fault interruption provides protection in case of accidental contact with control power and ground
- Control wiring—standard NEC color-coded modular bundles with quick disconnect feature for ease of trouble-shooting or ease of expendability. UL type MTW/AWM, CSA TEW 105 °C copper wire is standard
- Optional digital metering—IQ 250
- Mechanical wire lugs are included as standard equipment. Typical phase lugs range from (2) 6 AWG–350 kcmil to (4) 3 AWG–750 kcmil. Typical ground lug can accept wire from 6 AWG to 350 kcmil. Lugs are compatible with copper wire 90 °C
- Heavy-duty capacitor cells are standard on AUTOVAR detuned filter and optional on AUTOVAR 600. For 480 V units, standard-duty cells are 525 V rated, and heavy-duty cells are 600 V rated

## Support and Service

- Renewal parts are available through local Eaton distributors
- Factory trained service personnel are available through Eaton's Electrical Services & Systems

# Standards and Certifications

- AUTOVAR filter—UL and CSA listed
- Contactor—UL/CSA recognized; IEC 6b rated
- Entire cabinet assembly is UL 508A and CSA C22.2 No. 190 Listed
- Capacitors are UL 810 recognized

*AUTOVAR Filter—Reactor Cabinet*

35

## Technical Data and Specifications

**Table 35.2-7. Floor-Mounted Switched Detuned Filters—Low Voltage**

| kvar | Step x kvar | Rated Current Amperes | Enclosure Size ① | | | | Base Shipping Weight in Lb (kg) | Base Catalog Number (NEMA 1, no options) |
|---|---|---|---|---|---|---|---|---|
| | | | NEMA 1 without Main Breaker, No Suffix | NEMA 1 with Main Breaker, M Suffix | NEMA 3R without Main Breaker, W Suffix | NEMA 3R with Main Breaker, MW Suffix | | |
| **240 Vac** | | | | | | | | |
| 150 | 6 x 25 | 361 | L + L ② | L + L ② | L + L ② | L + L ② | 1830 (830.8) | **150THFSR232Y** |
| 200 | 8 x 25 | 481 | L + L ② | L + L ② | L + L ② | L + L ② | 2222 (1008.8 | **200THFSR232Y** |
| 250 | 10 x 25 | 601 | L + L ② | L + L ② | L + L ② | L + L ② | 2525 (1146.4) | **250THFSR232Y** |
| 300 | 12 x 25 | 720 | L + L ② | KK | L + L ② | KK | 2830 (1284.8) | **300THFSR232Y** |
| 350 | 7 x 50 | 844 | KK | KK | L + KK | L + KK | 3090 (1401.6) | **350THFSR231Y** |
| 400 | 8 x 50 | 965 | L + KK ② | C/F | L + KK ② | C/F | 3560 (1614.8) | **400THFSR232Y** |
| **480 Vac** | | | | | | | | |
| 100 | 2 x 50 | 120 | L | L | L + L ② | L + L ② | 1105 (501.2) | **100THFSRY31Y** |
| 150 | 3 x 50 | 180 | L | L | L + L ② | L + L ② | 1242 (564.6) | **150THFSR431Y** |
| 200 | 4 x 50 | 240 | L | L | L + L ② | L + L ② | 1438 (652.9) | **200THFSR431Y** |
| 250 | 5 x 50 | 300 | L | L + L ② | L + L ② | L + L ② | 1634 (741.8) | **250THFSR431Y** |
| 300 | 6 x 50 | 360 | L + L ② | L + L ② | L + L ② | L + L ② | 1830 (830.8) | **300THFSR432Y** |
| 350 | 7 x 50 | 420 | L + L ② | L + L ② | L + L ② | L + L ② | 2026 (919.8) | **350THFSR432Y** |
| 400 | 8 x 50 | 480 | L + L ② | L + L ② | L + L ② | L + L ② | 2222 (1008.8) | **400THFSR432Y** |
| 450 | 9 x 50 | 540 | L + L ② | L + L ② | L + L ② | L + L ② | 2371 (1076.4) | **450THFSR432Y** |
| 500 | 10 x 50 | 600 | L + L ② | L + L ② | L + L ② | L + L ② | 2525 (1146.4) | **500THFSR432Y** |
| 550 | 11 x 50 | 660 | L + L ② | KK | L + L ② | L + KK ② | 2750 (1248.5) | **550THFSR432Y** |
| 600 | 12 x 50 | 720 | L + L ② | KK | L + L ② | L + KK ② | 2830 (1284.8) | **600THFSR432Y** |
| 700 | 7 x 100 | 792 | KK | KK | L + KK ② | L + KK ② | 3090 (1401.6) | **700THFSR431Y** |
| 800 | 8 x 100 | 962 | L + KK ② | C/F | L + KK ② | C/F | 3560 (1614.8) | **800THFSR432Y** |
| 900 | 9 x 100 | 1083 | KK + KK ② | C/F | KK + KK ② | C/F | 3900 (1769.0) | **900THFSR432Y** |
| 1000 | 10 x 100 | 1203 | KK + KK ② | C/F | KK + KK ② | C/F | 4240 (1923.2) | **1000THFSR432Y** |
| 1100 | 11 x 100 | 1323 | KK + KK ② | C/F | KK + KK ② | C/F | 4500 (2041.2) | **1100THFSR432Y** |
| **600 Vac** | | | | | | | | |
| 100 | 2 x 50 | 96 | L | L | L + L ② | L + L ② | 1105 (501.2) | **100THFSR631Y** |
| 150 | 3 x 50 | 144 | L | L | L + L ② | L + L ② | 1242 (564.6) | **150THFSR631Y** |
| 200 | 4 x 50 | 192 | L | L | L + L ② | L + L ② | 1438 (652.9) | **200THFSR631Y** |
| 250 | 5 x 50 | 240 | L | L + L ② | L + L ② | L + L ② | 1634 (741.8) | **250THFSR631Y** |
| 300 | 6 x 50 | 288 | L + L(② | L + L ② | L + L ② | L + L ② | 1830 (830.8) | **300THFSR632Y** |
| 350 | 7 x 50 | 336 | L + L ② | L + L ② | L + L ② | L + L ② | 2026 (919.8) | **350THFSR632Y** |
| 400 | 8 x 50 | 384 | L + L ② | L + L ② | L + L ② | L + L ② | 2222 (1008.8) | **400THFSR632Y** |
| 450 | 9 x 50 | 432 | L + L ② | L + L ② | L + L ② | L + L ② | 2371 (1076.4) | **450THFSR632Y** |
| 500 | 10 x 50 | 480 | L + L ② | L + L ② | L + L ② | L + L ② | 2525 (1146.4) | **500THFSR632Y** |
| 550 | 11 x 50 | 529 | L + L ② | KK | L + L ② | L + KK ② | 2750 (1248.5) | **550THFSR632Y** |
| 600 | 12 x 50 | 576 | L + L ② | KK | L + L ② | L + KK ② | 2830 (1284.8) | **600THFSR632Y** |
| 700 | 7 x 100 | 672 | KK | KK | L + KK ② | L + KK ② | 3090 (1401.6) | **700THFSR631Y** |
| 800 | 8 x 100 | 768 | L + KK ② | L + KK ② | L + KK ② | L + KK ② | 3560 (1614.8) | **800THFSR632Y** |
| 900 | 9 x 100 | 864 | KK + KK ② | KK + KK ② | KK + KK ② | KK + KK ② | 3900 (1769.0) | **900THFSR632Y** |
| 1000 | 10 x 100 | 962 | KK + KK ② | C/F | KK + KK ② | C/F | 4240 (1923.2) | **1000THFSR632Y** |
| 1100 | 11 x 100 | 1058 | KK + KK ② | C/F | KK + KK ② | C/F | 4500 (2041.2) | **1100THFSR632Y** |

① Enclosure sizing for units with integrated surge protection or bottom entry can vary and may not be available on all kvar sizes. Contact Eaton's Technical Resource Center at 1-800-809-2772, choose option #4, then option #2.

② Dual enclosure design requires customer installation of factory supplied interconnecting wires.
C/F = Consult factory

**Table 35.2-8. Options**

| Description | Option Code |
|---|---|
| Remote alarm relay terminal block | **A** |
| Fully insulated main bus ① | **B** |
| Communicating PF controller (Modbus RS-485) | **C** |
| Hand-off auto switch ② | **H** |
| IQ 250 electronic meter ① | **Q** |
| Integrated main breaker, standard interrupting rating | **M** |
| Integrated main breaker with high interrupting rating, includes 100 kA busbar bracing | **M1** |
| Integrated main breaker with high interrupting rating, includes 100 kA busbar bracing | **M1** |
| 100 kA busbar bracing (calculated per UL 508A) ① | **N1** |
| Integrated CVX series surge protection, without sine wave tracking | **T1** |
| Integrated SPD series surge protection, 160 kA per phase, with sine wave tracking | **T2** |
| NEMA 3R (gasketed) weather-resistant enclosure ③ | **W** |
| Filter detuned to the 4.2nd harmonic (Standard tuning), remove Y from part number for optional detuning to the 4.7th harmonic ④ | **Y** |

① Not available for AUTOVAR 300.
② Manual control is available through menu controller on system, if H option is not selected
③ Only available on AUTOVAR 300, AUTOVAR 600 with heavy-duty cells, and AUTOVAR filters using 'L + L', 'L + KK', and 'KK + KK' enclosures.
④ Applies only to AUTOVAR detuned filter.

**Note:** Please include option codes at the end of the part number in alphabetical order. For example, if you ordered a 350THFSR432Y and added a Main Breaker (M) and Remote Alarm Relay Terminal Block (A), then the part number would be: 350THFSR432AMY. Remember that if you have any 'Special' (S option)—that letter must go at the end. If you would prefer the 4.7th harmonic tuning, do not include the 'Y' in the part number. Other tuning frequencies are available. Contact Eaton's Technical Resource Center (TRC) Power Factor Application Engineers at 1-800-809-2772, choose option #4, then option #2.

**Note:** Current transformers required for operation of AUTOVAR units. Please see IL157001EN for more information on current transformers.

## Dimensions

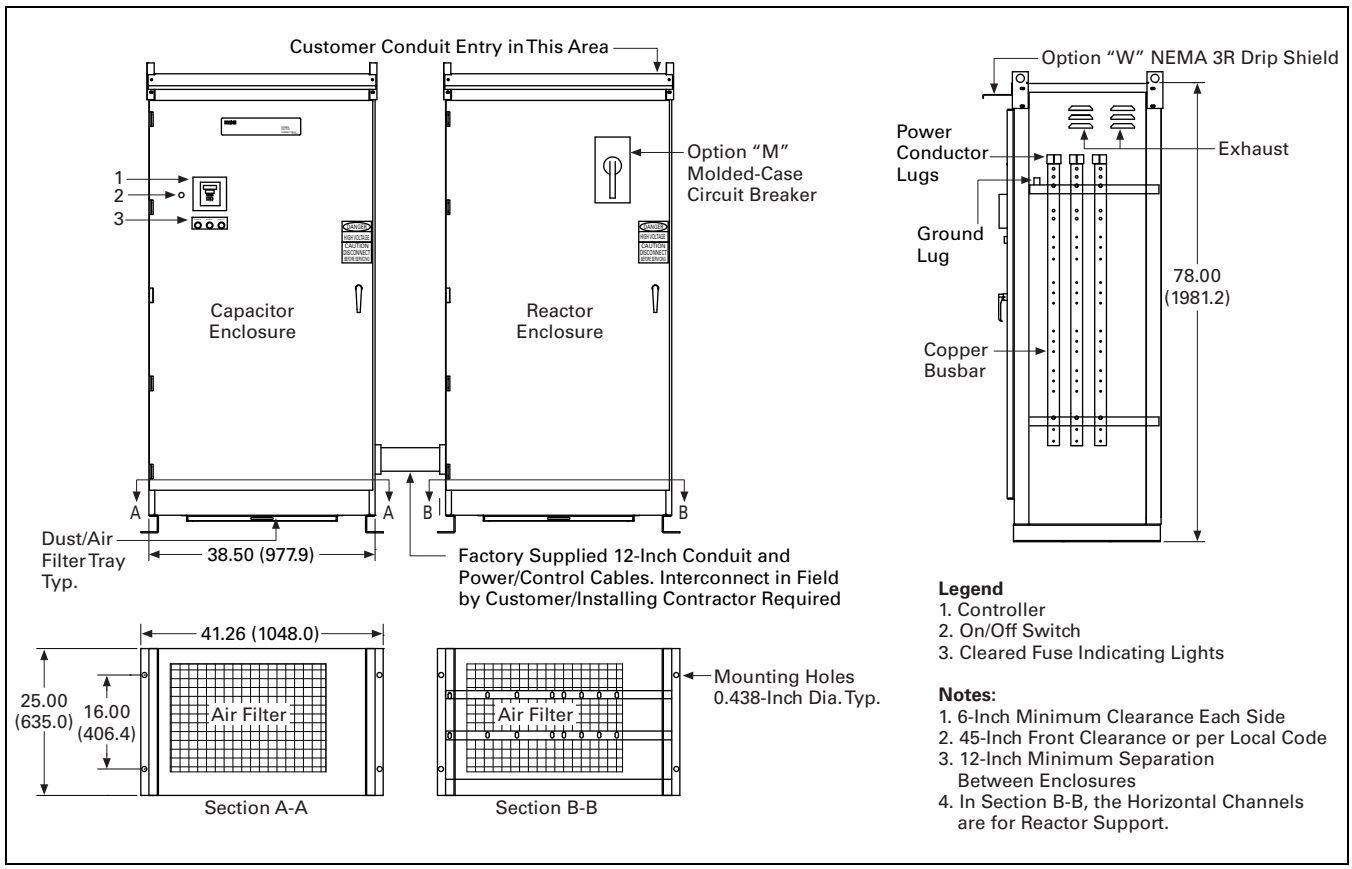



**Figure 35.2-5. AUTOVAR Filter "L + L" (2 Single Door) Enclosures**

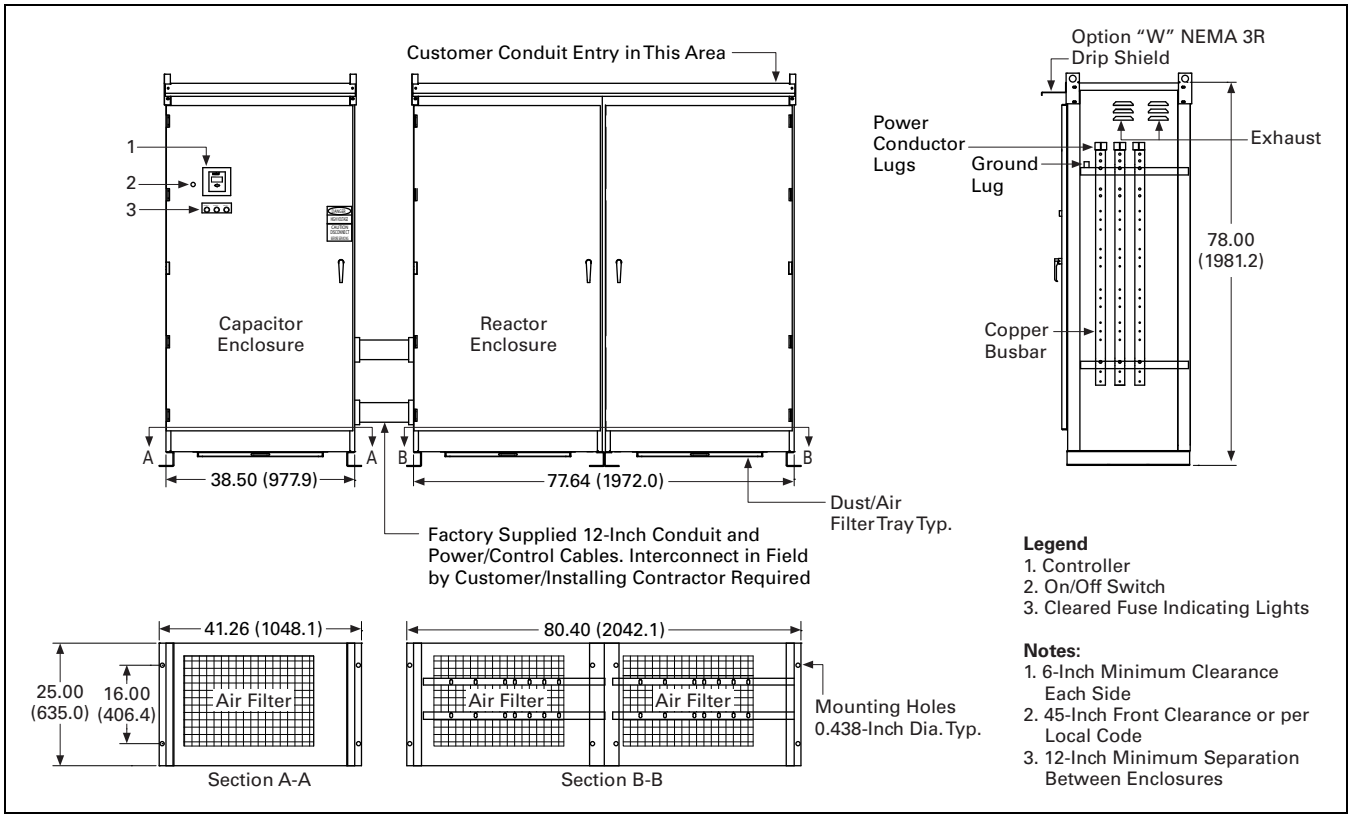



**Figure 35.2-6. "L + KK" Enclosure (AUTOVAR Detuned Filter Only)**

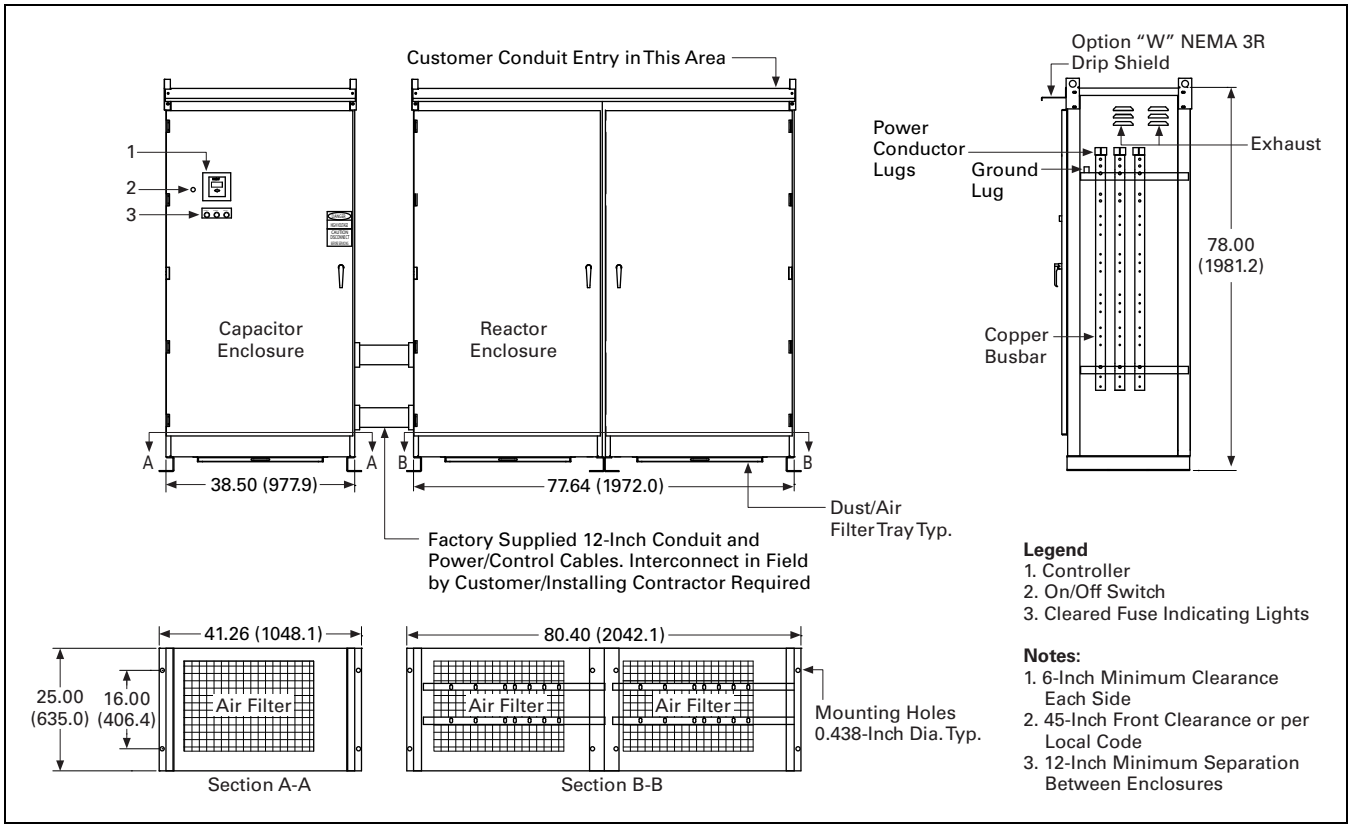



**Figure 35.2-7. AUTOVAR "KK + KK" Enclosures**

**Dimensions**

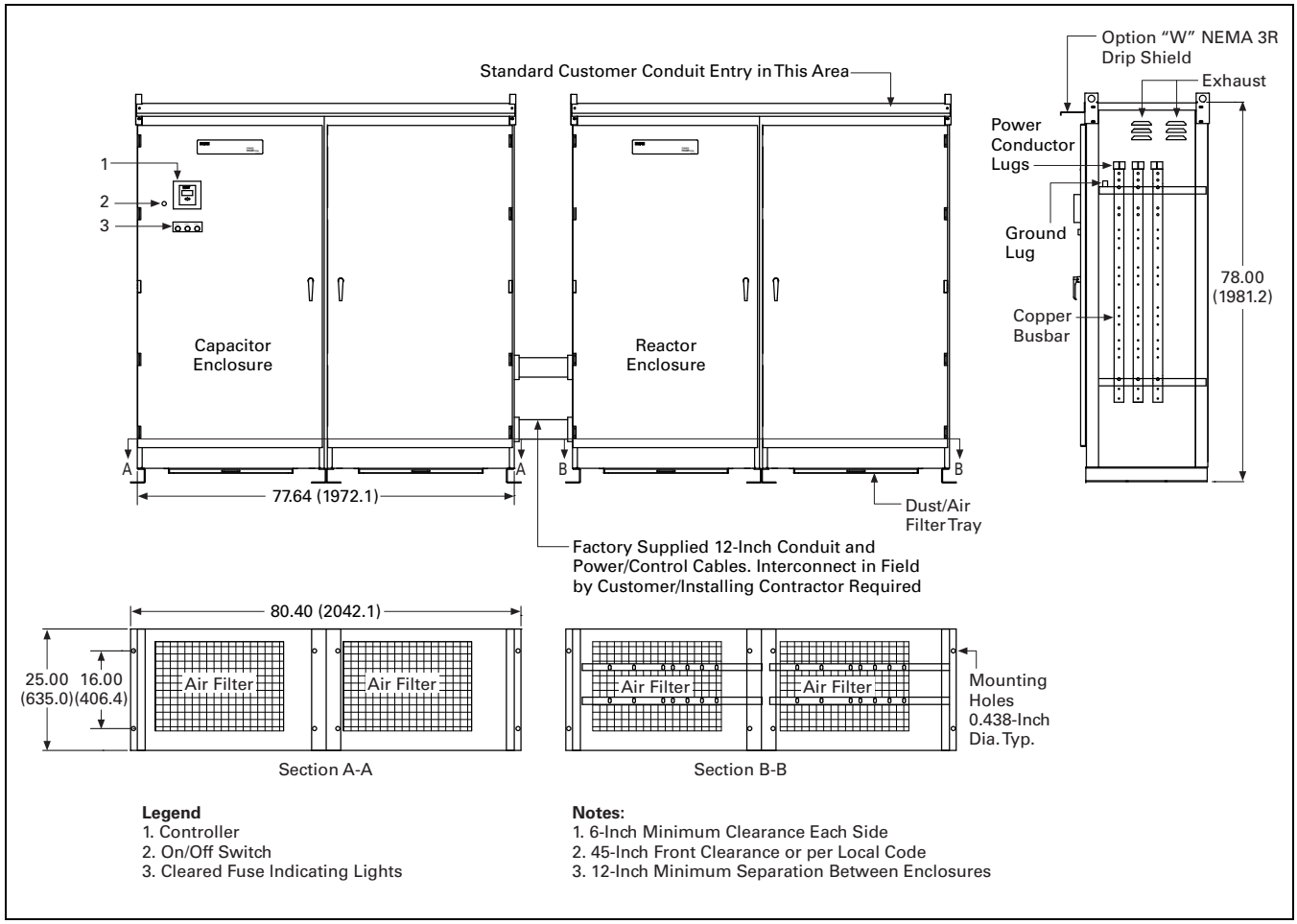



**Figure 35.2-8. AUTOVAR "KK + KK" Enclosures**

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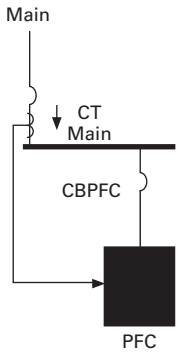
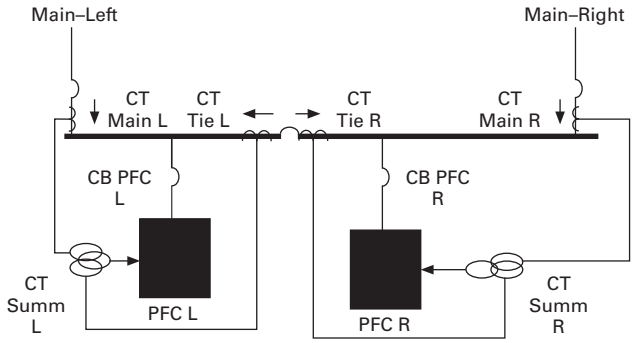


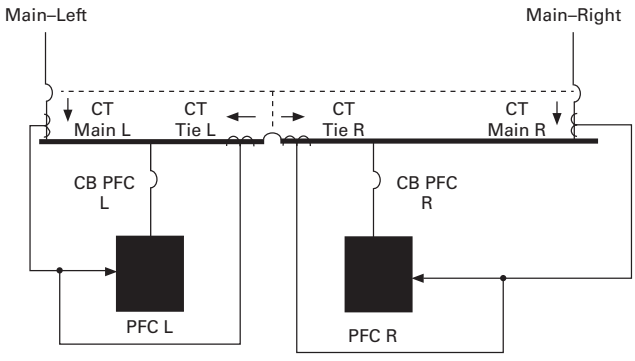

**Note:** Please follow the CT polarities per the arrows. CT should be installed on the A phase.

**Figure 35.2-9. Typical Current Transformer Scheme for Single-Ended Operation**




**Note:** This configuration provides individual PFC operation per side regardless of breaker positions. Please follow the CT polarities per the arrows. CTs should be installed on the A phase.

**Figure 35.2-10. Typical Current Transformer Scheme for Main-Tie-Main Configuration with Parallel Operation**




**Note:** This configuration provides individual PFC operation per side regardless of breaker positions. Please follow the CT polarities per the arrows. CTs should be installed on the A phase.

**Figure 35.2-11. Typical Current Transformer Scheme for Main-Tie-Main Configuration without Parallel Operation**

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# Active Harmonic Filter-Harmonic Correction Unit—NEMA 1 Enclosure Specifications

*Harmonic Correction Units (HCU2)*

## General Description

Eaton's HCU2 active harmonic filters are engineered to provide dynamic harmonic correction by actively injecting the required currents into an electrical distribution system to cancel the entire spectrum of harmonic currents at the point of connection.

## Features and Benefits

### Features

- Fast action
- 380–480 V ±10%, 600 V and 690 V with autotransformer
- 50/60 Hz ±3 Hz frequency
- Operating temperature range 0 °C to +40 °C
- NEMA® 1, NEMA 2, NEMA 12, IP31, IP54, and chassis mount versions available:
  - Wallmount (NEMA 1 designs)
  - Floor-standing (NEMA 2, NEMA 12, IP31 and IP54)
- Output capacity—self limited to 100% rated current
- Corrective capability— <5% TDD and near unity displacement power factor (requires at least 3% series input line reactor ahead of each nonlinear load)
- Color HMI touchscreen display
- Heat losses have been minimized. This results in lower operating costs and reduced requirements for equipment room cooling

### Benefits

- Can be sized to meet specific levels of harmonic correction, providing compliance with IEEE® 519 recommended levels
- Engineered to prevent overloading
- Scalable design can be expanded without impacting performance
- Broad spectrum of cancellation for robust protection (2nd to 51st harmonic)
- Helps improve power factor to maximize efficiency
- Easier and less expensive installation than passive filters, as active filter design reduces the need for detailed engineering studies
- HMI provides comprehensive control through icon-driven interface

## Standards and Certifications

- UL® 508/ CSA® C22.2 No. 14 listed

## Warranty

Standard warranty is 1 year, parts only, against manufacturing defects. Optional 2-year warranty coverage, parts only, against manufacturing defects is included with EESS commissioning, per Eaton Selling Policy 25-000. Optional 3-year warranty is available with EESS commissioning and service agreement.

## Sizing and Product Selection

**Table 35.3-1. Harmonic Correction Units Ratings—NEMA 1 Enclosed—Dimensions in Inches (mm)**

| Voltage | Frequency (Hz) | Total Current Amperes (rms) | Watt Losses (kW) | HCU2 Enclosure Type | Version | Cable Entry | Integral Disconnect | Unit Weight Lb (kg) | Model |
|---|---|---|---|---|---|---|---|---|---|
| 380–480 | 50/60 | 60 | 1.3 | Wallmount NEMA 1 | UL/CSA | Bottom | No | 220 (100) | **HCU2060D5N1** |
| 380–480 | 50/60 | 120 | 2.8 | Wallmount NEMA 1 | UL/CSA | Bottom | No | 268 (122) | **HCU2120D5N1** |
| 380–480 | 50/60 | 200 | 5.4 | Wallmount NEMA 1 | UL/CSA | Bottom | No | 409 (184) | **HCU2200D5N1** |
| 380–480 | 50/60 | 300 | 7.1 | Wallmount NEMA 1 | UL/CSA | Bottom | No | 504 (229) | **HCU2300D5N1** |
| 380–480 | 50/60 | 60 | 1.3 | Chassis mount | UL/CSA | Bottom | No | 198 (90) | **HCU2060D5IP00** |
| 380–480 | 50/60 | 120 | 2.8 | Chassis mount | UL/CSA | Bottom | No | 248 (113) | **HCU2120D5IP00** |
| 380–480 | 50/60 | 200 | 5.4 | Chassis mount | UL/CSA | Bottom | No | 385 (175) | **HCU2200D5IP00** |
| 380–480 | 50/60 | 300 | 7.1 | Chassis mount | UL/CSA | Bottom | No | 484 (220) | **HCU2300D5IP00** |
| 380–480 | 50/60 | 60 | 1.3 | Floor mount IP31 | CE | Top or bottom | Yes | 609 (277) | **HCU2060D5IP31** |
| 380–480 | 50/60 | 120 | 2.8 | Floor mount IP31 | CE | Top or bottom | Yes | 631 (287) | **HCU2120D5IP31** |
| 380–480 | 50/60 | 200 | 5.4 | Floor mount IP31 | CE | Top or bottom | Yes | 873 (397) | **HCU2200D5IP31** |
| 380–480 | 50/60 | 300 | 7.1 | Floor mount IP31 | CE | Top or bottom | Yes | 928 (422) | **HCU2300D5IP31** |
| 380–480 | 50/60 | 60 | 1.3 | Floor mount NEMA 2 | UL/CSA | Top or bottom | Yes | 609 (277) | **HCU2060D5N2** |
| 380–480 | 50/60 | 120 | 2.8 | Floor mount NEMA 2 | UL/CSA | Top or bottom | Yes | 631 (287) | **HCU2120D5N2** |
| 380–480 | 50/60 | 200 | 5.4 | Floor mount NEMA 2 | UL/CSA | Top or bottom | Yes | 873 (397) | **HCU2200D5N2** |
| 380–480 | 50/60 | 300 | 7.1 | Floor mount NEMA 2 | UL/CSA | Top or bottom | Yes | 928 (422) | **HCU2300D5N2** |
| 380–480 | 50/60 | 60 | 1.3 | Floor mount NEMA 12 | UL/CSA | Top or bottom | Yes | 609 (277) | **HCU2060D5N12** |
| 380–480 | 50/60 | 120 | 2.8 | Floor mount NEMA 12 | UL/CSA | Top or bottom | Yes | 631 (287) | **HCU2120D5N12** |
| 380–480 | 50/60 | 200 | 5.4 | Floor mount NEMA 12 | UL/CSA | Top or bottom | Yes | 873 (397) | **HCU2200D5N12** |
| 380–480 | 50/60 | 300 | 7.1 | Floor mount NEMA 12 | UL/CSA | Top or bottom | Yes | 928 (422) | **HCU2300D5N12** |
| 380–480 | 50/60 | 60 | 1.3 | Floor mount IP54 | CE | Top or bottom | Yes | 609 (277) | **HCU2060D5IP54** |
| 380–480 | 50/60 | 120 | 2.8 | Floor mount IP54 | CE | Top or bottom | Yes | 631 (287) | **HCU2120D5IP54** |
| 380–480 | 50/60 | 200 | 5.4 | Floor mount IP54 | CE | Top or bottom | Yes | 873 (397) | **HCU2200D5IP54** |
| 380–480 | 50/60 | 300 | 7.1 | Floor mount IP54 | CE | Top or bottom | Yes | 928 (422) | **HCU2300D5IP54** |
| 600 | 50/60 | 47 | 1.8 | Floor mount IP31 | CE | Top or bottom | Yes | 1012 (460) | **HCU2047D6IP31** |
| 600 | 50/60 | 94 | 3.9 | Floor mount IP31 | CE | Top or bottom | Yes | 1096 (498) | **HCU2094D6IP31** |
| 600 | 50/60 | 157 | 7.2 | Floor mount IP31 | CE | Top or bottom | Yes | 1437 (653) | **HCU2157D6IP31** |
| 600 | 50/60 | 235 | 9.9 | Floor mount IP31 | CE | Top or bottom | Yes | 1665 (757) | **HCU2235D6IP31** |
| 600 | 50/60 | 47 | 1.8 | Floor mount NEMA 2 | UL/CSA | Top or bottom | Yes | 1012 (460) | **HCU2047D6N2** |
| 600 | 50/60 | 94 | 3.9 | Floor mount NEMA 2 | UL/CSA | Top or bottom | Yes | 1096 (498) | **HCU2094D6N2** |
| 600 | 50/60 | 157 | 7.2 | Floor mount NEMA 2 | UL/CSA | Top or bottom | Yes | 1437 (653) | **HCU2157D6N2** |
| 600 | 50/60 | 235 | 9.9 | Floor mount NEMA 2 | UL/CSA | Top or bottom | Yes | 1665 (757) | **HCU2235D6N2** |
| 600 | 50/60 | 47 | 1.8 | Floor mount IP54 | CE | Top or bottom | Yes | 1036 (471) | **HCU2047D6IP54** |
| 600 | 50/60 | 94 | 3.9 | Floor mount IP54 | CE | Top or bottom | Yes | 1115 (507) | **HCU2094D6IP54** |
| 600 | 50/60 | 157 | 7.2 | Floor mount IP54 | CE | Top or bottom | Yes | 1485 (675) | **HCU2157D6IP54** |
| 600 | 50/60 | 235 | 9.9 | Floor mount IP54 | CE | Top or bottom | Yes | 1694 (770) | **HCU2235D6IP54** |
| 600 | 50/60 | 47 | 1.8 | Floor mount NEMA 12 | UL/CSA | Top or bottom | Yes | 1036 (471) | **HCU2047D6N12** |
| 600 | 50/60 | 94 | 3.9 | Floor mount NEMA 12 | UL/CSA | Top or bottom | Yes | 1115 (507) | **HCU2094D6N12** |
| 600 | 50/60 | 157 | 7.2 | Floor mount NEMA 12 | UL/CSA | Top or bottom | Yes | 1485 (675) | **HCU2157D6N12** |
| 600 | 50/60 | 235 | 9.9 | Floor mount NEMA 12 | UL/CSA | Top or bottom | Yes | 1694 (770) | **HCU2235D6N12** |
| 690 | 50/60 | 40 | 2.1 | Floor mount IP31 | CE | Top or bottom | Yes | 1063 (483) | **HCU2040D7IP31** |
| 690 | 50/60 | 80 | 4.5 | Floor mount IP31 | CE | Top or bottom | Yes | 1173 (533) | **HCU2080D7IP31** |
| 690 | 50/60 | 133 | 8.2 | Floor mount IP31 | CE | Top or bottom | Yes | 1558 (708) | **HCU2133D7IP31** |
| 690 | 50/60 | 200 | 11.4 | Floor mount IP31 | CE | Top or bottom | Yes | 1817 (826) | **HCU2200D7IP31** |
| 690 | 50/60 | 40 | 2.1 | Floor mount NEMA 2 | UL/CSA | Top or bottom | Yes | 1063 (483) | **HCU2040D7N2** |
| 690 | 50/60 | 80 | 4.5 | Floor mount NEMA 2 | UL/CSA | Top or bottom | Yes | 1173 (533) | **HCU2080D7N2** |
| 690 | 50/60 | 133 | 8.2 | Floor mount NEMA 2 | UL/CSA | Top or bottom | Yes | 1558 (708) | **HCU2133D7N2** |
| 690 | 50/60 | 200 | 11.4 | Floor mount NEMA 2 | UL/CSA | Top or bottom | Yes | 1817 (826) | **HCU2200D7N2** |
| 690 | 50/60 | 40 | 2.1 | Floor mount IP54 | CE | Top or bottom | Yes | 1087 (494) | **HCU2040D7IP54** |
| 690 | 50/60 | 80 | 4.5 | Floor mount IP54 | CE | Top or bottom | Yes | 1192 (542) | **HCU2080D7IP54** |
| 690 | 50/60 | 133 | 8.2 | Floor mount IP54 | CE | Top or bottom | Yes | 1606 (730) | **HCU2133D7IP54** |
| 690 | 50/60 | 200 | 11.4 | Floor mount IP54 | CE | Top or bottom | Yes | 1846 (839) | **HCU2200D7IP54** |
| 690 | 50/60 | 40 | 2.1 | Floor mount NEMA 12 | UL/CSA | Top or bottom | Yes | 1087 (494) | **HCU2040D7N12** |
| 690 | 50/60 | 80 | 4.5 | Floor mount NEMA 12 | UL/CSA | Top or bottom | Yes | 1192 (542) | **HCU2080D7N12** |
| 690 | 50/60 | 133 | 8.2 | Floor mount NEMA 12 | UL/CSA | Top or bottom | Yes | 1606 (730) | **HCU2133D7N12** |
| 690 | 50/60 | 200 | 11.4 | Floor mount NEMA 12 | UL/CSA | Top or bottom | Yes | 1846 (839) | **HCU2200D7N12** |

# Product Specifications

**Table 35.3-2. HCU2 Specifications**

| Description | Specification |
|---|---|
| **Technical Specifications** | |
| Standard rms output current ratings | 60 A, 120 A, 200 A, 300 A at 380 Vac to 480 Vac<br>47 A, 94 A, 157 A, 235 A at 600 Vac<br>40 A, 80 A, 133 A, 200 A at 690 Vac |
| Nominal frequency | 50/60 Hz, ±3 Hz auto sensing |
| Number of phases | Three-phase |
| Topology | Digital harmonic FFT<br>Digital reactive power |
| Losses | To 480 Vac <3%; to 690 VCA <5% |
| CT VA loading | 1.0 VA (5 A CT secondary) |
| Spectrum cancellation | 2nd to 51st, discrete; fully selectable per harmonic order (amplitude and on/off) |
| Control basis | Closed loop (for new installations)<br>Open loop compatible for retrofit applications |
| Harmonic attenuation | Closed Loop: <3% THD(i); max 20:1 THD(i) reduction with load harmonic current above 50% of Eaton HCU2 rating<br>Open Loop: <5% TDD<br>Requires 3% or higher inductive impedance per nonlinear load |
| Harmonic operational features | % THDi set point<br>% THDv set point |
| Harmonic avoidance | Output at specific harmonic order turned off if resonance or lack-of impedance detected; or manually turned off |
| Parallel operation | Up to 10 units per set of CT (to 51st order), any size combination<br>Backward compatibility with Eaton HCUE operated in parallel<br>Contact Eaton for applications of more than 10 units |
| Parallel operation options | Master/master (masters receive mains CT)<br>Master/slave<br>Multi-master/multi-slave<br>Same as Eaton HCUE for retrofits |
| Parallel sequence options | Lead/lag with unit rotation: one unit operates to full capacity before next unit turns on; timed rotation<br>Load share: All operating units function at the same output percentage |
| Parallel HMI control | Any unit permits viewing and changing parameter settings of complete system or any other unit in parallel system |
| Parallel communications | Proprietary COM bus between operating units |
| Power factor correction | Optimized unity PF, leading (capacitive) or lagging (inductive) power factor (Cos f) to target |
| Control response time | 25 µs |
| Harmonic correction time | 2 cycles |
| Reactive correction time | 1/4 cycle |
| Display | 144 mm QVGA TFT 64k-color touchscreen |
| Display parameters | Hundreds of parameters are available. Examples include THDi, THDv, oscilloscope for viewing many selected parameters, phasor diagrams, load power, measured currents for $I_h$, $I_s$, $I_f$, I neg seq, PF (Cos ø), injected currents for $I_h$, I reactive, I neg seq, etc. |
| Communications capability | Modbus® RTU, Modbus TCP/IP |
| Discrete input/outputs | 4 input and 4 output dry contacts; assignable |
| Noise level (ISO3746) | <70 dB at one meter from unit surface |
| Earthing (grounding) systems | EMC filter ground switch for Isolated Terra, high resistance ground or corner grounded systems |

**Table 35.3-2. HCU2 Specifications, Continued**

| Description | Specification |
|---|---|
| **Environmental Conditions** | |
| Operating temperature | 0 °C to 40 °C |
| Relative humidity | 0–95%, noncondensing |
| Seismic rating | Complies with IBC and ASCE7 |
| Operating altitude | 1000 m, (derate 1%/100 m above), maximum 4800 m |
| Automatic rollback of output | Occurs whenever heatsink temperature sensor exceeds temperature limit |
| Ambient temperature protection | Absolute shutdown if air inlet temperature reaches 51 °C |
| Preset output limits (rms) | Programmable set limit due to altitude or ambient temperature—becomes fixed output limit |
| Storage (in original shipping container) | Temperature: –20 °C to 60 °C<br>Relative humidity: to 95%, noncondensing<br>Clean, dry, and protected<br>No conductive particles permitted |
| Contaminant levels—operating<br>(IEC 60721-3-3) | Chemical Class 3C2<br>Mechanical Class 3S2<br>No conductive particles permitted |
| **Reference Standards** | |
| Design | CE EMC Certification IEC/EN 60439-1, EN 61000-6-4 Class A, EN 61000-6-2 |
| Protection (enclosure) | IP00, IP20, IP31, IP54, UL Type 1, UL Type 2, UL Type 12, UL Type Open |
| Standards compliance/certification | cULus (UL 508, CSA 22.2 No. 14)<br>CE Certified, ABS, Lloyds, other local standards |
| **Installation** | |
| Wallmount | IP00 (UL Type open) and IP20 (NEMA 1) configurations |
| Free-standing | IP31, IP54, NEMA 2 and NEMA 12 |
| Circuit protection | NEMA 1 and chassis mount—external means required<br>Free-standing enclosures—incoming circuit breaker with mechanical door interlock |
| AIC rating (input circuit breaker) | To 415 Vac—200 kA cULus; 125 kA IEC<br>To 480 Vac—200 kA cULus; 75 kA IEC<br>To 600 Vac—100 kA cULus; 100 kA IEC<br>To 690 Vac—No cULus; 100 kA IEC |
| Cable entry | Wallmount and chassis mount—bottom only<br>Free-standing—top and bottom entry through gland plates |
| PCBA protection | Conformal coating on all PCBs<br>Pollution Degree 2 |
| Cooling configuration | Separate air plenums for heat sink section and control section:<br>Heatsink (high heat plenum) input from bottom and exhaust out top<br>All components in high heat plenum rated IP54 or better ≥ no filtering required<br>Control section air supply must be clean and dry (filtering may be required)<br>No conductive particles permitted |
| Air supply | 60 A to 480 Vac: 570 m3/h, 335 cfm; to 690 Vac: 920 m3/h, 541 cfm<br>120 A to 480 Vac: 1030 m3/h, 606 cfm; to 690 Vac 1380 m3/h, 812 cfm<br>200 A to 480 Vac: 2100 m3/h, 1236 cfm; to 690 Vac: 2850 m3/h, 1677 cfm<br>300 A to 480 Vac: 2100 m3/h, 1236 cfm; to 690 Vac: 2850 m3/h, 1677 cfm |
| **Service Provisions** | |
| HMI | Plain language output (without cryptic codes)<br>USB port for upload of new software and download of operational records |
| Service port | USB port: commission, program, or diagnostics via a laptop computer when power is on or off; laptop provides power to control board when no unit power is present |
| Commissioning | On-board step-by-step process; CT automatic sizing, phase rotation, and polarity; external transformer ratio and phase shift; heat test, and more |

**Table 35.3-3. Current Transformer Ratings—Dimensions in Inches (mm)**

| Ratio | Type | Nominal window size | Model |
|---|---|---|---|
| 300/5 to 3000/5 | Split | 4.00 x 7.00 (101.6 x 177.8) | TX2 |
| 500/5 to 4000/5 | Split | 5.00 x 7.00 (127.0 x 177.8) | TX4 |
| 500/5 to 5000/5 | Split | 4.00 x 11.00 (101.6 x 279.4) | TX5 |

**Note:** Two current transformers are required for three-phase loads. Three current transformers are required when single-phase loads are present. CT rating based on service entrance ampacity. Startup and commissioning by factory trained personnel is recommended. Additional CTs required if power factor correction capacitors are being used in conjunction with the active harmonic filter. See Eaton publication IL157001EN for more information on the TX2, TX4, and TX5 current transformers.

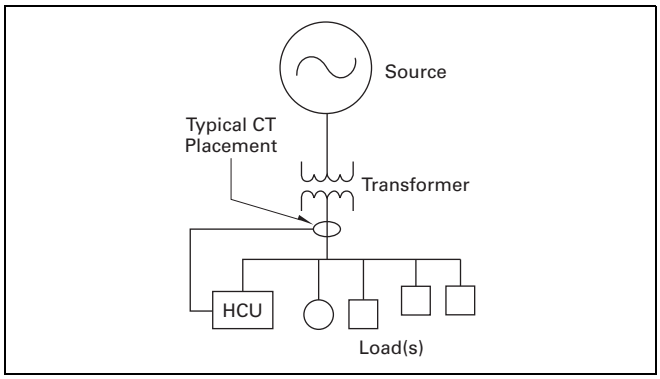


**Figure 35.3-1. Installation Diagram**

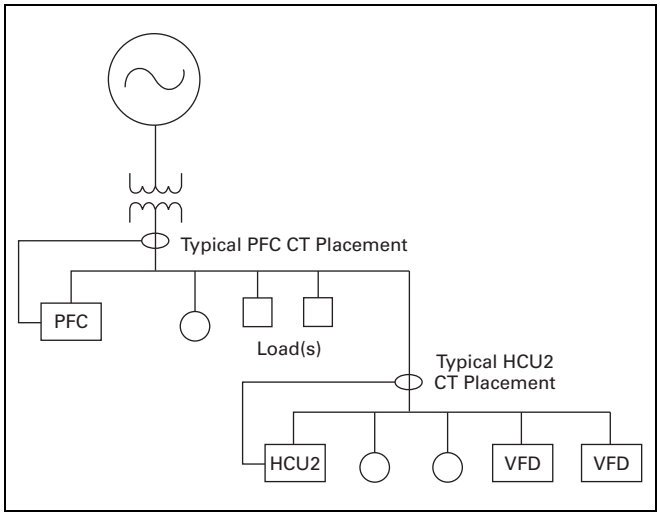


**Figure 35.3-2. Typical Scheme with Passive Detuned PFC Filter and HCU2**

## Model Drawings

**Layout Dimensions— NEMA 1 Wallmounted Enclosures**

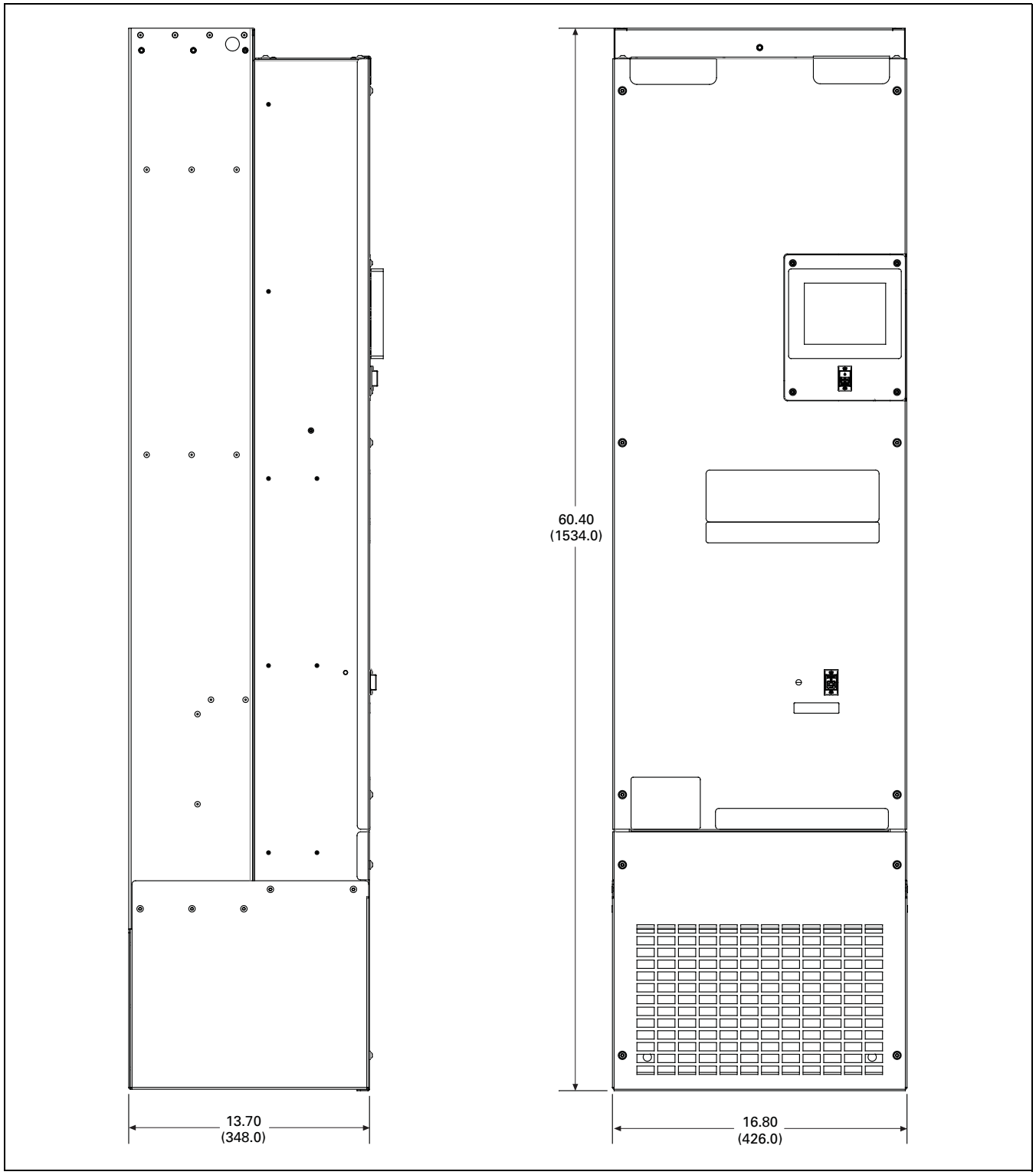


**Figure 35.3-3. NEMA 1, 60 A—Dimensions in Inches (mm)**

## Layout Dimensions—NEMA 1 Wallmounted Enclosures

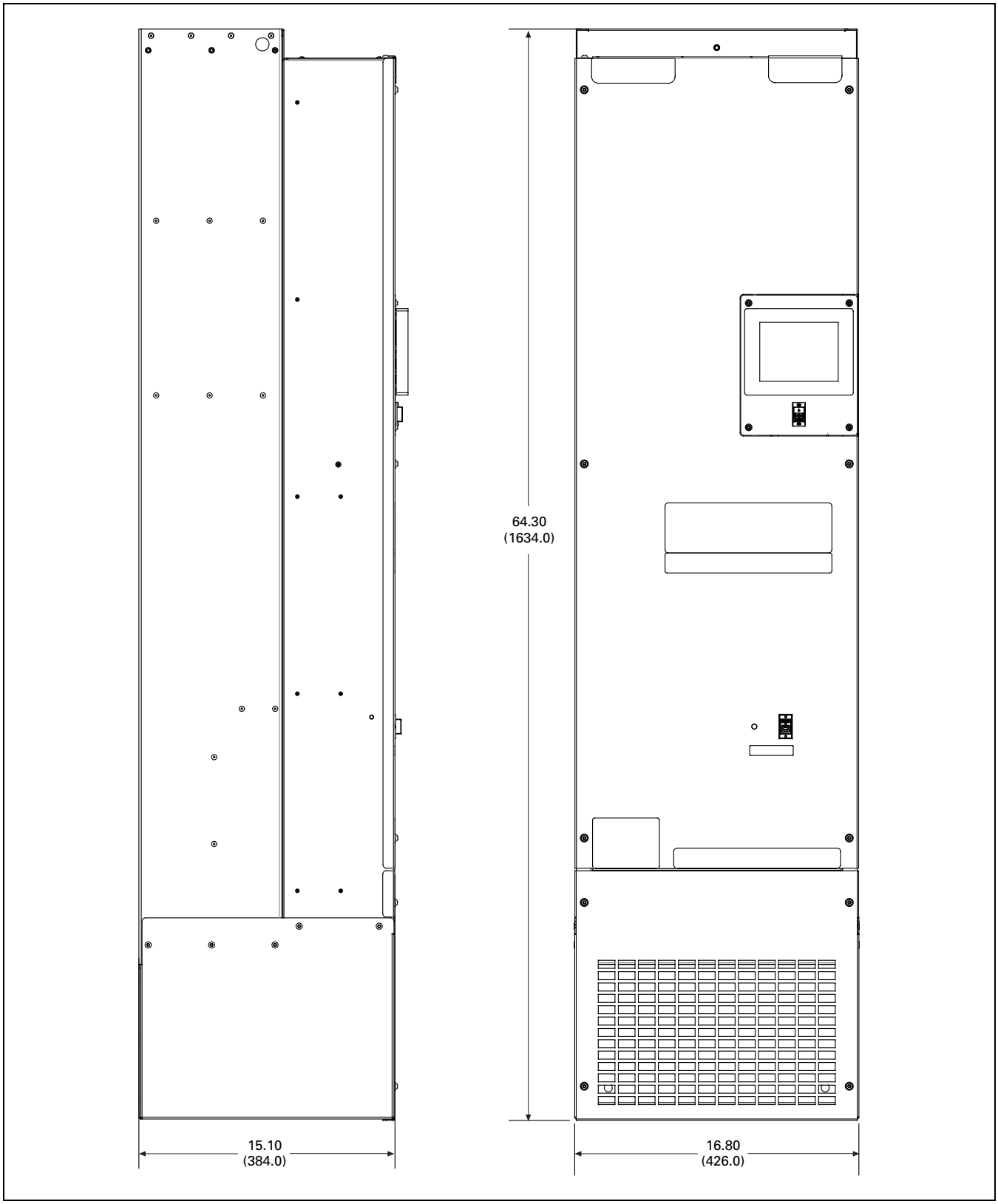


**Figure 35.3-4. NEMA 1, 120 A—Dimensions in Inches (mm)**

## Layout Dimensions—NEMA 1 Wallmounted Enclosures

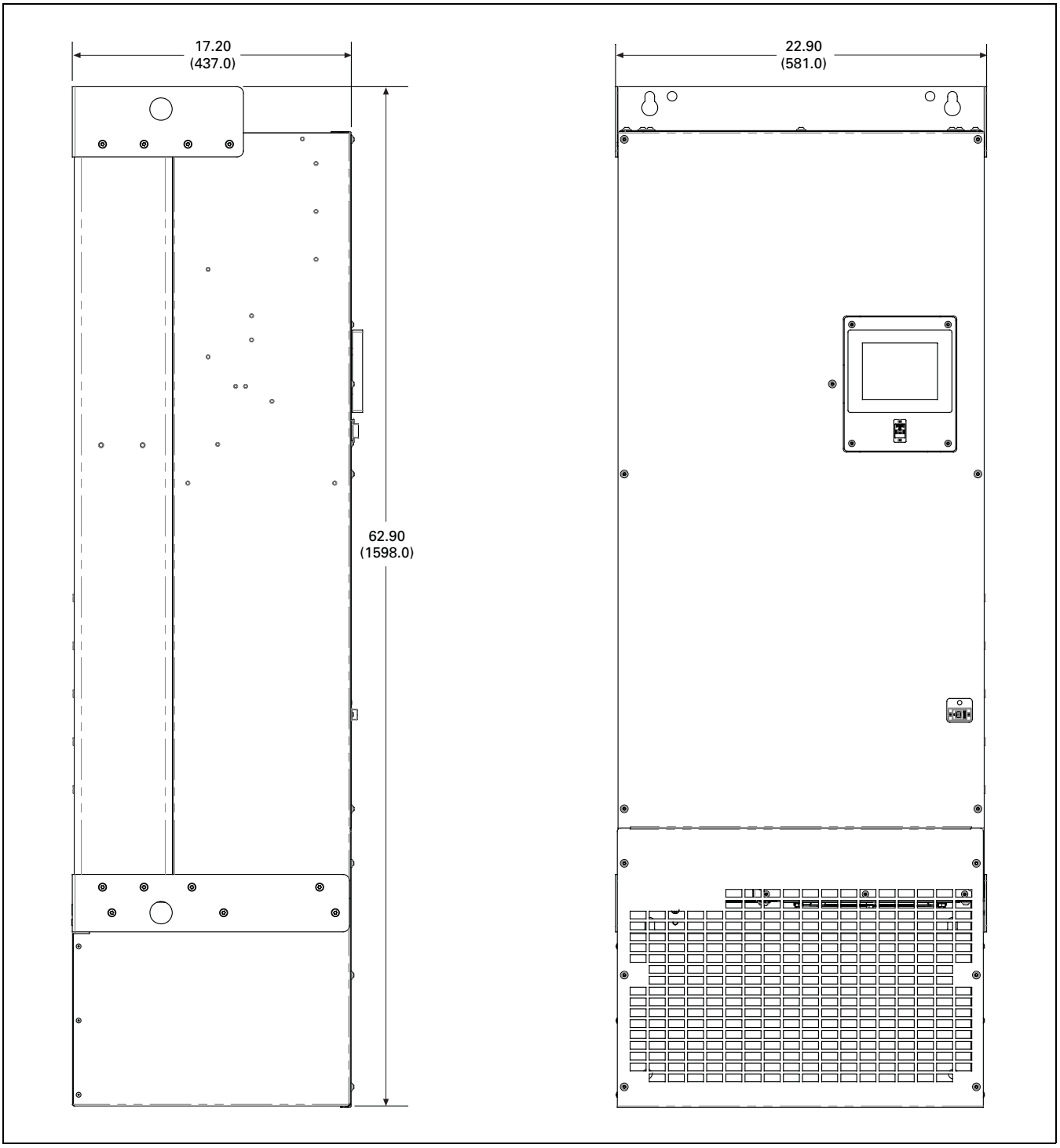


**Figure 35.3-5. NEMA 1, 200 A—Dimensions in Inches (mm)**

## Layout Dimensions—NEMA 1 Wallmounted Enclosures

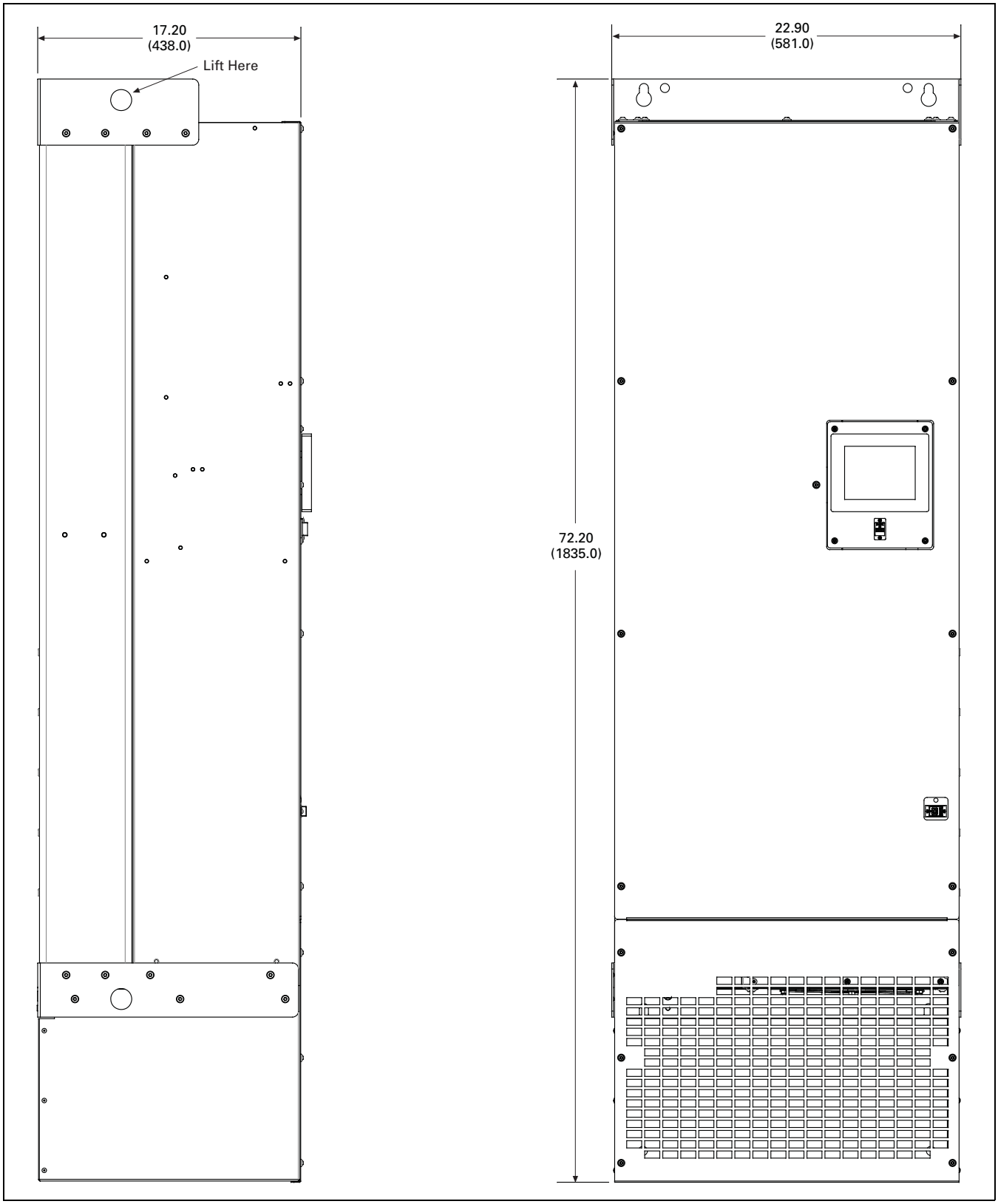


**Figure 35.3-6. NEMA 1, 300 A—Dimensions in Inches (mm)**

## Layout Dimensions—380–480 V, NEMA 2, NEMA 12, IP31 and IP54 Units

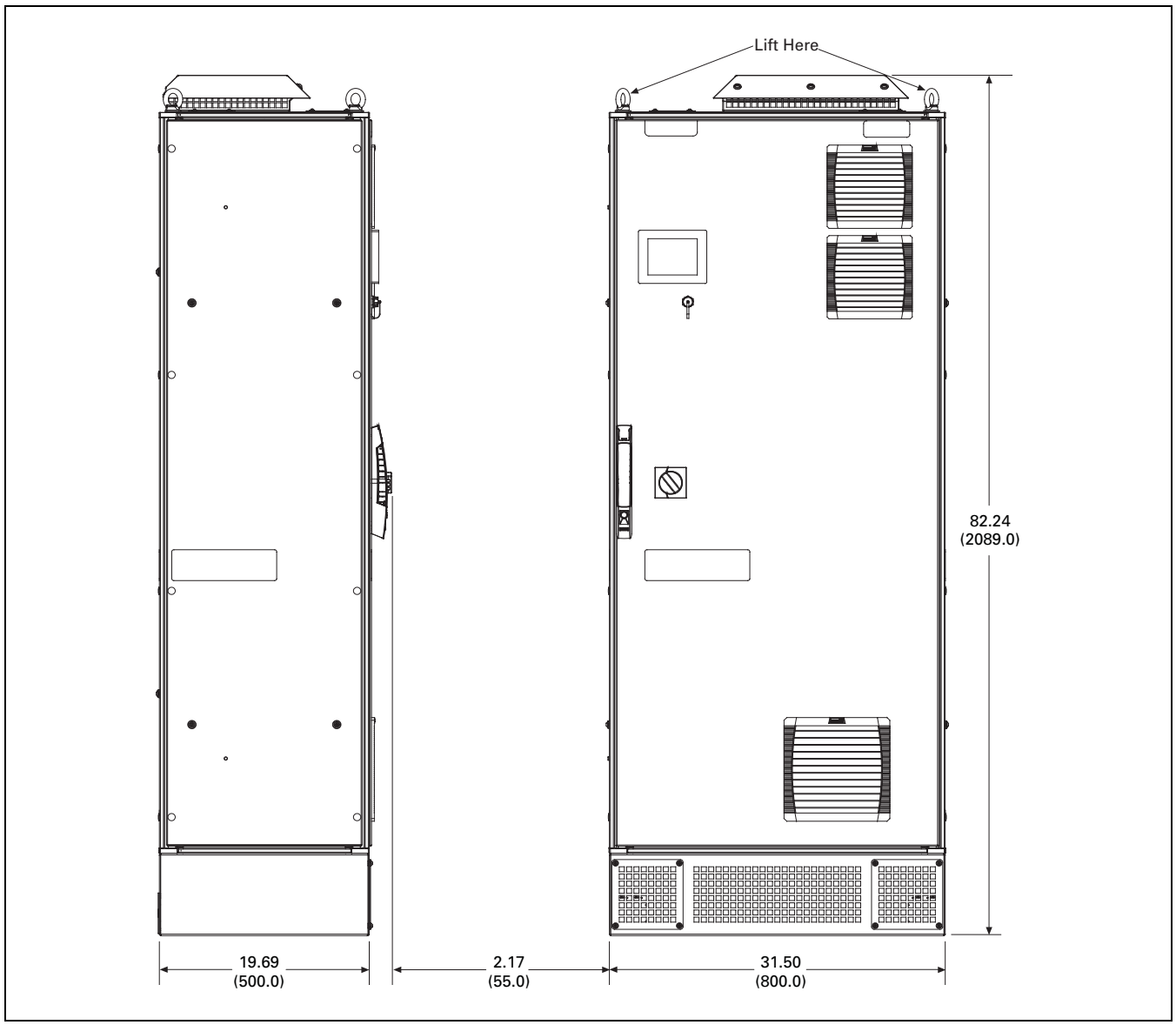


**Figure 35.3-7. 60 A and 120 A, 380–480 V, NEMA 2, NEMA 12, IP31 and IP54 Units—Dimensions in Inches (mm)**

**Layout Dimensions—380–480 V, NEMA 2, NEMA 12, IP31 and IP54 Units**

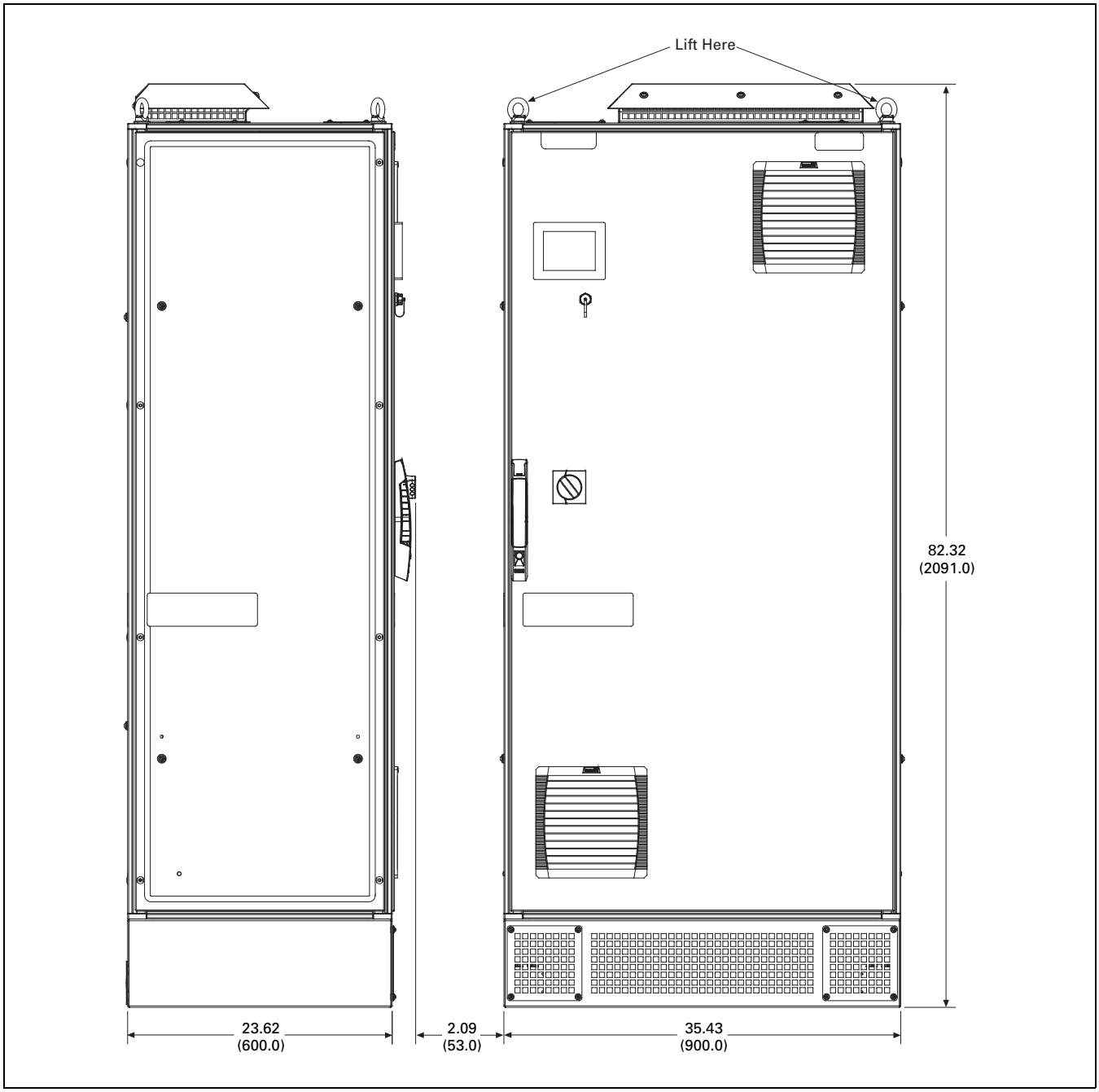


**Figure 35.3-8. 200 A and 300 A, 380–480 V, NEMA 2, NEMA 12, IP31 and IP54 Units—Dimensions in Inches (mm)**

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# Transient-Free Statically Switched Capacitor Bank

*Eaton Transient-Free Statically Switched Capacitor System*

## General Description

The Eaton transient-free statically switched (TFSS) capacitor systems represent the "next level" of power system enhancements by using semi-conductor devices to switch capacitors at the same potential or zero potential difference, thereby eliminating the possible problem of transients caused by capacitor switching and increasing the speed of capacitive var compensation. This level of performance is needed when high-current loads rapidly switch on and off and require power factor, voltage flicker, sag or harmonic correction. These disturbances can be found in many industries, including rock crushing, arc-welding, plastic injection molding and crane applications.

Transient-free statically switched capacitor units are available in two broader models.

The FTE model is a real-time transient-free system, used to compensate extremely rapid loads within one cycle of operation (typically 5–20 msec).

The FTA model is a fast transient-free system, used to compensate any loads within 3–4 seconds.

Units are available in a variety of tuning orders/ percentage reactor combinations.

## Application Description

Applications to correct power factor and/or provide voltage support can include:

- Flicker reduction
- Motor starting
- Bus voltage stabilization
- Grid fault ride-through
- On-site generation support
- Spot welding
- Wind turbines
- Other dynamic loads

Three current transformers with a 5A secondary are required for proper operation of a TFSS system. Primary CT current rating is based on service entrance ampacity.

Startup and commissioning by factory-trained personnel is required for proper operation and warranty of a TFSS system.

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## Univar XV (5 kV Class)


*Univar XV Fixed Medium Voltage PFC Unit*

## General Description

Capacitors for medium voltage, heavy-duty applications:

- Univar capacitors are designed for power factor correction in applications where a fixed amount of capacitance (kvar) is required
- 2400 V, 4160 V, 4800 V
- Fast economical payback
- Individual units or multiple assemblies can be designed
- Indoor dustproof/outdoor waterproof enclosures (NEMA 1, 3R and 12)
- Floor mounting
- Two- or three-phase fused options for 2400–4800 V
- NEMA 3R terminal box

**Note:** NEC Article 460.8 (b)(1)requires capacitors to have overcurrent protection in all ungrounded conductors (except if connected on the load side of a motor overload protection device). Three-phase capacitors fused only on two phases will not provide adequate protection if a line-to-ground fault should occur in the unfused phase.

## Application Description

- Large motors
- Motor control centers
- Branch circuits
- Service entrances

## Features, Benefits and Functions

### Standard Features

#### Enclosure Terminal Box

14-gauge steel finished with durable baked-on enamel. The wiring enclosure is gasketed to create a weatherproof, dustproof seal. Universal mounting flanges are provided for floor installation. The elimination of knockouts permits indoor/outdoor use. Unit meets NEMA 1, 3R and 12 requirements. Enclosure is painted ANSI 61 gray.

#### Features

- Viewing window
- Top and side entry
- Removable front cover
- Three fuses

#### Fusing

Fuses are rated 50,000 A symmetrical interrupting capacity. Ratings are 165% to 250% of rated current. Fuses have visual pop-up blown fuse indication standard.

#### Discharge Resistors

These reduce the residual voltage to less than 50 V residual within 5 minutes of de-energization.

#### Grounding Stud

- Standard

#### Power Line Terminals

- Large size for easy connection
- Plated copper one-hole termination pad

#### Operating Temperature

- –40 °F to 115 °F (–40 °C to +46 °C)

### Optional Features

- CSA testing and labels

# Technical Data and Specifications

**Table 35.5-1. UNIVAR Three-Phase Ratings**

| Volts | Hertz | kvar |
|---|---|---|
| 2400 | 60 | 25–825 |
| 4160 | 60 | 25–900 |
| 4800 | 60 | 25–900 |

**Table 35.5-2. Three-Phase Fused**

| kvar | 2400 V | 4160 V | 4800 V | Dimension (A) Inches (mm) | Approx. Weight Lb (kg) | Figure Number |
|---|---|---|---|---|---|---|
| 25 | **25243MVF3** | **25413MVF3** | **25483MVF3** | 34.44 (875.0) | 72 (32) | **Figure 35.5-1** |
| 50 | **50243MVF3** | **50413MVF3** | **50483MVF3** | 34.44 (875.0) | 72 (32) | **Figure 35.5-1** |
| 75 | **75243MVF3** | **75413MVF3** | **75483MVF3** | 34.44 (875.0) | 72 (32) | **Figure 35.5-1** |
| 100 | **100243MVF3** | **100413MVF3** | **100483MVF3** | 36.19 (919.0) | 77 (34) | **Figure 35.5-1** |
| 125 | **125243MVF3** | **125413MVF3** | **125483MVF3** | 36.19 (919.0) | 85 (38) | **Figure 35.5-1** |
| 150 | **150243MVF3** | **150413MVF3** | **150483MVF3** | 36.19 (919.0) | 90 (40) | **Figure 35.5-1** |
| 175 | **175243MVF3** | **175413MVF3** | **175483MVF3** | 36.19 (919.0) | 95 (42) | **Figure 35.5-1** |
| 200 | **200243MVF3** | **200413MVF3** | **200483MVF3** | 36.19 (919.0) | 101 (45) | **Figure 35.5-1** |
| 225 | **225243MVF3** | **225413MVF3** | **225483MVF3** | 41.94 (1065.0) | 111 (49) | **Figure 35.5-1** |
| 250 | **250243MVF3** | **250413MVF3** | **250483MVF3** | 41.94 (1065.0) | 111 (49) | **Figure 35.5-1** |
| 275 | **275243MVF3** | **275413MVF3** | **275483MVF3** | 41.94 (1065.0) | 123 (55) | **Figure 35.5-1** |
| 300 | — | **300413MVF3** | **300483MVF3** | 41.94 (1065.0) | 123 (55) | **Figure 35.5-1** |
| 300 | **300243MVF3** | — | — | 36.19 (919.0) | 176 (78) | **Figure 35.5-2** |
| 325 | **325243MVF3** | **325413MVF3** | **325483MVF3** | 36.19 (919.0) | 181 (80) | **Figure 35.5-2** |
| 350 | **350243MVF3** | **350413MVF3** | **350483MVF3** | 36.19 (919.0) | 186 (83) | **Figure 35.5-2** |
| 375 | **375243MVF3** | **375413MVF3** | **375483MVF3** | 36.19 (919.0) | 192 (85) | **Figure 35.5-2** |
| 400 | **400243MVF3** | **400413MVF3** | **400483MVF3** | 36.19 (919.0) | 198 (88) | **Figure 35.5-2** |
| 425 | **425243MVF3** | **425413MVF3** | **425483MVF3** | 41.94 (1065.0) | 210 (93) | **Figure 35.5-2** |
| 450 | **450243MVF3** | **450413MVF3** | **450483MVF3** | 41.94 (1065.0) | 218 (97) | **Figure 35.5-2** |
| 475 | **475243MVF3** | **475413MVF3** | **475483MVF3** | 41.94 (1065.0) | 218 (97) | **Figure 35.5-2** |
| 500 | **500243MVF3** | **500413MVF3** | **500483MVF3** | 41.94 (1065.0) | 218 (97) | **Figure 35.5-2** |
| 525 | **525243MVF3** | **525413MVF3** | **525483MVF3** | 41.94 (1065.0) | 230 (103) | **Figure 35.5-2** |
| 550 | **550243MVF3** | **550413MVF3** | **550483MVF3** | 41.94 (1065.0) | 242 (108) | **Figure 35.5-2** |
| 575 | — | **575413MVF3** | **575483MVF3** | 41.94 (1065.0) | 242 (108) | **Figure 35.5-2** |
| 575 | **575243MVF3** | — | — | 36.19 (919.0) | 265 (118) | **Figure 35.5-3** |
| 600 | — | **600413MVF3** | **600483MVF3** | 41.94 (1065.0) | 242 (108) | **Figure 35.5-2** |
| 600 | **600243MVF3** | — | — | 36.19 (919.0) | 271 (121) | **Figure 35.5-3** |
| 625 | **625243MVF3** | **625413MVF3** | **625483MVF3** | 41.94 (1065.0) | 285 (127) | **Figure 35.5-3** |
| 650 | **650243MVF3** | **650413MVF3** | **650483MVF3** | 41.94 (1065.0) | 293 (131) | **Figure 35.5-3** |
| 675 | **675243MVF3** | **675413MVF3** | **675483MVF3** | 41.94 (1065.0) | 301 (134) | **Figure 35.5-3** |
| 700 | **700243MVF3** | **700413MVF3** | **700483MVF3** | 41.94 (1065.0) | 301 (134) | **Figure 35.5-3** |
| 725 | **725243MVF3** | **725413MVF3** | **725483MVF3** | 41.94 (1065.0) | 301 (134) | **Figure 35.5-3** |
| 750 | **750243MVF3** | **750413MVF3** | **750483MVF3** | 41.94 (1065.0) | 301 (134) | **Figure 35.5-3** |
| 775 | **775243MVF3** | **775413MVF3** | **775483MVF3** | 41.94 (1065.0) | 313 (140) | **Figure 35.5-3** |
| 800 | **800243MVF3** | **800413MVF3** | **800483MVF3** | 41.94 (1065.0) | 325 (145) | **Figure 35.5-3** |
| 825 | **825243MVF3** | **825413MVF3** | **825483MVF3** | 41.94 (1065.0) | 337 (151) | **Figure 35.5-3** |
| 850 | — | **850413MVF3** | **850483MVF3** | 41.94 (1065.0) | 337 (151) | **Figure 35.5-3** |
| 875 | — | **875413MVF3** | **875483MVF3** | 41.94 (1065.0) | 337 (151) | **Figure 35.5-3** |
| 900 | — | **900413MVF3** | **900483MVF3** | 41.94 (1065.0) | 337 (151) | **Figure 35.5-3** |

**Note:** Add suffix "C" for CSA label.

## Dimensions

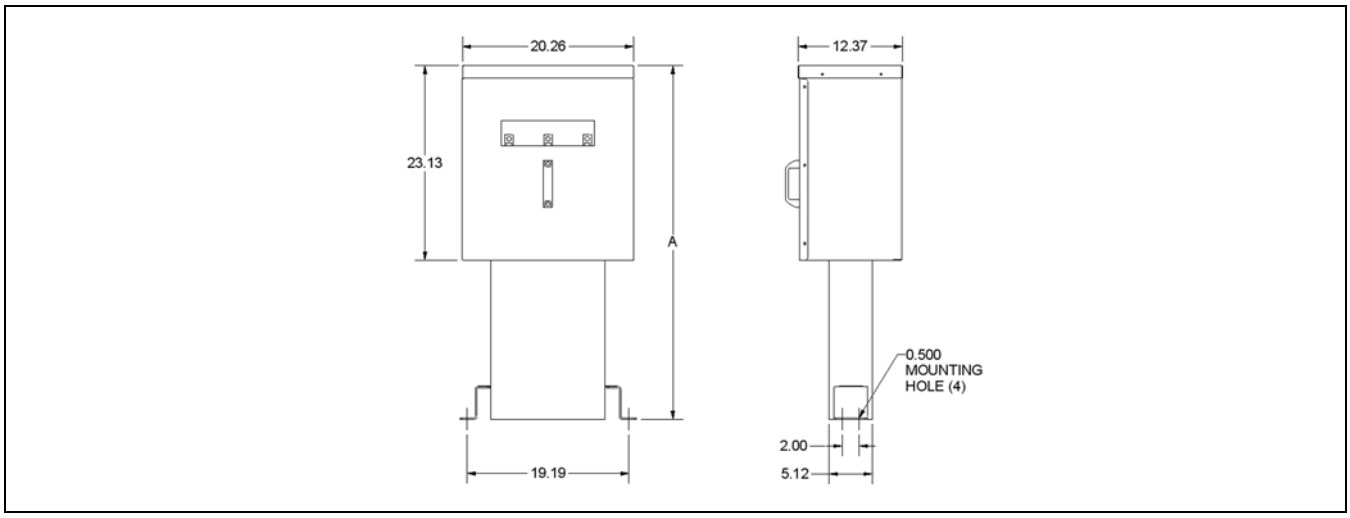



**Figure 35.5-1. UNIVAR XV 5 kV Class, 25–300 kvar**

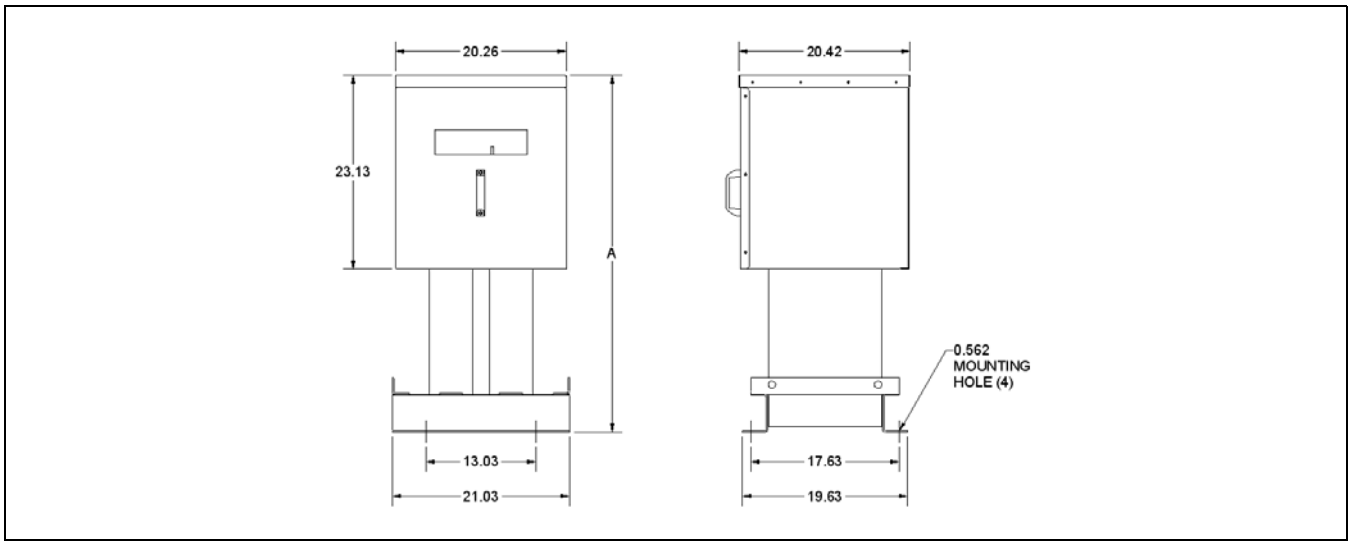



**Figure 35.5-2. UNIVAR XV 5 kV Class, 300–600 kvar**

35

## Dimensions

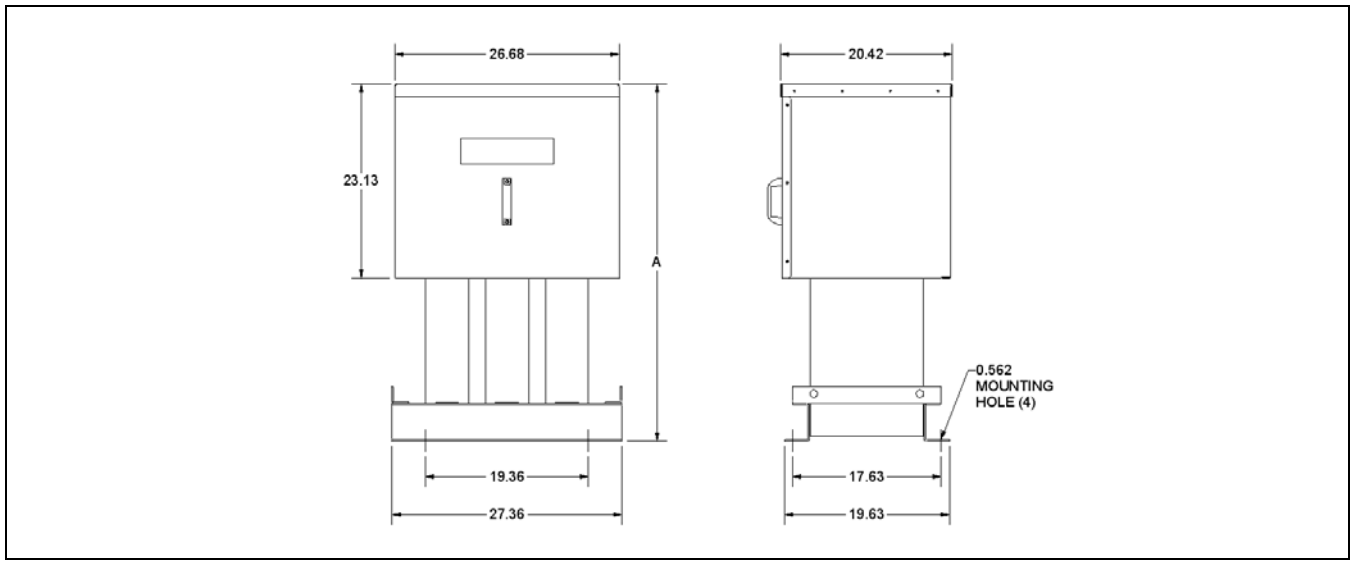
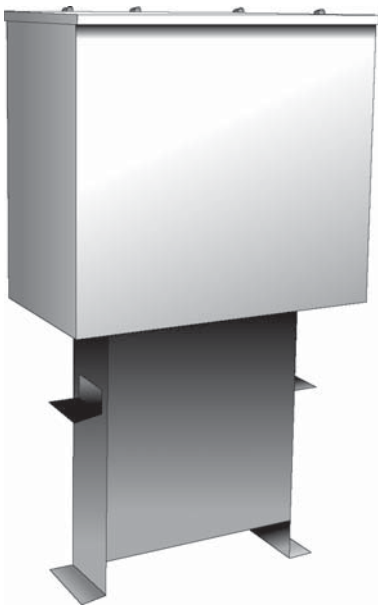



**Figure 35.5-3. UNIVAR XV 5 kV Class, 575–900 kvar**

## Univar (15 kV Class)



*Univar Fixed Medium Voltage PFC Unit*

## General Description

Capacitors for medium voltage, heavy-duty applications:

- Univar capacitors are designed for power factor correction in applications where a fixed amount of capacitance (kvar) is required.
- 6600 V, 7200 V, 12,470 V or 13,800 V
- Fast economical payback
- Individual units or multiple assemblies can be designed
- Indoor dustproof/outdoor waterproof enclosures (NEMA 1, 3R and 12)
- Floor mounting
- All units above 4800 V are supplied with fusing on all three phases
- NEMA 3R terminal box

## Application Description

- Large motors
- Motor control centers
- Branch circuits
- Service entrances

## Features, Benefits and Functions

### Standard Features

#### Enclosure

16-gauge steel finished with durable baked-on enamel. The wiring enclosure is gasketed to create a weatherproof, dustproof seal. Universal mounting flanges are provided for floor installation. The elimination of knockouts permits indoor/outdoor use. Unit meets NEMA 1, 3R and 12 requirements. Enclosure is painted ANSI 70 gray.

#### Fusing

Fuses are rated 50,000 A symmetrical interrupting capacity. Ratings are 165% to 250% of rated current. Fuses have visual pop-up blown fuse indication standard.

#### Discharge Resistors

These reduce the residual voltage to less than 50 V residual within 5 minutes of de-energization.

#### Grounding Stud

- Standard

#### Power Line Terminals

- Large size for easy connection

#### Operating Temperature

- –40 °F to 115 °F (–40 °C to +46 °C)

### Optional Features

- CSA testing and labels

## Technical Data and Specifications

**Table 35.5-3. Univar Three-Phase Ratings**

| Volts | Hertz | kvar |
|---|---|---|
| 6600 | 60 | 50–400 |
| 7200 | 60 | 50–400 |
| 12,470 | 60 | 50–500 |
| 13,800 | 60 | 50–500 |

**Table 35.5-4. Standard Three Fuses (6600–13,800V)—Refer to Figure 35.5-4 Below**

| Standard Three Fuses | | | | | Dimensions | | | | Approx. Weight Lb (kg) | Standard Drawing Number |
|---|---|---|---|---|---|---|---|---|---|---|
| kvar | 6600 V | 7200 V | 12,470 V | 13,800 V | (A) Inches (mm) | (B) Inches (mm) | (C) Inches (mm) | (D) Inches (mm) | | |
| 50 | **50663FKED3** | **50723FKED3** | **50123FKED3** | **50133FKED3** | 4.25 (108.0) | 45.50 (1156.0) | 14.46 (367.0) | 0.25 (6.0) | 198 (90) | 5D10243 |
| 100 | **100663FKED3** | **100723FKED3** | **100123FKED3** | **100133FKED3** | 4.25 (108.0) | 45.50 (1156.0) | 14.46 (367.0) | 0.25 (6.0) | 198 (90) | 5D10243 |
| 150 | **150663FKED3** | **150723FKED3** | **150123FKED3** | **150133FKED3** | 4.25 (108.0) | 45.50 (1156.0) | 14.46 (367.0) | 0.25 (6.0) | 198 (90) | 5D10243 |
| 200 | **200663FKED3** | **200723FKED3** | **200123FKED3** | **200133FKED3** | 5.62 (143.0) | 45.50 (1156.0) | 14.46 (367.0) | 0.25 (6.0) | 220 (100) | 5D10243 |
| 250 | **250FKY66323** | **250FKY72323** | **250FKY12323** | **250FKY13323** | 5.62 (143.0) | 48.50 (1232.0) | 17.46 (443.0) | 0.25 (6.0) | 246 (112) | 5D10243 |
| 300 | **300FKY66323** | **300FKY72323** | **300FKY12323** | **300FKY13323** | 5.62 (143.0) | 53.50 (1359.0) | 17.46 (443.0) | 0.25 (6.0) | 246 (112) | 5D10243 |
| 350 | **350FKY66323** | **350FKY72323** | **350FKY12323** | **350FKY13323** | 5.62 (143.0) | 53.50 (1359.0) | 17.46 (443.0) | 0.25 (6.0) | 246 (112) | 5D10243 |
| 400 | **400FKY66323** | **400FKY72323** | **400FKY12323** | **400FKY13323** | 5.62 (143.0) | 57.25 (1454.0) | 22.46 (570.0) | 0.25 (6.0) | 281 (128) | 5D10243 |
| 450 | — | — | **450FKY12323** | **450FKY13323** | 5.62 (143.0) | 57.25 (1454.0) | 22.46 (570.0) | 0.25 (6.0) | 281 (128) | 5D10243 |
| 500 | — | — | **500FKY12323** | **500FKY13323** | 5.62 (143.0) | 57.25 (1454.0) | 26.21 (666.0) | 0.25 (6.0) | 336 (153) | 5D10243 |

## Dimensions

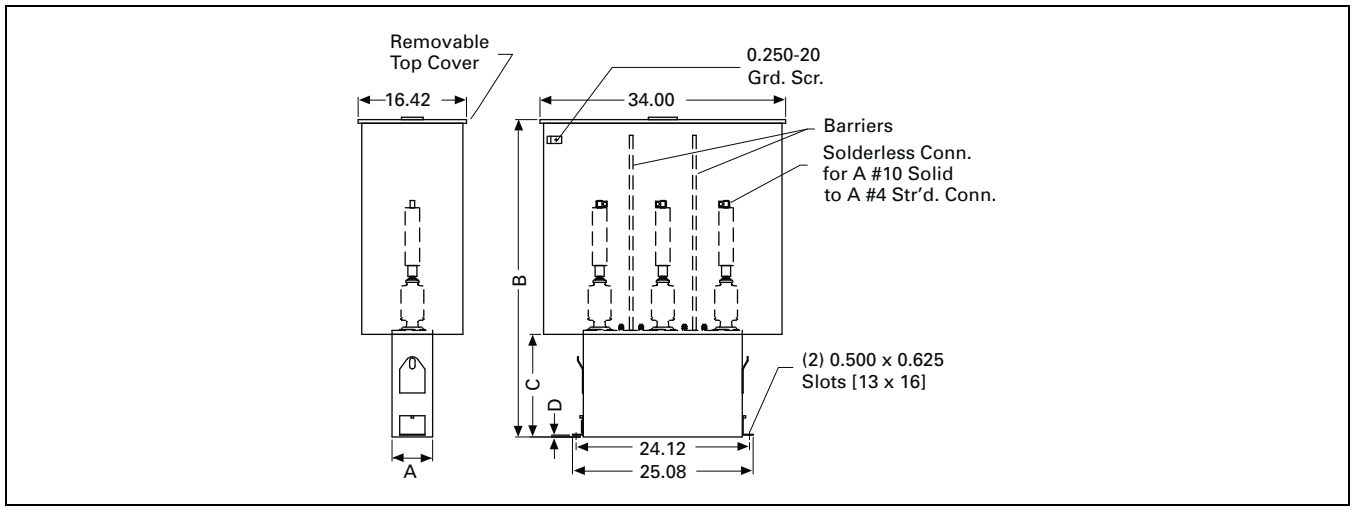



**Figure 35.5-4. UNIVAR 15 kV Class, 50–500 kvar**

# Metal-Enclosed Medium Voltage

***Safety and Aesthetics are Just Two Compelling Reasons to Use Metal-Enclosed PFC Systems***

# Application Description

## Utility Customers

Metal-enclosed power factor correction systems are fully assembled, tested and ready for installation. Very little field assembly is required. Installation and maintenance costs for metal-enclosed systems are low compared to pole and rack mounted capacitor banks. Metal-enclosed systems and harmonic filters are less vulnerable to wildlife and airborne contaminants that can cause tracking and faults. In addition, metal-enclosed systems significantly reduce the risks and the associated liability involving untrained personnel. All live parts are contained in a grounded, key interlocked enclosure and no internal hardware is accessible. Metal-enclosed systems are aesthetically pleasing due to their low profile, and can be painted to match the surrounding architecture. These are just some of the reasons more and more utilities are using metal-enclosed capacitor and harmonic filter systems.

## Industrial Customers

Large industrial power users can use the benefits associated with medium voltage power factor correction and harmonic filtering. Medium voltage solutions usually support the scale and scope of larger services. Medium voltage applications can be found in the following types of industries as examples: automotives, pulp and paper, plastics, petrochemical and heavy manufacturing.

Individual fixed capacitors provide power factor correction directly at the cause of the problem, such as a large horsepower MV motor. Medium voltage systems allow large industrials to correct power factor at or close to the point of common coupling (PCC), where the utility electrical system meets theirs. This allows correction for an entire facility, instead of having to correct at multiple locations. The Eaton NEMA 3R design also allows the system to be placed outdoors, saving valuable manufacturing floor space. The savings can be enormous, in materials, installation costs and floor space. In short, medium voltage solutions provide a cost-effective alternative to many local low voltage power factor correction units, while protecting the customer's entire electrical distribution system.

## Commercial Customers

Many commercial customers are purchasing power from their utility at higher voltages today (2.4–15 kV), and can also take advantage of medium voltage power factor correction systems. These solutions can meet the needs of large office complexes, hospitals and universities, among others. The benefits of safety (key interlocking, no exposed live parts, etc.), and aesthetics (low profile, can be painted to match environment) both meet the needs of these applications where there are large numbers of untrained personnel in proximity of electrical equipment.

## Advantages

Eaton's purchase of the Commonwealth Sprague capacitor systems business, with its over 70 years of market experience, provides a combination that allows the end user to obtain a world-class solution to fill their power factor needs. Quality and reliability are of paramount importance to not only the Eaton engineering team, but are also the backbone of all Eaton products and services. This commitment to quality means the customer can have a great deal of confidence with the medium voltage capacitor or harmonic filter solution from Eaton's electrical business.

# Benefits

## Ease of Installation

Eaton makes installation easy. All systems are completely assembled in the factory, with all equipment pre-wired and pre-tested for easy on-site installation. Only shipping splits must be connected in the field. Splice kits connect bus systems, and control wiring is easily connected at each enclosure. Current limiting fuses, contactor assemblies, and the incoming switch assembly can be removed from the enclosure if needed. Line terminals are completely accessible from the front of the system.

## Personnel Safety

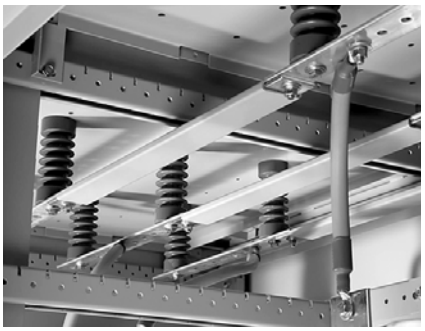
Positive mechanical isolating switch with visible disconnect completely grounds and isolates the unit from the line connectors. A screened barrier protects personnel from live parts. All medium voltage doors are mechanically interlocked with the disconnect switch. Key interlocks are provided standard on all enclosure doors, and can be coordinated with upstream disconnect devices. The low voltage control section has a separate door-in-door design, and is segregated from the medium voltage sections so that an operator can work in that section safely.

## Ease of Maintenance

All components are front-accessible, facilitating routine inspection or parts replacement. A viewing window is standard on all compartment doors.

## Flexibility

Systems are expandable. The customer can add stages in the future by connecting the phase bus in the field via splice kits. Structures can be bolted together in the field.



***Insulated Splice Kits Allow for Simple Interconnection in the Field***

# AUTOVAR MV (2.4–14.4 kV)

***Medium Voltage Metal-Enclosed PFC Capacitor Bank***

## General Description

The AUTOVAR medium voltage automatic power factor capacitor systems are designed for power factor correction in applications where plant power factor can be constant or changing, and an engineered solution is required. These systems can be a fixed amount of capacitance with a disconnect, a number of switched capacitance stages or a combination of both. The AUTOVAR medium voltage capacitor system can switch stages of capacitance in and out automatically based on information collected by the power factor controller on the door-in-door control panel.

## Features, Benefits and Functions

- Voltages from 2400 to 14,400 V
- Reactive power ratings through 10 MVAR
- Harmonic tuned, de-tuned or multi-tuned filter designs available
- Externally fused capacitor units standard
- Blown fuse indication standard
- Integral load interrupter switch, NEMA 2- or 4-hole termination pad
- Delivered fully assembled, tested and ready for interconnection
- Integral protection and control system
- Top or bottom cable entry
- Earthing switch
- 60 kV BIL up to 4.8 kV
- 95 kV BIL from 7.2 kV to 14.4 kV
- Up to 12 automatic switched capacitor stages
- Warning labels
- Removable air filters without opening enclosure doors
- Adjustable blocking timers to prevent re-closing of a capacitor stage in less than 200 seconds
- Meets the following requirements:
  - ANSI
  - IEEE
  - NEC
  - NESC
  - CSA (when specified)
- Main incoming fuses are rated 50 kAIC to provide main bus protection, as well as backup protection for the capacitor systems
- Standard bus bracing is 25 kA symmetrical
- 4.00-inch base channel is standard

## Standard Features

### Enclosure

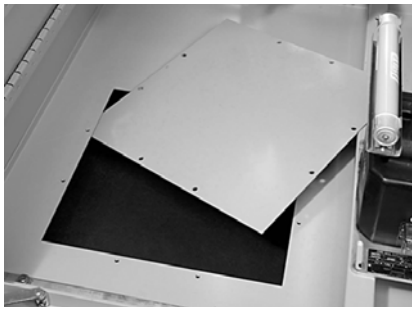
Free-standing, 11-gauge steel construction with 3-point padlockable latching handles and stainless steel hinges. The enclosure is painted with a corrosion-resistant ANSI 61 light gray enamel paint as standard. Other colors are available as an option. NEMA 3R construction is standard, NEMA 3R stainless steel is available as an option.

Enclosure is CSA approved. Enclosure design is modular and future sections can be added on the left or right.

See **Figure 35.6-1** for typical dimensions and elevations.

See **Figure 35.6-2** for a typical single-line drawing.

***Medium Voltage PFC Enclosure***



***Bottom Plate Incoming Cutout Provided Standard***

### Load Interrupter Air Disconnect Switch

Integral disconnect switch, externally operated, mechanically chain driven with visible blades is available as per NEC requirements. Disconnect switch is mechanically interlocked with the ground switch, and with the customer's upstream device (if applicable). Incoming section is front-accessible only for safety, and barrier isolates live connections from the user.

***Incoming Main Switch and Fuses***

### Ground Switch

A ground switch is provided to ground the load-side terminals of the incoming switch (or MLO) for safety during maintenance. Optional controls are available to permit closing contactors after the grounding switch has been closed to ground capacitors immediately (rather than waiting 5 minutes for full discharge).

### Vacuum Switches

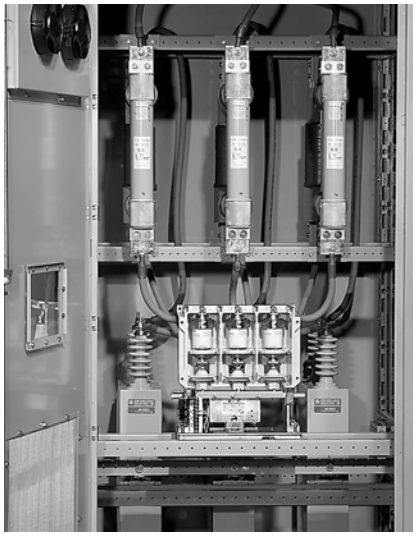
On 2.4 to 4.8 kV multi-stage capacitor systems, each stage is controlled by low maintenance Eaton "SL" AMPGARD three-pole vacuum contactors.

On 6.6 to 14.4 kV multi-stage capacitor systems, each stage is controlled by low maintenance single-pole vacuum switches.

*15 kV Switched Capacitor Stage Enclosure*

### Vacuum Contactors

The type SL power contactors were designed and engineered specifically for use in AMPGARD starters. They are self-supporting, compact, three-pole vacuum contactors. The SL contactor uses a solid-state control board, allowing the user maximum flexibility to change control voltages and dropout times in the field simply by adjusting DIP switch settings. The SL contactor is available for 2.4 –4.8 kV volts at ratings of 200 A and 800 A (the highest rated 800 A contactor available), and contactor interruption ratings of 8500 A allowing for higher levels of coordination with power fuses.



*5 kV Switched Capacitor Stage Enclosure*

### Individual Capacitor Fusing

Each capacitor is externally fused with current limiting fuses. Fuses are equipped with blown fuse indication. Internally fused capacitors are also available as an option.

Fuses are rated for capacitor protection. Standard fuses are rated 50 kAIC.

### Environmental Controls

- Exhaust fans: Exhaust fans are provided for forced air ventilation of all enclosures as standard
- Thermal controls: Thermostats are included as standard to help maintain an acceptable internal environment for all components
- Space heaters: Space heaters are provided to control moisture and humidity inside all enclosures
- Each compartment has individual thermostats for fan and space heater controls

### Capacitors

Low loss, double-bushing capacitors that meet or exceed IEC 871, IEEE Std. 18 and CSA standards are supplied. Capacitors are available in delta, ungrounded wye or solidly grounded wye. The dielectric fluid is environmentally friendly, biodegradable, non-PCB. Capacitor units are equipped with internal discharge resistors which reduce the residual voltage to less than 50 V within 5 minutes of de-energization.

## Filtered Units

Eaton's medium voltage detuned filter systems are designed for industrial, utility and commercial power systems to improve power factor, increase system capacity and reduce $I^2R$ losses. The reactors are typically tuned to the 4.7th harmonic, to mitigate the most damaging 5th level harmonic. This is the most common harmonic produced by six pulse variable speed drives. These filters are designed to the unique specifications of each electrical distribution system. Medium voltage capacitor banks can also be configured with de-tuned anti-resonant detuned filters, typically set to the 4.2nd harmonic. This helps avoid harmonic resonance problems, provides harmonic filtering, and avoids the overloading that is possible with an improperly applied filter.

*Detuned Filter Capacitor Stage Enclosure*

## Key Interlock System

The key interlock system controls the sequential operation of the load break switch (or circuit breaker) and the ground switch to permit safe entry into the capacitor system. All capacitor stage enclosures are also interlocked with the ground switch. If applicable, the customer's upstream disconnect device can be interlocked as well. See **Figure 35.6-2** for key interlock operation on a typical single-line drawing.

### Blown Fuse Detection System

A visual pop-up blown fuse detection system is provided as standard.

### Control Power Transformer

A fused control power transformer rated for 1.5 kVA is provided as standard for protection, control and operation of the capacitor or harmonic filter system.

### Surge Protective Device (SPD)

An SPD unit is supplied standard for protection of all low voltage controls in the system.

## Control Panel

A door-in-door NEMA 3R swing-out control panel is provided on the main incoming structure as standard. This unit includes a viewing window so that all controls and information can be viewed without opening the panel. All low voltage controls and logic are accessible from the front of the system, and are isolated from the medium voltage section.

Included:

- PFC power factor controller
- Multifunction digital meter/relay
- Full voltage LED lights for status, alarm and trip indication
- Manual stage operation switches
- Any special controls requested by the customer



*Control Panel*

### Digital Controller

Automatic metal-enclosed capacitors and harmonic filter systems come equipped with an automatic controller that switches each capacitor stage based upon power factor. The customer simply programs in the target PF to meet. The controller analyzes current PF, the size of each stage, and turns on and off stages to meet the customer's programmed target. Power factor controller comes with the following alarms as standards:

- Over/under compensation
- No current input
- Step fault
- Step warning
- Target power factor not reached
- Vthd harmonics
- Ithd harmonics
- Over/undervoltage

Up to 12 steps of capacitance can be designed into any system. Customers can note this feature when designing for future expansions.

### Communications

Communications of power factor data via RS-485. Modbus is available as an option. Communicated information from the controllers:

- Voltage
- Current
- Target power factor
- Current power factor
- Active power
- Apparent power
- Reactive power
- Number of steps in the circuit
- All alarm status
- All counters
- Time and date

### Inrush Reactors

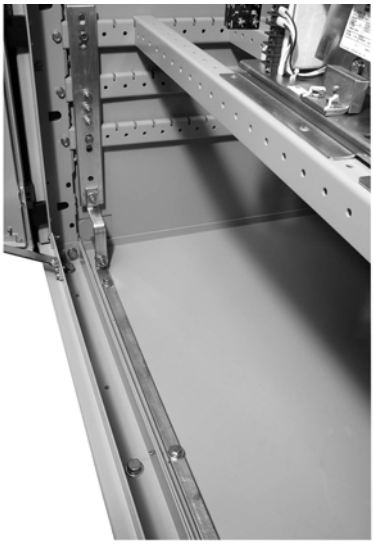
Inrush reactors are provided as standard on all switched (non-harmonic filtered) capacitor systems for protection against transients from back-to-back switching. Reactors in harmonic filtered applications provide this same protection.

### Bus

Continuous 1/4 x 2 inch silver-plated copper bus rated 500 A standard is provided throughout the line-up for easy interconnection, field installation and future expansion.

*Phase Bus*

Continuous 1/4 x 1 inch silver-plated copper ground bus is provided throughout the line-up for easy interconnection, field installation and future expansion. Ground studs are available in all structures for customer connection.



*Continuous Ground Bus with Pad in Each Section*

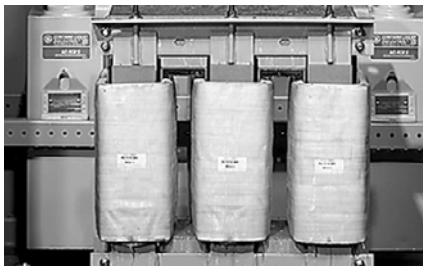
## Additional Standard Controls and Features

- Three-phase manual current monitoring, for maintenance purposes
- Unbalance alarm and unit shutdown on all wye-connected systems
- Overload protection for detuned filters
- Unit alarm and isolated fail-safe contacts for customer use on all systems. Controls allow sufficient time (5 minutes) to allow the capacitors time to discharge before re-energization can occur
- Temperature alarms on all harmonic filter units
- Manual stage controls (H-O-A Selector Switches)

## Optional Features

### Detuned Filter Reactors

Iron core reactors provide the necessary reactance to tune the capacitor system to a desired frequency. Filters are available in 4.2H, 4.4H, 4.6H, 4.7H or other tuning frequencies. Iron core reactors are 100% copper windings, low loss, 115 °C rise with 220 °C insulation VPI varnish.



*Harmonic Filter*

### Lightning Arresters

Optional heavy-duty distribution class/intermediate/station lightning arresters protect the capacitor system from lightning and switching transients.

### 15 kV Capacitor Vacuum Switch

15 kV capacitor vacuum switch is available in vacuum contactor in oil dielectric or vacuum contactor in solid dielectric. Vacuum switches are certified to ANSI C37.66 Standard.

### Harmonic Manager Multifunctional Digital Meter/Relay

Multifunctional harmonic manager meter/relay with current and voltage harmonic monitoring and various alarm/trip set points.

### Enclosure Options

NEMA 3R stainless steel construction for highly caustic environments.

### Alarm Strobe

Strobe light can be provided for visual indication of faults and alarms.

### Unbalance Protection

Neutral PT or CT-based unbalance protection for wye ungrounded capacitor configuration.

### Bus Options

Fully insulated main copper bus. Silver plating is standard, tin plating is optional.

### Time Delayed Enclosure Entry Interlock

Electrically controlled solenoid time delay to allow adjustable time delay between opening of main switch and entry into capacitor section.

### Heavy-Duty Capacitor Units

Capacitor units suited to the rigors of industrial power systems for power factor harmonic filter and excessive switching applications. Heavy-duty capacitor units have 125% continuous rms overvoltage capability, 15,000 A fault handling capability, 100 kA transient current withstand capability, +55 °C (+131 °F) ambient temperature operation and 135% peak overvoltage capability.

### Zero Voltage Crossing and Synchronous Closing Vacuum Capacitor Switch

Eliminates voltage and current transients on the electrical system due to capacitor switching. Increases the life of capacitors and contactors by reducing inrush current and voltage stress.

### Incoming Switch Options

200 A, 600 A and 1200 A incoming switches are available. Standard switch rating is 40 kA momentary. Optional 61 kA momentary rating is available.

## Dimensions

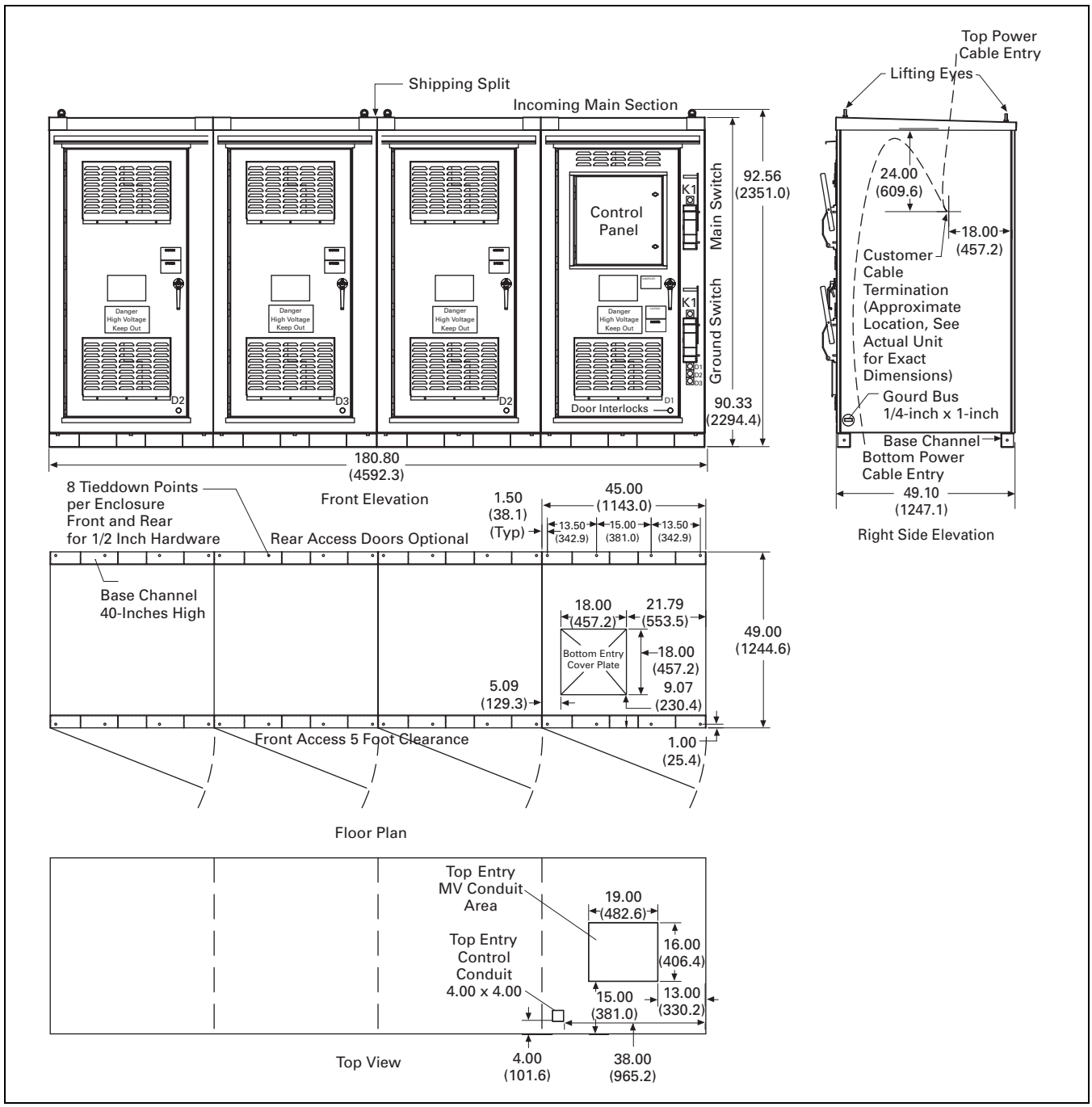



**Figure 35.6-1. Typical Engineered Metal-Enclosed Power Factor Correction System Dimensional Data**

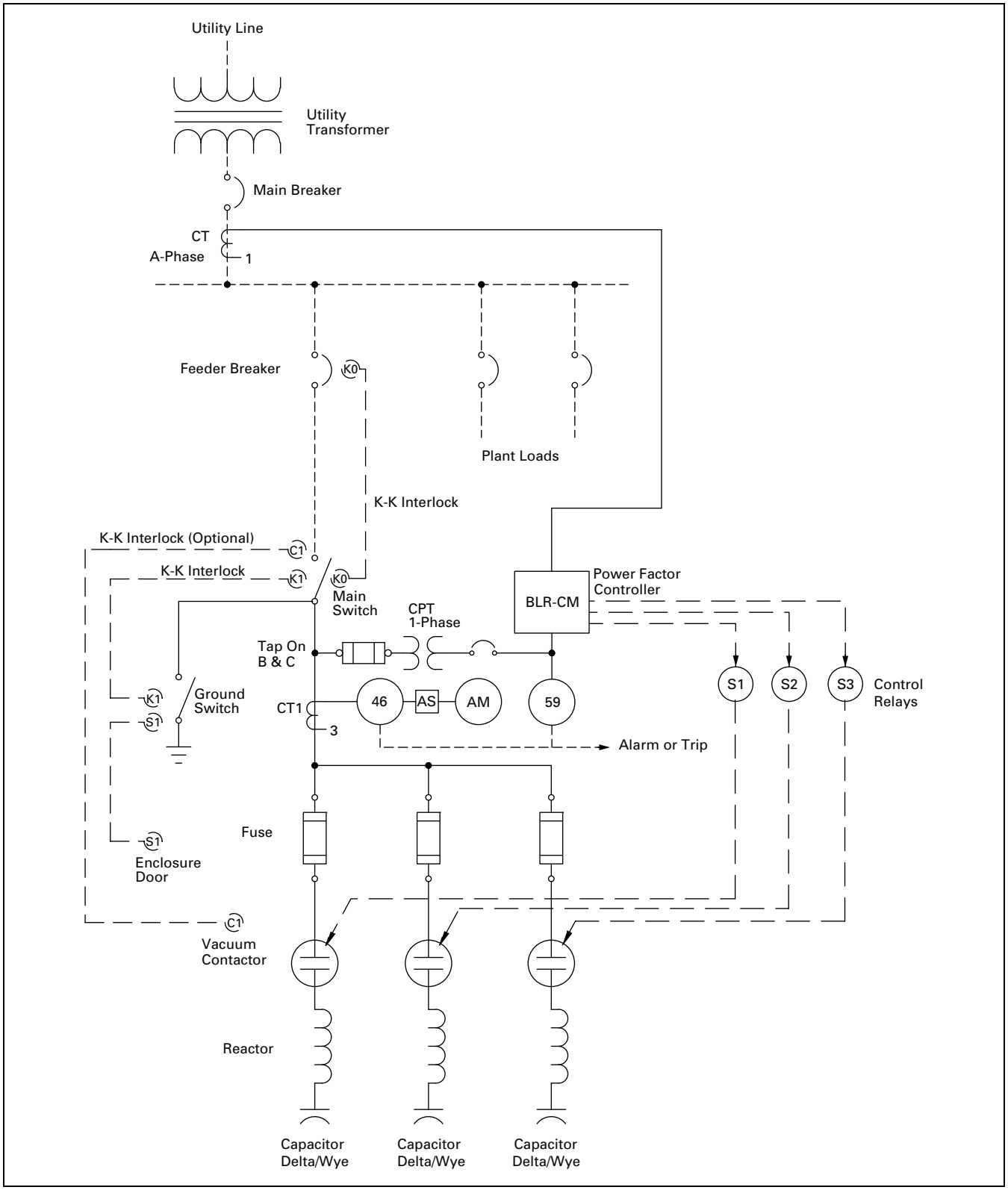



**Figure 35.6-2. Typical Medium Voltage Automatic Power Factor Correction Single-Line Drawing**

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