

# Pad-Mounted Capacitor Banks



*Dead-front compartment with bushing wells to accommodate inserts and elbow connectors (not furnished) for cable entry.*



*Live-front Compartment with optional clear polycarbonate barrier enhances component visibility.*

## Federal Pacific Pad-Mounted Capacitor Banks for Distributed Capacitance On Underground Distribution Systems

Pad-mounted capacitor banks have been utilized in the electric power industry from the beginning of underground distribution systems. Federal Pacific has the capability to build capacitor banks in a variety of configurations skid-mounted for the mining industry, open-structure for substations, and metal-enclosed for commercial and industrial markets. Now, Federal Pacific develops a comprehensive offering of pad-mounted capacitor banks for electric utility accounts that has broad applicability throughout the industry, including non-utility facilities.

### Capacitor Banks Improve System Performance

As the length of a distribution feeder increases, the higher the voltage drop will become. Therefore, capacitors are installed to boost the voltage back within the operating tolerance of the system and thereby provide voltage stability. Without capacitors, load circuits will operate at reduced voltage . . . motors will run slower and overheat, lights will not burn as bright, relays in process industries will drop out, etc., creating end-user system disturbances.

Capacitors extend the range of substations by allowing feeder circuits to have longer runs of cable. Extending the range of the substation also means that capacitors serve to increase network capacity.

For individual customer facilities, it may be necessary or desirable to provide improved voltage regulation at the installation. For this purpose, on-site pad-mounted capacitor banks close to customer loads provide power factor correction.

These three benefits: (1) voltage stability, (2) increased network capacity and (3) power factor correction all combine to provide (4) cost savings through lower system losses. As a result, capacitor banks contribute significantly to the economical operation of electric power systems.

### Capacitor Characteristics

Capacitors as an electrical device have a unique characteristic – they are a reactive impedance device that stores and discharges energy to assist in the regulation of voltage. For applications in the electric power industry, individual capacitor units are rated in kvars (kilovolt-amperes reactance) and are applied in a bank . . . called a shunt-capacitor bank. For underground distribution systems, these capacitor banks are installed in pad-mounted enclosures as small distributed installations that are tapped onto the main-primary feeder circuits at a considerable distance from the substation. These distributed banks can be fixed on the circuit or switched on and off as dictated for system stability.



*Figure 2. Pad-mounted capacitor banks bring esthetic view to field installations and components are not exposed to the environment.*



*Figure 3. Incoming connections are through bushing wells that accommodate inserts and elbows (not furnished) to the protective devices, which in this installation are current-limiting fuses visible through the polycarbonate barrier.*

A three-phase shunt capacitor bank is arranged with one or more capacitors in each phase (called a leg) of the bank. Typical sizes for individual capacitors are 100 kvars, 200 kvars, 300 kvars up to 600 kvars. Units less than 100 kvars are also available. If there is more than one capacitor in each leg, the capacitors are connected in parallel. For capacitors in parallel, the kvars add so that a bank with two 200 kvar capacitors per phase would be a 1200 kvar bank.

## Capacitor Bank Components

When developing a capacitor bank, establish the required size of the capacitor bank based on the capacitance necessary to offset the inductive reactance of the connected load. Assume a 1200 kvar shunt capacitor bank is required. Each leg will require 400 kvars, which can be accomplished using two (2) 200 kvar capacitors connected in parallel per phase or, alternately, one 400 kvar capacitor per leg.

In addition to the capacitors, the components required for a pad-mounted capacitor bank include: 600-ampere bushings or 200-ampere bushing wells for connecting and terminating incoming cables; fuses for isolating the bank if it becomes faulted; capacitor switch for switching the bank on/off; inductive reactors to limit in-rush currents; and, for a switched bank, a voltage transformer for control power. In a pad-mounted capacitor bank, these components are arranged as illustrated in Figure 4.

**Bushings (600 amperes) or bushing wells (200 amperes)** are used to provide input connections from the main primary feeder to the pad-mounted capacitor bank. These connections can be either radial through a single three-phase set of connectors, or looped through two three-phase sets of connectors. Federal Pacific brand cycloaliphatic epoxy bushings and bushing wells are provided for all capacitor banks. Federal Pacific bushings and bushing wells are designed to ANSI 386 requirements and therefore accommodate all similarly designed loadbreak and non-loadbreak elbow connectors, components and accessories. Loadbreak elbows are not to be used for switching the capacitors.

**Fuses** are applied in pad-mounted capacitor banks to provide protection for the circuit in the event of a fault in the bank, such as an internal fault in the capacitor. In the smaller pad-mounted capacitor banks, each leg is fused and the bank taken off line when one capacitor fails because the overvoltage is too great on the remaining capacitors. Current-limiting fuses help to prevent capacitor case rupture. See Figures 3 and 4.

**Switches** are applied in each leg to take the bank on or off line. Capacitor switching is an extremely tough duty and switching can be frequent. The duty is severe because the rate of rise of the recovery voltage during a switching operation is very steep, which can cause a restrike if the dielectric is not adequate. Therefore, air is not typically used as the insulating medium for capacitor switches because the length of the air gap, and therefore the size of the switch, has to be great to avoid a restrike.

The frequent switching requirement is best handled by a vacuum switch, which has very little wear on its contacts during switching. Insulating medium available for the vacuum interrupter includes oil, SF<sub>6</sub> gas and solid dielectric. Federal Pacific offers the customer the opportunity to select the brand of capacitor switch it prefers.

**Inductive reactors** are applied in capacitor banks to tame the capacitor switching duty by (a) reducing switching in-rush surges and (b) limiting the fault current. The reactors used in Federal Pacific's Pad-mounted Capacitor Bank are made by Federal Pacific's Transformer Division, which has made inductive reactors for capacitor-bank applications for many years.

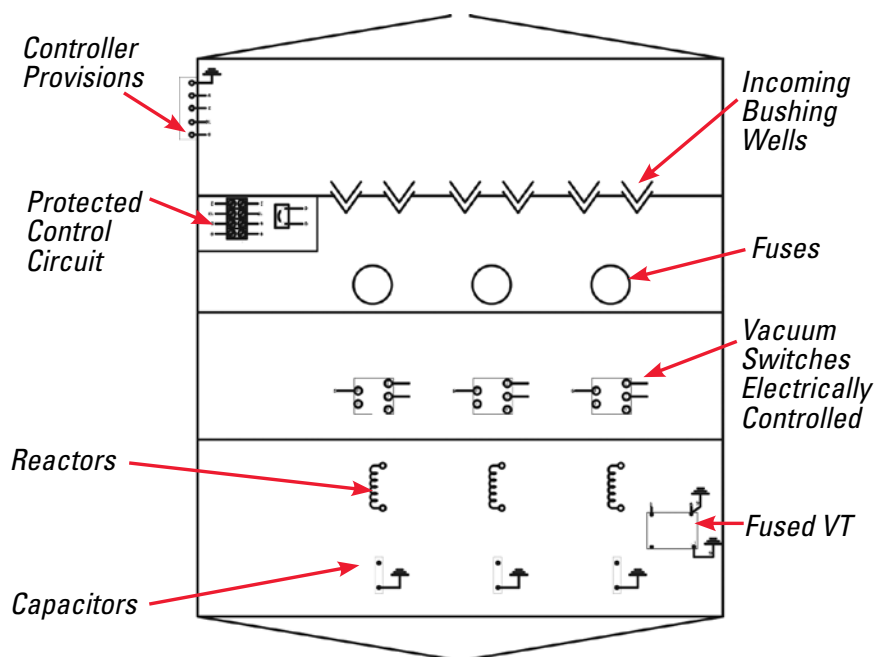
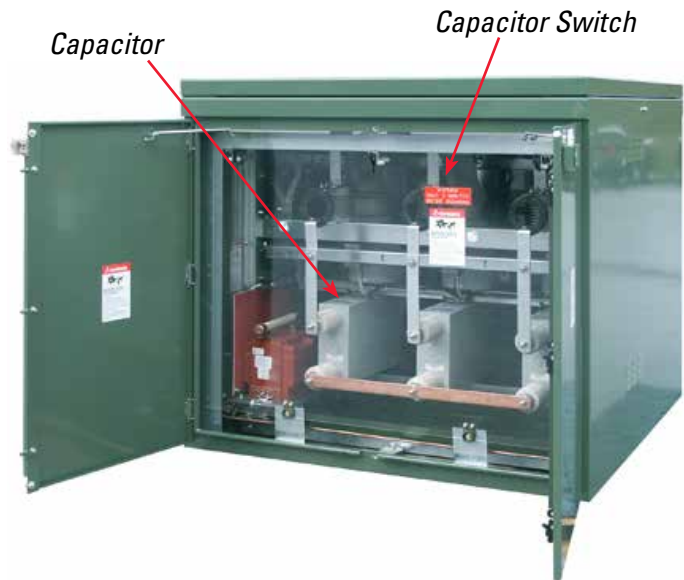


Figure 4. Physical orientation of components within the pad-mounted capacitor bank are illustrated in the above diagram.

**Control components** are applied in capacitor banks to supply control power, sensing and the automatic switching capability necessary to switch the bank on and off line. A fused voltage transformer (1500kva) is tapped to the high-voltage circuit and supplies all control power for the pad-mounted capacitor bank. The secondary of the voltage transformer includes a low-voltage circuit breaker for switching and protecting the secondary circuit. Optionally, the transformer can be used to provide sensing voltage input proportional to the line voltage to a controller. The optional controller (or controller socket) uses the input voltage as a measure of line voltage, which establishes whether the capacitor bank is to be switched on or off line. Such switching can be performed manually locally using the handle on the capacitor switch, which is hookstick operable. Or, optionally, electrically with the capacitor switch relayed for automatic switching that will include a capacitor-trip device, and remotely when appropriate communication components are provided by the customer. All of these components can be arranged within a compact enclosure. The circuit diagram for a typical pad-mounted capacitor bank is illustrated in Figure 6.

Pad-mounted capacitor banks have valued advantages for the underground distribution system.

1. First, they extend the ability of the power supply system to support longer lines to the load.
2. Second, growing systems into newer developments are more typically served underground and pad-mounted capacitor banks fit this growth segment.
3. Third, the enclosed components offer a more esthetic appearance than exposed overhead components, making them well suited for utility, industrial, commercial and institutional installations.
4. Fourth, the enclosure affords considerable protection from environmental flora and fauna.
5. Fifth, access to components is easier to achieve at ground level than on a pole.
6. Sixth, component integration can be arranged in a fairly compact low-profile enclosure.



*Figure 5. Capacitor bank components isolated from the environment in a ventilated, 11-gauge steel enclosure with three-point latches.*

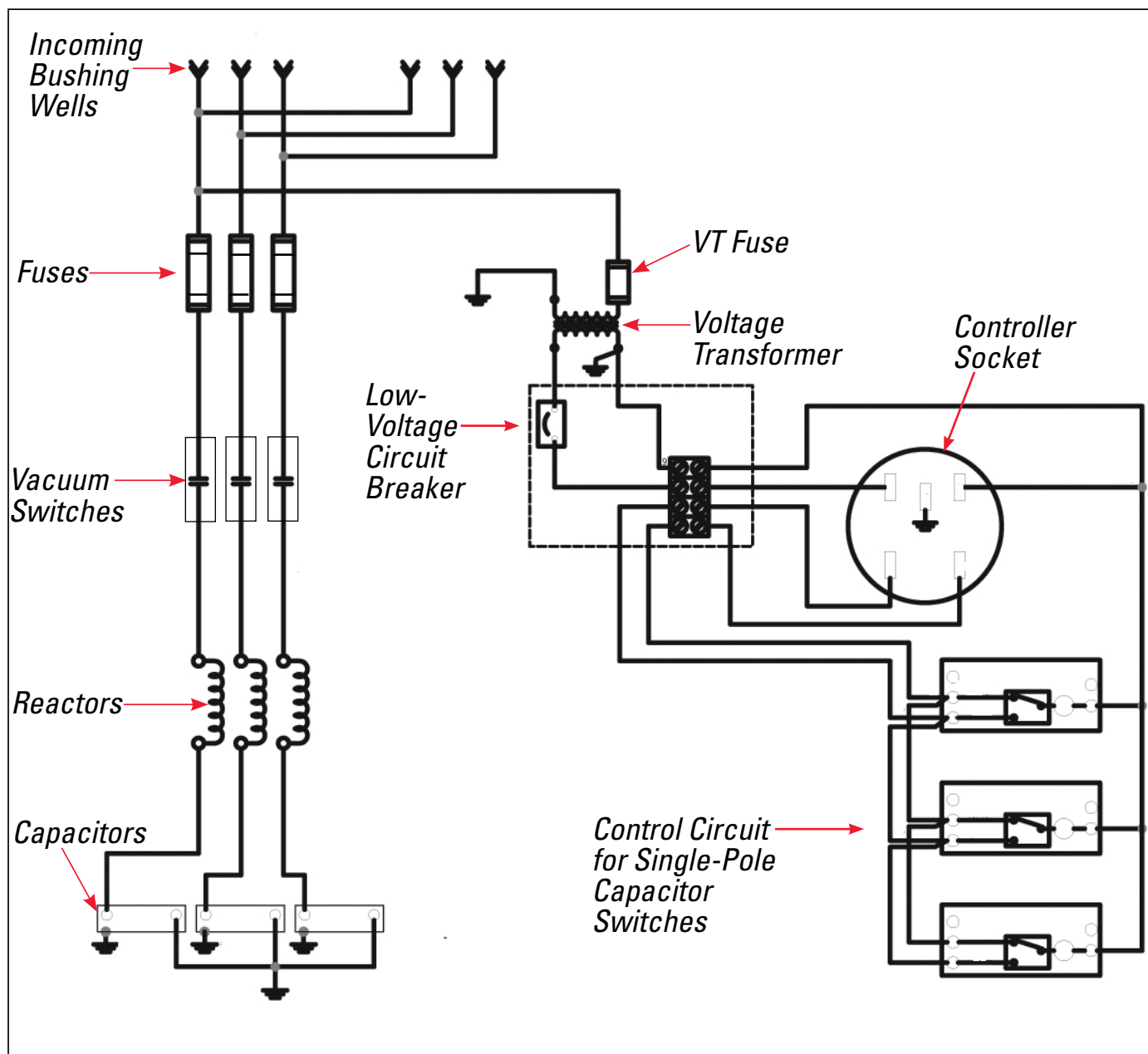


Figure 6. Circuit diagram for typical pad-mounted capacitor bank illustrates relationship of high-voltage and low-voltage components within the enclosure.



## Dead-front Compartment for Cable Entrance

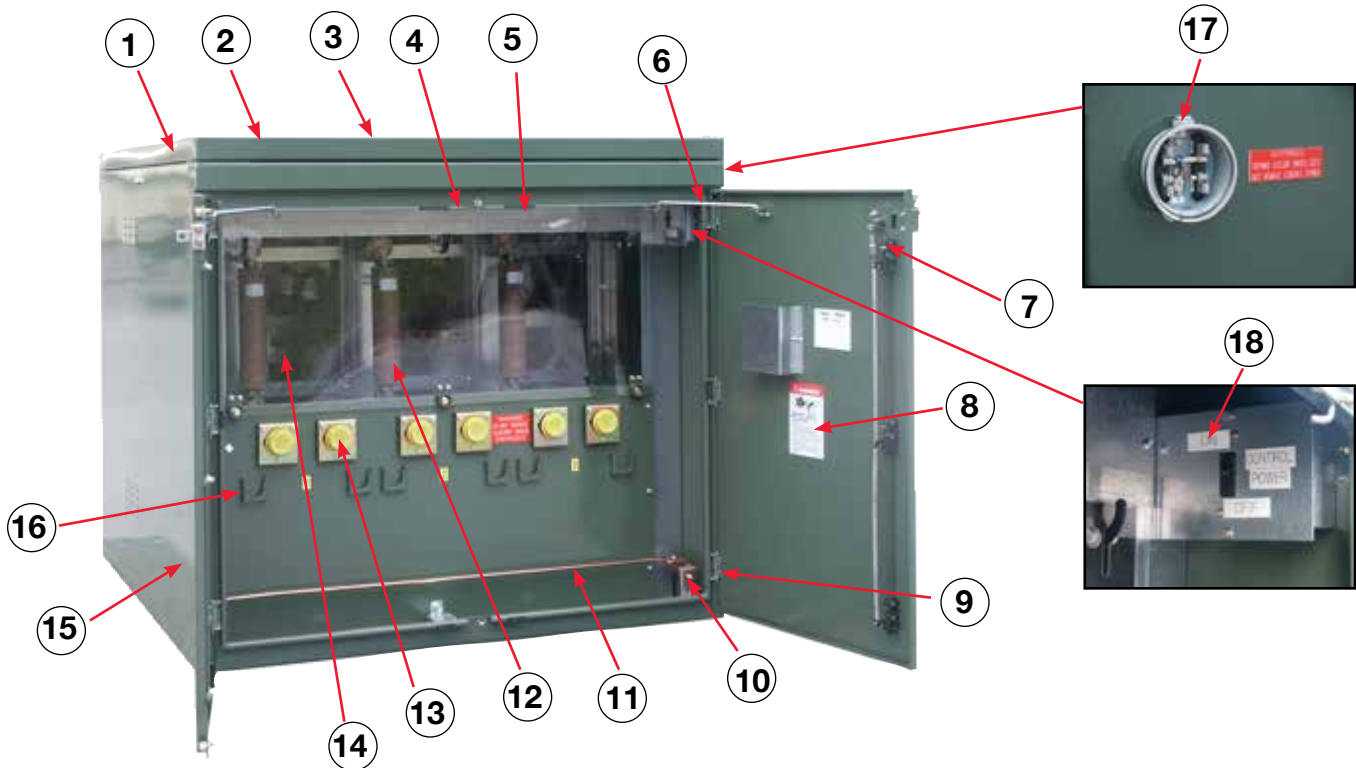


Figure 7. Pad-mounted Capacitor Bank - Features of the deadfront compartment.

1. **Ventilated at Roof**—Interior ventilation maze helps keep interior dry.
2. **"No-Drip" Compound**—Coating insulates underside of roof to control moisture condensation.
3. **Cross Break on Roof**—Provides slope to roof to keep moisture from collecting on top.
4. **Ventilated at Doors**—Deep overlapping of doors with enclosure door-opening flanges develops a ventilation maze to increase air movement inside while restricting penetration.
5. **Gasket Bumpers**—Around door opening on flanges protect finish from metal-to-metal contact.
6. **Stainless Steel Windbrace**—Secures doors open from wind-blown closure.
7. **Automatic Door Latches**—Self-latching, self-resetting three-point arrangement has no fast moving parts to snag personnel; automotive-type door latches pass NTSB automotive test requirements.
8. **Hazard Alerting Signs**—Necessary warning are provided on long-life labels
9. **Stainless Steel Hinges and Pins**—Insure proper door operation without sticking.
10. **Enclosure Ground Pad**—In termination compartment allows connection of concentric neutrals and enclosure ground rod.
11. **Ground Bus**—Round edge copper bus across full width of compartment allows connection of grounds.
12. **Current-Limiting Fuses**—Provide protection for capacitor bank.
13. **200-Ampere Bushing Wells**—FP cycloaliphatic bushing wells meet ANSI 386 requirements; accommodate all brands of inserts and elbows—not to be operated when capacitor switch is closed.
14. **Removable Clear Polycarbonate Barrier (optional)**—Secured to Enclosure with pentahead bolts; lifts off to provide access to fuses. Red GPO-3 insulating fiberglass barriers are standard.
15. **11-Gauge Steel Enclosure**—Meets ANSI C57.12.28 enclosure security requirements.
16. **Parking Stands**—Allow installation of standoff bushings to accommodate elbows removed from energized connector interface.
17. **Provisions for Controller**—Options available to provide mounting ring and controller (on side on enclosure).
18. **Control-Power Switch**—Option allows on/off control of power to mounting ring and controller.

## Livefront Compartment for Cable Entrance

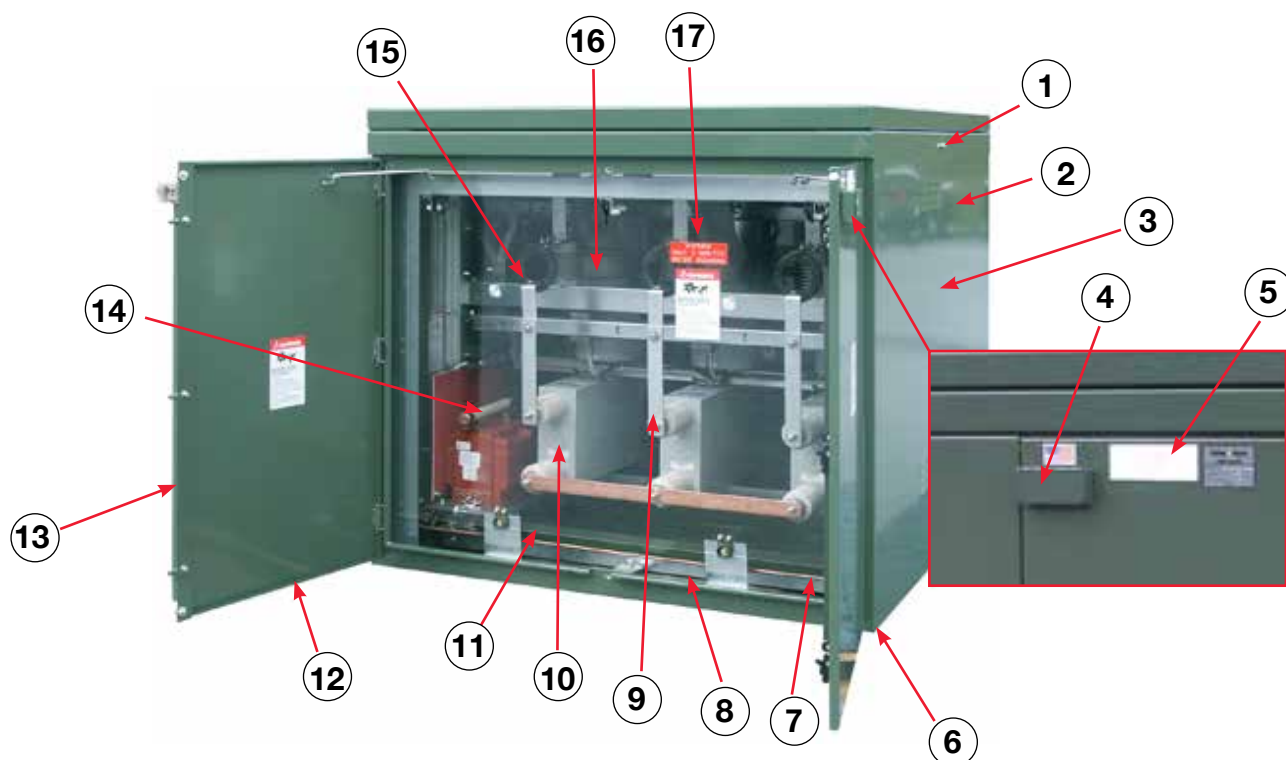


Figure 8. Pad-mounted Capacitor Bank - Features of the live-front compartment.

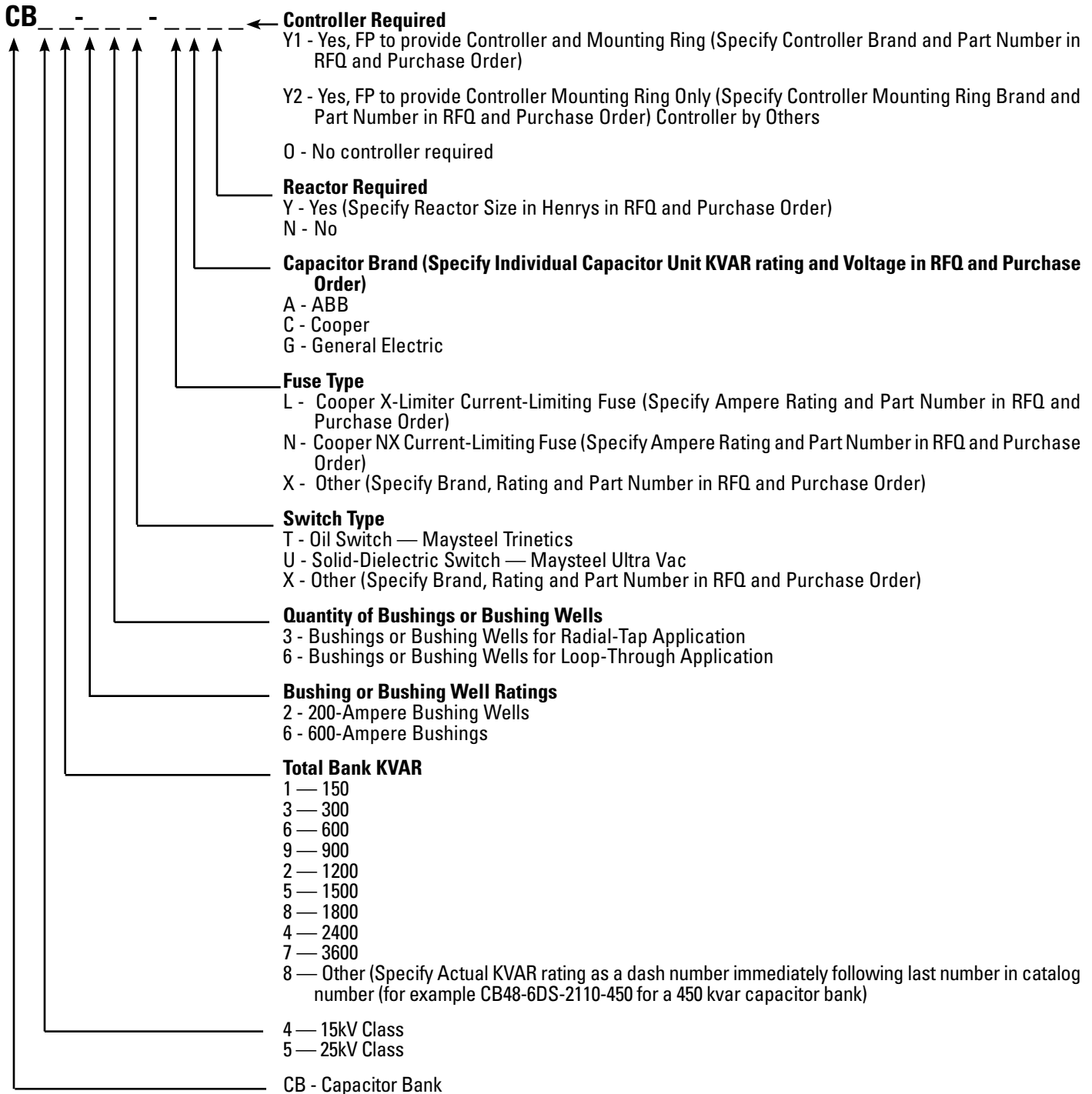
1. **Blind-Tapped Holes** – Provide secure location for lifting angles with protective non-hydroscopic material to keep angle from scratching enclosure during handling and installation.
2. **Louvers** – Provide additional ventilation for enclosures in areas requiring increased air circulation.
3. **Enclosure and Finish** – Exceed security requirements in ANSI C57.12.28.
4. **Stainless Steel Door Handle** – Hinged cover blocks access to pentahead bolt until padlock is removed.
5. **Nameplate and Signs** – Provide pertinent unit information and optional signs for customer designations.
6. **Gasketing on Flange** – At bottom of enclosure provides protection during installation; seals enclosure bottom to pad.
7. **Ground Bus** – Flat round-edge copper bus for enclosure ground full width of door opening.
8. **Galvanized Floor Plate** – Below essential areas provide further isolation from environment, but leaves openings at grounding areas.
9. **Aluminum Bus** – Interconnecting components is standard; copper bus is optional.
10. **Capacitors** – Sized to meet bank requirements with copper bus interconnecting ground bushings.
11. **Containment Reservoir** – Collection pan for any liquid leaking from damaged capacitors.
12. **Passive Door** – Secured closed with pentahead bolts and is overlapped by active door.
13. **Finish** – Standard Color is Munsell No. 7GY3.29/1.5 Dark Green (optional colors available).
14. **Fused Voltage Transformer** – Provides control power for switched bank controllers and operation of capacitor switches.
15. **Reactors** – One per phase to limit in-rush currents limit fault current.
16. **Capacitor Switch** – Single-pole manual switching or switched bank with controller for capacitor circuits.
17. **Removable Clear Polycarbonate Barrier (optional)** – Secured to enclosure with pentahead bolts; lifts off to provide access to capacitors and VT fuses. Red GPO-3 insulating fiberglass barriers are standard.



## HOW TO ORDER:

Federal Pacific will develop 15kV and 25kV pad-mounted capacitor banks sized to 3600 kvars. The customer is to select (1) the desired components, choosing capacitors, bushings, bushing wells, current-limiting fuses, capacitor switch, reactor, choosing from the brands listed for each component, (2) the desired optional features from those listed and (3) whether the bank is to be manual, switched or automatic.

## Pad-mounted Capacitor Bank Catalog Number Designations:





## OPTIONAL FEATURES

When ordering, specify optional features desired by adding individual suffix letter designations following the last digit of the catalog number of the unit specified developed using the chart of Catalog Number Designations in the "HOW TO ORDER" section on page 8.

For example, a 15kV 1200 kvar capacitor bank with 200-ampere bushing well for loop-through application using a solid-dielectric switch and NX current-limiting fuses, GE capacitors, a mounting ring for a controller and copper bus instead of aluminum will have the designation: CB42-26U-NGYY2-C.

## BARRIERS

- B6 Clear Polycarbonate Barrier instead of red GPO-3 fiberglass
- B7 Hinged Barriers instead of lift-off barriers on deadfront side.
- B8 Hinged Barriers instead of lift-off barriers on livefront side.

## SPECIAL FINISH COLOR & MATERIALS

- C All Copper Bus
- F2 ANSI 61 Light Gray
- F3 ANSI 70 Sky Gray
- F5 Coal Tar Coating on Lower Three Inches of Cabinet
- F6 Type 304 Stainless-Steel External Surfaces (doors, roof, and enclosure).
- F7 Stainless-Steel or Non-Ferrous Hardware, including internal mounting angles, brackets, etc. and with three-point roller latch on door replacing automatic door-latch system.
- F8 All stainless steel – Combines -F7 and -F8

**Consult factory if other features are required.**

## UNIT DIMENSIONS

kV Voltage	KVAR	Height	Width	Depth
15	150-1800	60"	64"	68"
	2400 and up	CONSULT FACTORY		
25	CONSULT FACTORY			



*Figure 9. Pad-mounted capacitor banks provide an esthetic installation, avoiding overhead clutter.*



*Figure 10. Pad-mounted capacitor banks provide power factor correction near industrial loads.*

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