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# Metal-enclosed, pad-mounted capacitor banks installation instructions

Powering Business Worldwide

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## Contents

## Safety for life

Eaton's Cooper Power series products meet or exceed all applicable industry standards relating to product safety. We actively promote safe practices in the use and maintenance of our products through our service literature, instructional training programs, and the continuous efforts of all Eaton employees involved in product design, manufacture, marketing and service.

We strongly urge that you always follow all locally approved safety procedures and safety instructions when working around high-voltage lines and equipment and support our "Safety For Life" mission.

## Safety information

The instructions in this manual are not intended as a substitute for proper training or adequate experience in the safe operation of the equipment described. Only competent technicians, who are familiar with this equipment should install, operate and service it.

A competent technician has these qualifications:

- Is thoroughly familiar with these instructions.
- Is trained in industry-accepted high- and low-voltage safe operating practices and procedures.
- Is trained and authorized to energize, de-energize, clear, and ground power distribution equipment.
- Is trained in the care and use of protective equipment such as flash clothing, safety glasses, face shield, hard hat, rubber gloves, clampstick, hotstick, etc.

Following is important safety information. For safe installation and operation of this equipment, be sure to read and understand all cautions and warnings.

### Hazard Statement Definitions

This manual may contain four types of hazard statements:

**DANGER**

**Indicates a hazardous situation which, if not avoided, will result in death or serious injury.**

**WARNING**

**Indicates a hazardous situation which, if not avoided, could result In death or serious injury.**

**CAUTION**

**Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.**

**CAUTION**

**Indicates a hazardous situation which, if not avoided, could result in equipment damage only.**

### Safety instructions

Following are general caution and warning statements that apply to this equipment. Additional statements, related to specific tasks and procedures, are located throughout the manual.

**DANGER**

**Hazardous voltage. Contact with high voltage will cause death or severe personal injury. Follow all locally approved safety procedures when working around high- and low-voltage lines and equipment.**

**WARNING**

**Before installing, operating, maintaining, or testing this equipment, carefully read and understand the contents of this manual. Improper operation, handling or maintenance can result in death, severe personal injury, and equipment damage.**

**WARNING**

**This equipment is not intended to protect human life. Follow all locally approved procedures and safety practices when installing or operating this equipment. Failure to comply may result in death, severe personal injury and equipment damage.**

**WARNING**

**Power distribution and transmission equipment must be properly selected for the intended application. It must be installed and serviced by competent personnel who have been trained and understand proper safety procedures. These instructions are written for such personnel and are not a substitute for adequate training and experience in safety procedures. Failure to properly select, install or maintain power distribution and transmission equipment can result in death, severe personal injury, and equipment damage.**

# Product information

## Introduction

Service Information MN230009EN covers instructions for the installation of metal-enclosed, pad-mounted capacitor banks. The single-phase capacitors in these assemblies are furnished in hermetically sealed cases containing pack assemblies impregnated with a dielectric fluid; refer to MN230002EN for installation, maintenance, and field-testing instructions of individual capacitors. Where applicable, the requirements of national and/or local codes and insurance underwriters must be followed.

## Read this manual first

Read and understand the contents of this manual and follow all locally approved procedures and safety practices before installing or operating this equipment.

## Additional information

These instructions cannot cover all details or variations in the equipment, procedures, or process described nor provide directions for meeting every possible contingency during installation, operation, or maintenance. For additional information, contact your Eaton's Cooper Power series product representative.

## Shipment

Pad-mounted capacitor banks are packaged on pallets/skids or in open/closed crates, and shipped on flat-bed trailers, closed vans or containers.

**Figure 1. Metal-enclosed, pad-mounted, capacitor bank**

## Receipt inspection

Upon receipt, carefully inspect all equipment for damage or loss. If any discrepancies are revealed, immediately file a claim against the transportation agency and notify Eaton's Power Systems division.

Use the factory bills of material and construction drawings to verify receipt of all equipment. The inspection should include the following items:

- Inspect enclosure for shipping damage.
- Inspect internal connections and assemblies for proper torque
- Inspect all insulators and bushings for cracks.
- Verify all nameplate data to ensure the equipment is as ordered.

## Storage instructions

Unless the capacitor equipment is to be installed immediately, store to minimize the possibility of mechanical and weather damage. In particular, protect the capacitor bushings, all porcelain, electronic gear and other fragile items against mechanical damage.

## Warranty

The performance of Eaton's Cooper Power series pad-mounted capacitor banks is warranted for a period of one year from the date of shipment. Eaton will, at its option, correct, by repair or replacement, components which may fail because of defects in material or workmanship. The warranty is valid only if the equipment has been inspected completely upon receipt, installed properly, and has not been subjected to abnormal conditions. Such corrections shall constitute a fulfillment of all liabilities of Eaton. The company will not be liable for consequential damages or any expenses incurred in installation or transportation.

The proliferation of nonlinear loads in power systems has given rise to potential harmonic distortion problems when applying capacitors. When applying capacitor banks, a system study is recommended to determine if there will be any resonance between the capacitors and the system that may accentuate existing harmonics. Eaton can perform these studies.

Any other unusual/abnormal service conditions such as those listed in the **Unusual Service Conditions** section of these instructions, should be brought to the attention of Eaton. Modifications to the bank may require revision of the quoted price.

### Instruction manual

Instruction manuals will be forwarded to you prior to the shipment of the equipment and a copy will be enclosed with the shipment. Thoroughly read and understand the instruction manual prior to movement, installation, operation and maintenance of the capacitor bank. The instruction manual will contain the following at a minimum:

- Final Drawings
- Bills of Materials
- Torque Requirements
- These Instructions
- Drawings and Instructions for other Equipment supplied (as available).

### Capacitor fusing

Each phase of a pad-mounted capacitor bank is constructed of one or more series groups of parallel connected capacitor units. Capacitor units are typically protected with external current-limiting fuses. The capacitors may be group fused or protected with dedicated individual fuses. Capacitors may also be internally fused.

### Standards

ISO 9001 Certified Quality Management System

**⚠ WARNING**

**Hazardous voltage. Residual capacitive voltage may be present in the capacitor units after de-energizing. Follow the appropriate shorting procedure to discharge any residual voltage. Failure to comply can cause serious injury or death.**

**⚠ DANGER**

**Hazardous voltage. Explosion hazard. Do not energize a capacitor unit that has been shorted terminal-to-terminal or that has bulged or otherwise damaged tank. Failure to comply will result in death or severe personal injury.**

## Safety precautions

1. Lift all banks with the supplied lifting lugs. Do not lift any equipment by bushings or insulators unless directed by its instructions, if applicable.
2. DO NOT ground a capacitor bank immediately after the bank has been disconnected from the system. For capacitor banks with units containing discharge resistors designed to discharge the capacitor unit from peak rated voltage to less than 50 V in 5 minutes, allow five minutes before grounding. For capacitor banks with units containing discharge resistors designed to discharge the capacitor unit from peak rated voltage to less than 75 V in 10 minutes, allow ten minutes before grounding. In the absence of design information, wait ten minutes before grounding.
3. Ground all parts after de-energization and before touching any current carrying bus or terminals. Ground the neutral of ungrounded capacitor banks.
4. Before handling, short circuit the terminals of all capacitor units.
5. For capacitor banks with units containing discharge resistors designed to discharge the capacitor unit from peak rated voltage to less than 50 V in five (5) minutes, wait at least five (5) minutes before re-energizing the bank after it has been disconnected from the system. For capacitor banks with units containing discharge resistors designed to discharge the capacitor unit from peak rated voltage to less than 75 V in ten (10) minutes, wait at least ten (10) minutes before re-energizing the bank after it has been disconnected from the system. These times may be reduced with consultation of the factory.
6. DO NOT re-fuse and energize a capacitor unit which has a blown fuse without first measuring the capacitance of the capacitor unit to ensure it is within its acceptable tolerance. **Energizing shorted or partially shorted capacitor units may produce unexpected results including catastrophic failure of the capacitor unit and associated equipment.**
7. DO NOT energize a capacitor unit that has been shorted terminal-to-terminal or that has a bulged or otherwise damaged tank. **See Recommended Refusing Procedures.**
8. Use all precautions for capacitor equipment in the same manner as listed under the your company's regulations for high tension equipment.
9. The tank of the capacitor units provides a hermetic seal for the internal elements and dielectric fluid. DO NOT drop, jar, or otherwise handle a capacitor in a manner that would violate the integrity of the hermetic seal. DO NOT lift capacitor units by the bushings. Use only the hanger brackets.

*See Service Information MN230002EN High-Voltage, Single-Phase Installation and Maintenance Instructions* for guidance on the proper handling of individual capacitor units.

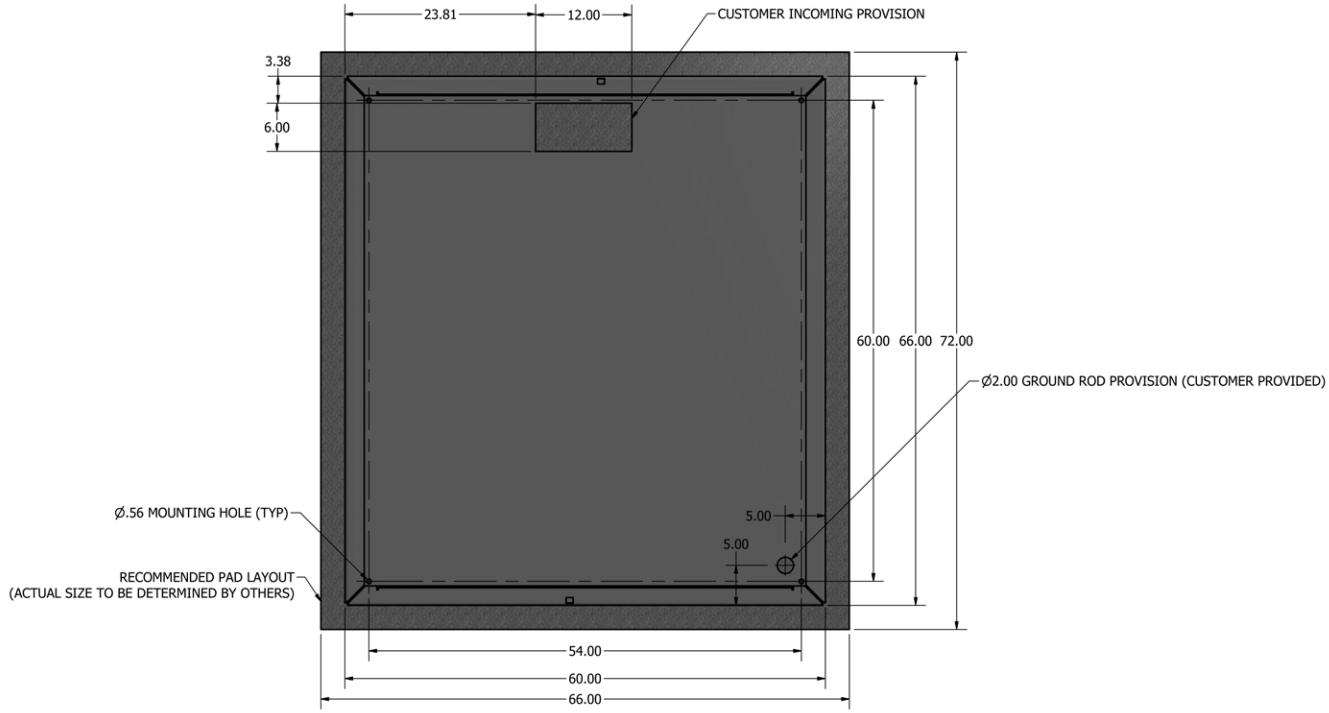


**Figure 2. Typical pad layout**

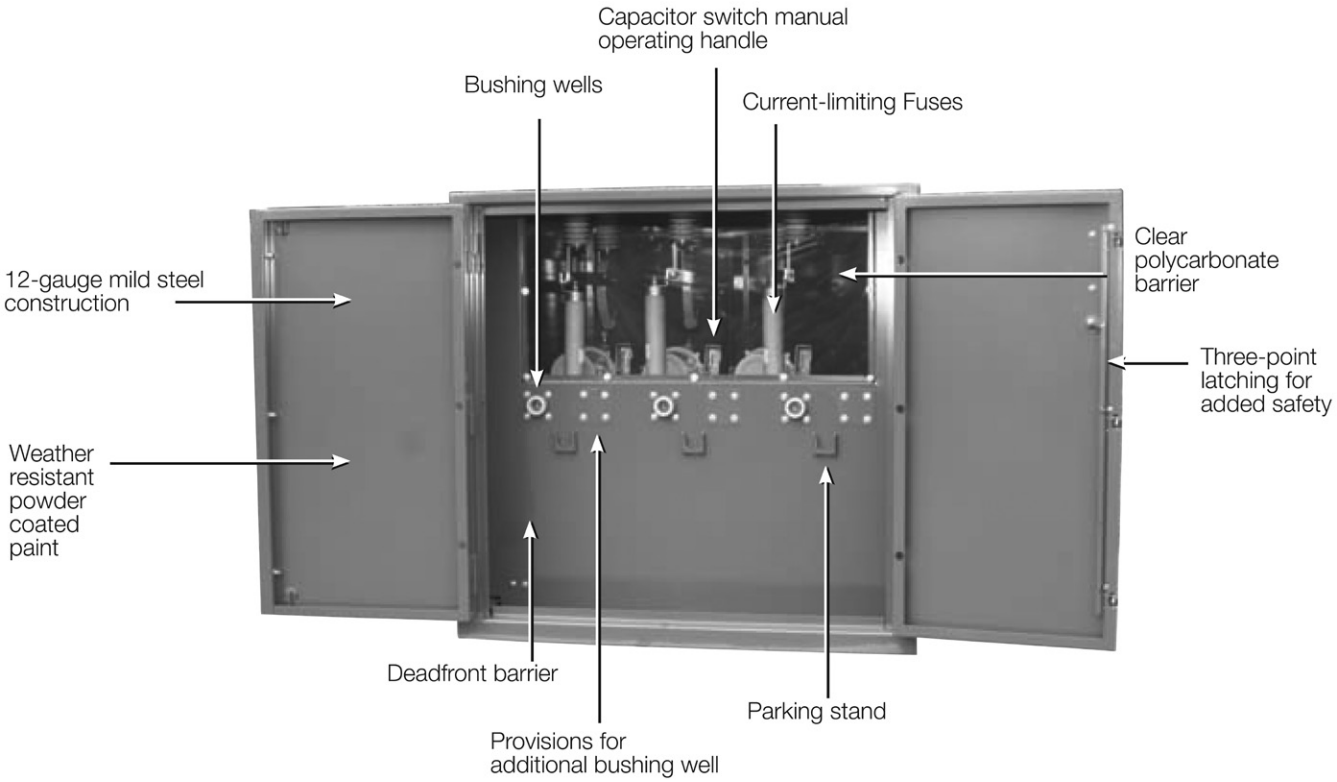


**Figure 3. Typical pad-mounted capacitor bank equipment front section**

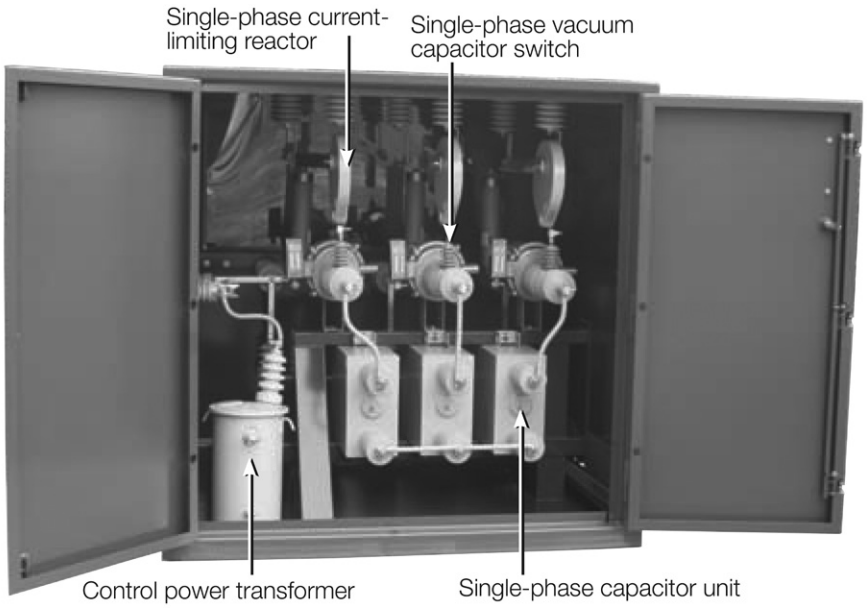


**Figure 4. Typical pad-mounted capacitor bank equipment rear section**

## Equipment description

Pad-mounted capacitor banks (Figures 1 and 3) are suitable for indoor or outdoor installation. The enclosures are typically constructed using mild carbon steel, with a powder coating. Stainless steel options are available. Each bank will be housed in a metal enclosure with configured provisions for interconnect to the power system and convenient access panels.

## Installation instructions

Pad-mounted capacitor banks may be suitable for both indoor and outdoor installation depending on the enclosure design.

Anchor bolt plans (Figure 2) are furnished with the capacitor bank assembly drawings. The design of all concrete footings and foundations are dependent on the soil conditions at the installation site and are thus the responsibility of the customer. Anchor bolts are selected and furnished by the customer.

### Field Integration drawings

Field integration drawings are supplied with the instruction manual. Prior to installation, study the integration drawings to develop a plan for integration into the system. The drawings will identify customer access points and provisions for system connections.

### Moving capacitor equipment

When the pad-mounted capacitor bank is to be moved, it must be lifted using the lifting lugs provided. The lifting lugs are designed to support the weight of only one bank. Using lifting points other than those provided may result in damage to the enclosure and/or the installed components. Do not attempt to slide or skid the pad-mounted capacitor bank, unless enclosure is designed with skids. Lifting speed must be smooth and constant to avoid impulse loading.

Lift all other parts by structural members only in accordance with their respective instructions, if applicable. Do not lift any equipment by the bushings or insulators unless directed by its instructions, if applicable.

### Fuse installation and connections

If the capacitor units are protected with current-limiting fuses, the fuses may be shipped separately from the bank. See the bank instruction manual for drawings showing the current-limiting fuse correctly installed in the bank.

### Electrical connections

The conductor used to connect the capacitor bank to the system should have a continuous current rating of at least 35 percent more than the nominal current rating of the bank.

The assembly of all electrical connections is of vital importance to the proper operation of the capacitor bank. Although the pad-mounted capacitor bank is site-ready, it is highly recommended that the torque of all electrical connections be checked prior to energizing the bank, as shipping could cause loosening of connections.

### Grounding

Each pad-mounted capacitor bank is suppled with a twohole NEMA pad for grounding. Connect a suitable size conductor from the two-hole NEMA pad to the ground as indicated on assembly drawings.

### Series reactors

Series reactors may be supplied for current-limiting and/or tuning of the bank. Reactors connected in series with the capacitor bank should have a continuous current rating of at least 35 percent more than the nominal current rating of the bank. This requirement may be relaxed for highly tuned capacitor/reactor combinations where the currents are more predictable.

### Surge arresters

It is recommended that capacitor banks be protected against overvoltages due to lightning or switching surges with surge arresters.

## Capacitor switching

### Capacitive currents

The capacitor bank switching device should have a continuous current rating of at least 35 percent more than the nominal current rating of the bank. The switching device should be capable of energizing and de-energizing the bank at maximum system voltage, with the maximum harmonic distortion of the bank current and with the bank neutral grounded or ungrounded as applicable.

Grounded wye capacitor banks subject the capacitor bank switching device to a 2 per unit recovery voltage. Ungrounded wye capacitor banks subject the capacitor bank switching device to recovery voltages higher than 2 per unit and as high as 4.1 per unit. The voltage rise across series connected tuning reactors result in higher recovery voltages than encountered when switching banks without series connected reactors.

Capacitor switching devices not rated for capacitor switching may restrike resulting in high system voltage surges that can damage the capacitor bank, arresters and other equipment.

### Inrush currents

When the capacitor bank switch is closed, a highfrequency, high-magnitude current flows into the bank attempting to equalize the system and capacitor voltages. If the bank is isolated from other banks, the inrush current is limited by the inductance of the source and the capacitance of the bank. Typical values for this inrush current are 5 to 20 times the nominal bank current at frequencies of several hundreds of hertz.

If two or more capacitor banks are connected on the same bus, very high magnitude and frequency currents are possible during switching. Only the impedance of the banks and the circuit limit the current. Care should be taken when applying capacitor banks of differing sizes or more than two banks back-to-back as the resulting transient currents due to switching may apply an $I^2t$ duty to the individual fuses beyond their withstand.

It is recommended that the factory be consulted when the banks will be switched back-to-back or anytime there is doubt regarding the magnitude and frequency of the currents, or the suitability of the installation.

**⚠ DANGER**

**Hazardous voltage. Contact with high voltage will cause death or severe personal injury. Follow all locally approved safety procedures when working around high- and low-voltage lines and equipment.**

## Initial inspection and testing

The entire bank should be carefully inspected prior to initial energization. Included in the initial inspection should be a check of the following points:

1. Many electrical joints can relax due to material deformation or heavy vibration during shipping. Eaton's Power System division recommends checking the torque all electrical joints before initial energization.
2. Verify the mechanical assembly of the bank is in accordance with the outline drawings and is sound.
3. Verify all shipping bracing is removed.
4. Wipe clean all insulators and bushings. Visually inspect for damage such as chips and cracks. Dirty insulators and bushings may cause flashover and damage to the equipment.
5. Visually inspect all capacitor units for damaged tanks and leaks.
6. Verify settings of all protective relaying and ensure it is activated.
7. Test operate all load-break, disconnect, and grounding switches and secondary accessory equipment.
8. Just prior to energization, open all grounding and shorting switches and ensure all grounding and shorting tackle is removed.
9. Verify all supplied interlock or other safety devices operate properly.

## Initial energization

Immediately after initial energization, perform the following:

1. Verify that the voltage rise is as expected.
2. If the pad-mount bank is fitted with unbalance protection, check the level of unbalance at the unbalance detection relay. A small inherent unbalance may be nulled if the relay has such capability.

## Operation

### Unusual service conditions

Unusual service conditions may require special construction or operation and should be brought to the attention of the factory. Among such unusual service conditions are:

1. Operation at altitude above 6000 feet (1800 m).
2. Residual voltage at energization greater than 10% of rated voltage.
3. Exposure to damaging fumes or vapors, salt air, steam, excessive moisture or dripping water.
4. Exposure to explosive dust or gases.
5. Exposure to excessive, abrasive or conductive dust.
6. Exposure to severe weather conditions.
7. Exposure to abnormal vibration, shocks or tilting including earthquakes.
8. Unusual transportation or storage conditions.
9. Installation that prevents adequate ventilation.
10. Operation in ambient temperatures outside (above or below) the rating of the equipment.
11. Voltage stress on the insulation and dielectric outside the continuous and momentary ratings.
12. Operation at frequencies other than the rated frequency.
13. Unusual wave form distortion or harmonics causing excessive kvar loading or voltages.
14. Back-to-back switching.
15. Any other unusual or special operating requirements.

### Overvoltage operation

The capacitors are designed for continuous contingency operation at 110% of rated voltage. Operation of the capacitor bank at voltages above 110% of rated voltage for extended periods of time will shorten the life of the capacitors and should be permitted only in emergency conditions.

These overvoltages are permissible since a safety factor is provided in the design of the capacitors. The magnitude of overvoltage that can be tolerated without loss of capacitor life is dependent upon the number and duration of the applied overvoltage. The values shown in Table 1 are based on full life expectancy, with overvoltages occurring a maximum of 300 times during the life of the capacitor. For operation at overvoltages beyond those shown in Table 1, consult your Eaton's Cooper Power series product representative.

**Table 1. Overvoltage operations**

| Duration | Times rated voltage[1] |
|---|---|
| 6 cycles | 2.20 |
| 15 cycles | 2.00 |
| 1 second | 1.70 |
| 15 seconds | 1.40 |
| 1 minute | 1.30 |
| 30 minutes | 1.25 |
| 30 minutes every 24 hours | 1.15[2] |

1 Multiplying factors apply to rms rated voltage. Crest voltage must not exceed rms by more than $\sqrt{2}$.
2 There is no limit to the number of overvoltages during the life of the capacitor unit.

### Undervoltage operation

The bank may be operated at voltages which are less than the capacitor voltage ratings. However, full kvar output varies in direct proportion with the square of the ratio of the applied voltage to the rated voltage.

**⚠ WARNING**

**Hazardous voltage. This procedure must only be performed on a capacitor bank or unit that has been removed from service. Failure to comply can result in serious injury or death.**

## Inspection and maintenance

### Routine maintenance

Eaton's Cooper Power series pad-mounted capacitor banks are virtually maintenance-free. As guided by customer experience, periodic maintenance should include the following:

1. Visual examination of the bank looking for foreign matter and damaged or excessively dirty insulators.
2. Visual examination of all capacitor units for damaged or excessively dirty bushings, leakage or unusual swelling.
3. Visual examination of all external fuses for damage.

4. Examination of all electrical connections for signs of overheading.
5. Examine all metal parts for signs of corrosion.
6. If supplied with relay protection, the protective relaying should be tested at an interval consistent with customer practices.
7. If supplied with unbalance protection, check the level of unbalance at the unbalance detection relay.

## Recommended refusing procedures

Use the following refusing procedure for banks:

1. De-energize and isolate the capacitor bank.
2. Ground the incoming phases and neutral after allowing the capacitor bank to discharge. See SAFETY PRECAUTIONS.
3. Temporarily short circuit all capacitor units to ensure the capacitor units are safe to handle.
4. Check the capacitance of the unit with the operated fuse with a capacitance meter to verify that it is within tolerance. If the bank is group fused, measure the capacitance of each capacitor in the phase if wyeconnected. If delta and 2 fuses have operated, measure the capacitance of each capacitor in the affected phase. If delta and only one fuse has operated, measure the capacitance of each capacitor in both phases fed by the fuse. Each fuse feeding the failed capacitor in a delta-connected bank should be replaced.

   When group fusing is used, other items are also protected by the fuse. Eaton recommends verifying all components for proper function prior to re-energizing the bank.

   Group fusing in addition to individual capacitor fusing is an optional arrangement for pad-mounted capacitor banks. If a group fuse operates without any of the individual capacitor fuses operating, check all components for proper functioning and check all capacitors per the recommendations provided for group fusing. If an individual capacitor fuse operates, but not the group fuse, verify fuses have not operated without indication and check all capacitors per the recommendations provided for group fusing. The nominal capacitance of a capacitor unit can be calculated with the following formula:

$$C = \frac{Q}{2\pi f V^2} \times 10^9$$

Where: C = Unit Capacitance in µF

Q = Unit nameplate kvar

π = 3.1416

$f$ = Unit nameplate frequency

V = Unit nameplate voltage in volts

**⚠ DANGER**

**Hazardous voltage. Explosion hazard. Do not energize a capacitor unit that has been shorted terminal-to-terminal or that has bulged or otherwise damaged tank. Failure to comply will result in death or severe personal injury.**

If the unit capacitance is within tolerance, inspect the tank for bulges or other damage and the busings for damage. Replace the capacitor with any such damage.

**Note:** Due to the process by which the capacitor units are filled with dielectric fluid, the tank will have inherently have a very slight bulge. This is normal.

## Ordering replacement capacitor units

Replacement capacitor units should be rated for application in the particular pad-mounted capacitor bank. It is important that replacement capacitor units meet the rating, duty and dimensions of the originally supplied capacitor units.

## Field testing

Checking the capacitance of a unit is the best way to determine whether or not the capacitor is partially failed. High voltage insulation strength tests may be used, on two-bushing units, in an effort to identify capacitors which would fail in the near future if they were re-energized. The results of this type of testing and the problems related to high-voltage testing in the field indicate that the value of this type of test is somewhat limited.


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