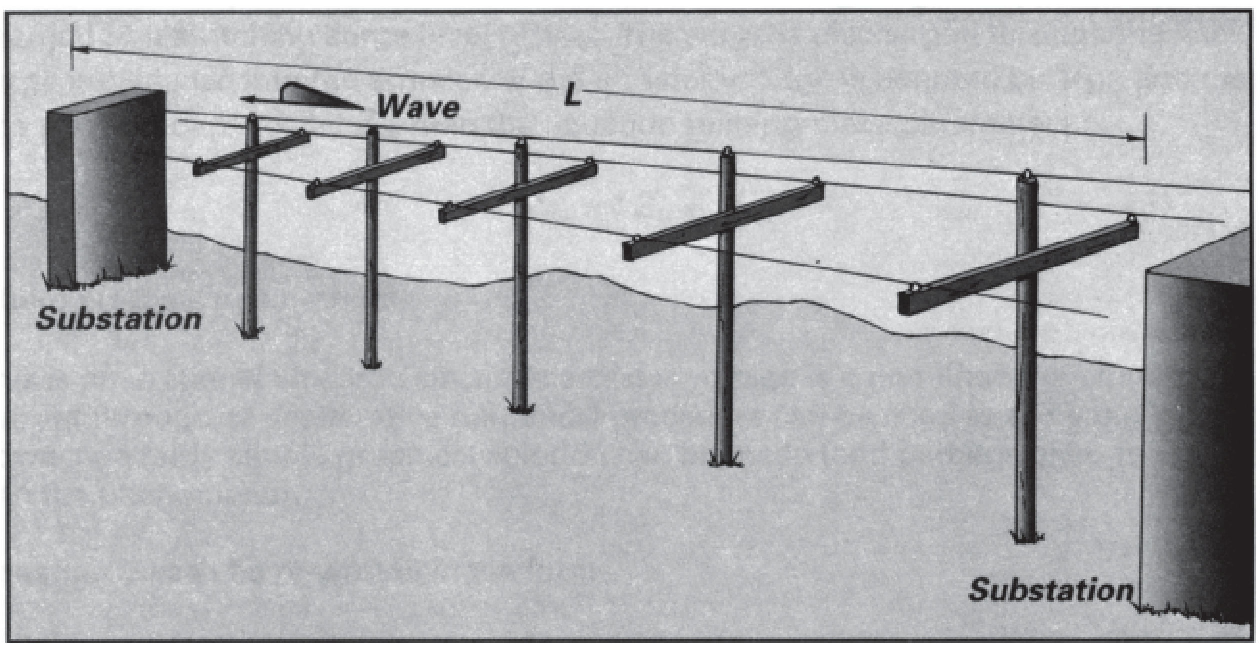
Calculation of Arrester Energy During Transmission Line Switching Surge Discharge



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Calculation of Arrester Energy Duty During Transmission Line Switching Surge Discharge

A switching surge line discharge produces a substantially rectangular impulse of current through a metal oxide arrester connected to the end of the line. The associated arrester voltage is also substantially rectangular. The energy discharged into the arrester is given by

$$E = V_a \cdot I_a \cdot t \qquad (1)$$

where V_a is the arrester voltage, I_a is the arrester current and t_d is the duration of the switching impulse. The duration of the switching impulse is typically in the order of one or two milliseconds, for line lengths in the range of 100-200 miles, and can be estimated as the time for a surge to travel twice the length of the line,

$$t = \frac{2L}{c} \qquad (2)$$

where L is the line length and c is the surge travel speed (approximately the speed of light, 3 x 108 m/s or 186,000 mi/s).

The arrester discharge voltage and current can be determined through knowledge of the arrester and line parameters and the level of the switching surge. Suppose the line is charged to a switching surge level of V_{ss}. The surge is discharged through the line surge impedance into the arrester. If the arrester voltage is denoted by V_{arr}, and the line surge impedance by Z_o, then the equation relating these parameters is

$$V_{ss} = I\,Z_o + V_{arr} \qquad (3)$$

where I is the surge current.

This is an irrational equation since the arrester voltage is a non-linear function of the current through it. An iterative numerical procedure can be used to solve the equation, however a fairly simple graphical solution can be made (and perhaps gives more insight into the phenomena).

Equation (3) can be re-written in the form

$$V_{ss} - I\,Z_o = V_{arr} \qquad (4)$$

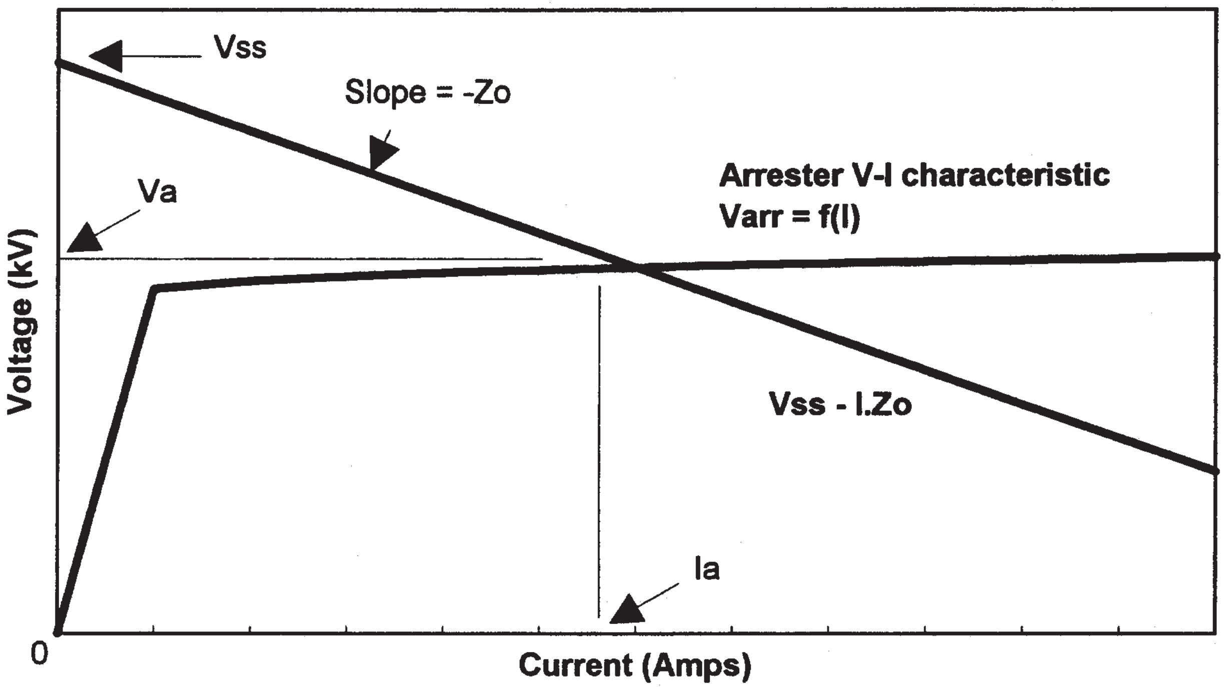
The arrester voltage and discharge current which satisfies this equation is determined from the intersection of the curves

$$V = V_{ss} - I\,Z_o \text{ and } V = V_{arr} \qquad (5)$$

($V = V_{arr}$ is simply the volt-amp curve of the arrester).

The graphical solution is depicted in Figure 1. The two curves intersect at the point $V = V_a$, $I = I_a$, the arrester discharge voltage and discharge current needed in equation (1) to calculate the energy discharged into the arrester.

Figure 1



It is possible to construct families of curves for different surge arrester ratings, different switching surge levels and different line surge impedances. Examples are given in the following figures for 69, 115, 138 and 161 kV lines protected by PVN arresters. For each figure, a 2.6 per unit switching surge level is used, representative of typical situations. (A different per unit value would simply result in a proportional shift in the $V_{ss} - I Z_o$ curves in the direction of the y-axis as would voltage regulation from nominal).

Example Calculation

138 kV line, 200 miles (322 km) long, surge impedance 400 ohms.
PVN surge arrester, 84 kV MCOV

From the 138 kV figure, find the intersection of the 400 ohm curve with the 84 kV MCOV curve, to obtain

$$V_a = 190 \text{ kV and } I_a = 250 \text{ A}$$

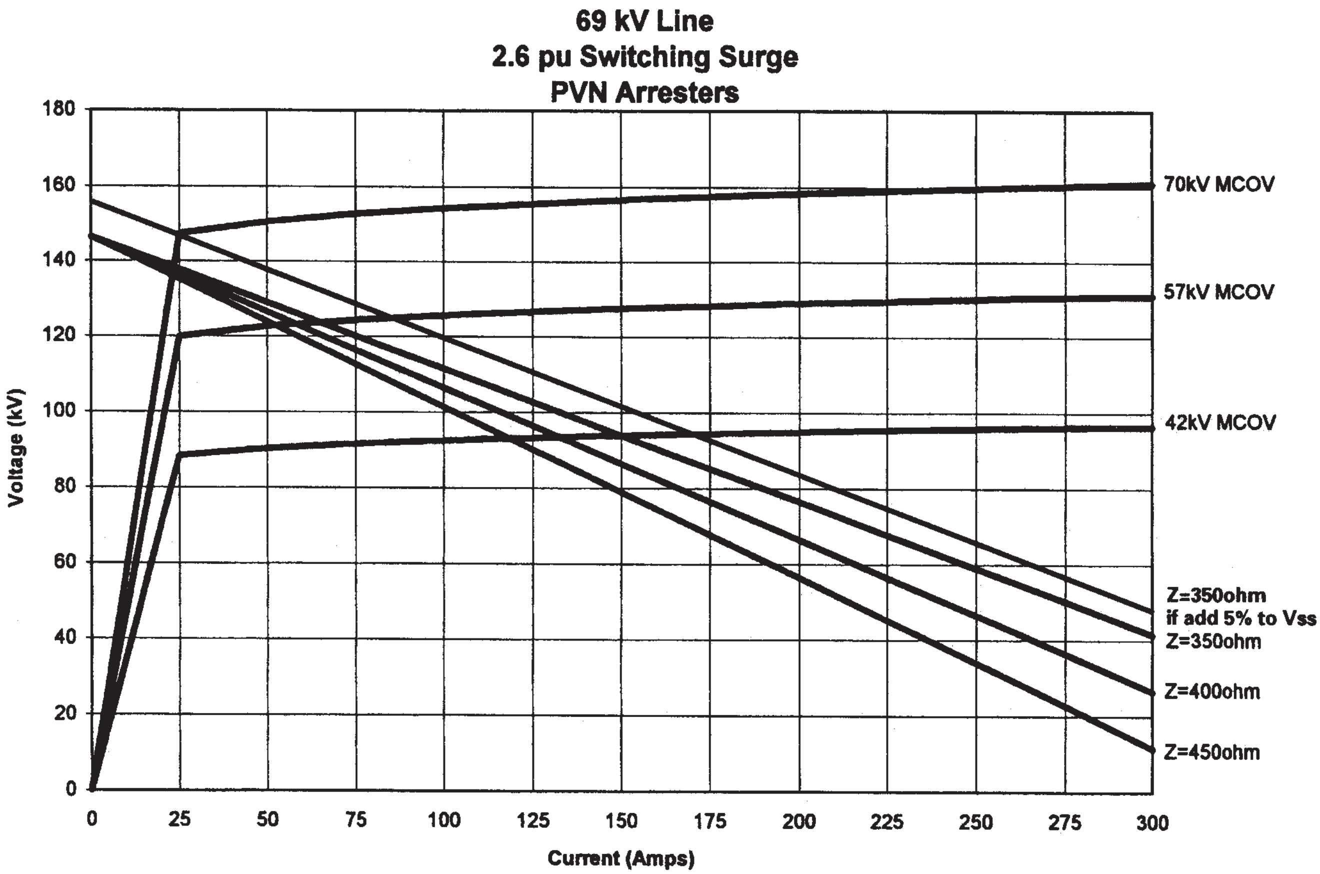
The surge duration is

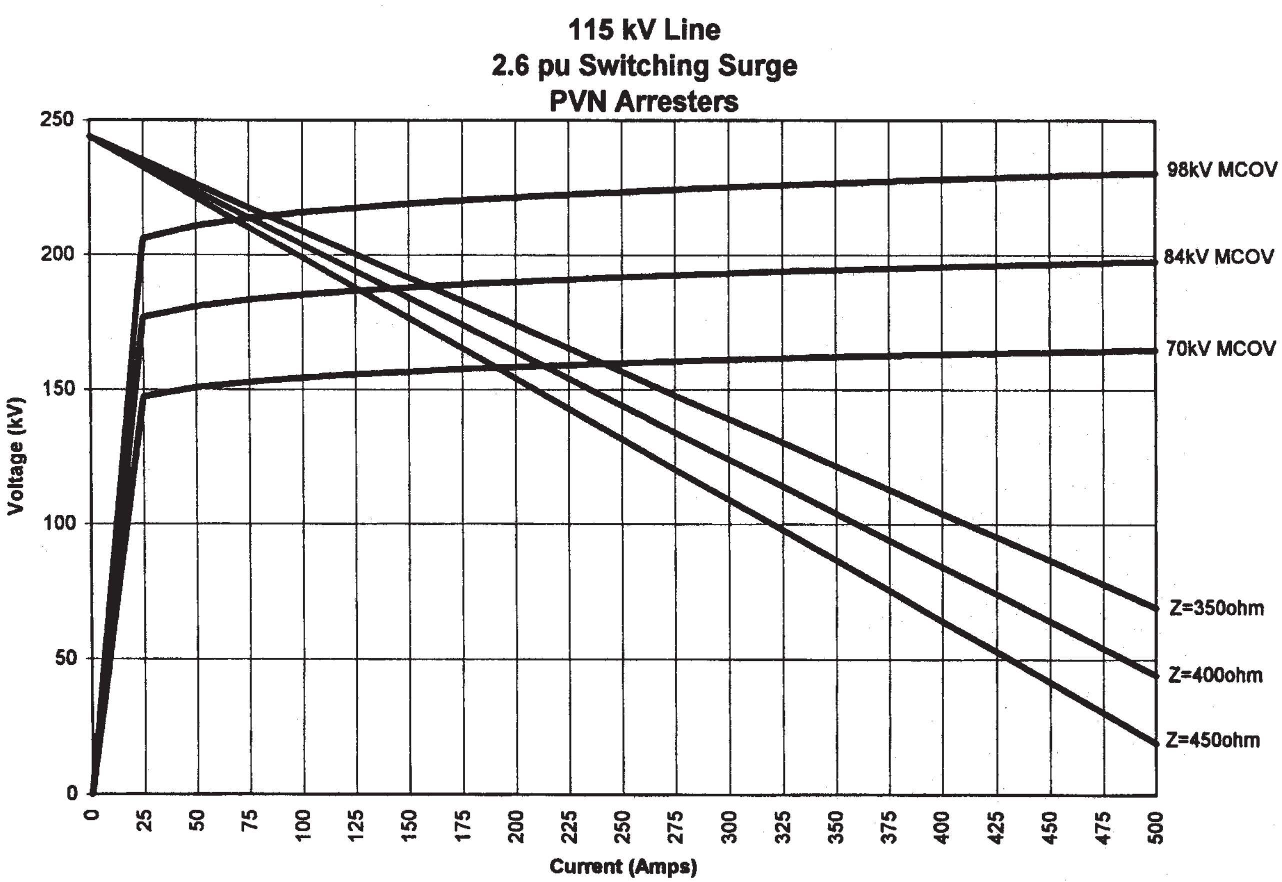
$$t = 2 L/c$$
$$= 2 \times 322 \times 10^3 / 3 \times 10^8$$
$$= 2.15 \times 10^{-3} \text{ s.}$$

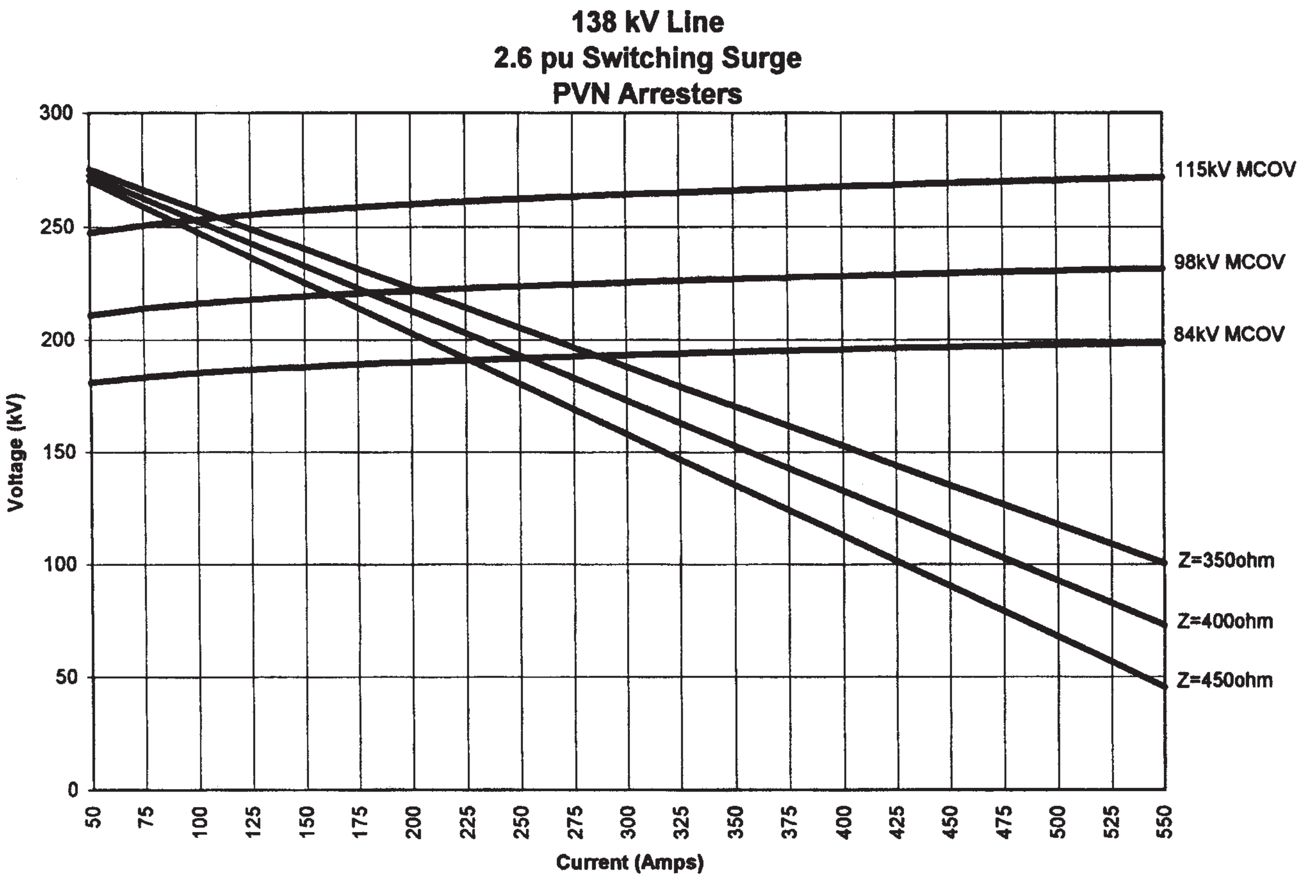
The energy discharged is

$$E = V_a \bullet I_a \bullet t$$
$$= 190 \times 10^3 \times 250 \times 2.15 \times 10^{-3} \text{ J}$$
$$= 102.1 \text{ kJ}$$

For the 84 kV MCOV arrester, the energy discharged is 102.1/84 = 1.21 kJ/kV of MCOV


69 kV Line
2.6 pu Switching Surge
PVN Arresters
Voltage (kV)
Current (Amps)
70kV MCOV
57kV MCOV
42kV MCOV
Z=350ohm
if add 5% to Vss
Z=350ohm
Z=400ohm
Z=450ohm


115 kV Line
2.6 pu Switching Surge
PVN Arresters
Voltage (kV)
Current (Amps)
98kV MCOV
84kV MCOV
70kV MCOV
Z=350ohm
Z=400ohm
Z=450ohm


138 kV Line
2.6 pu Switching Surge
PVN Arresters
Voltage (kV)
Current (Amps)
115kV MCOV
98kV MCOV
84kV MCOV
Z=350ohm
Z=400ohm
Z=450ohm
300
250
200
150
100
50
0
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
525
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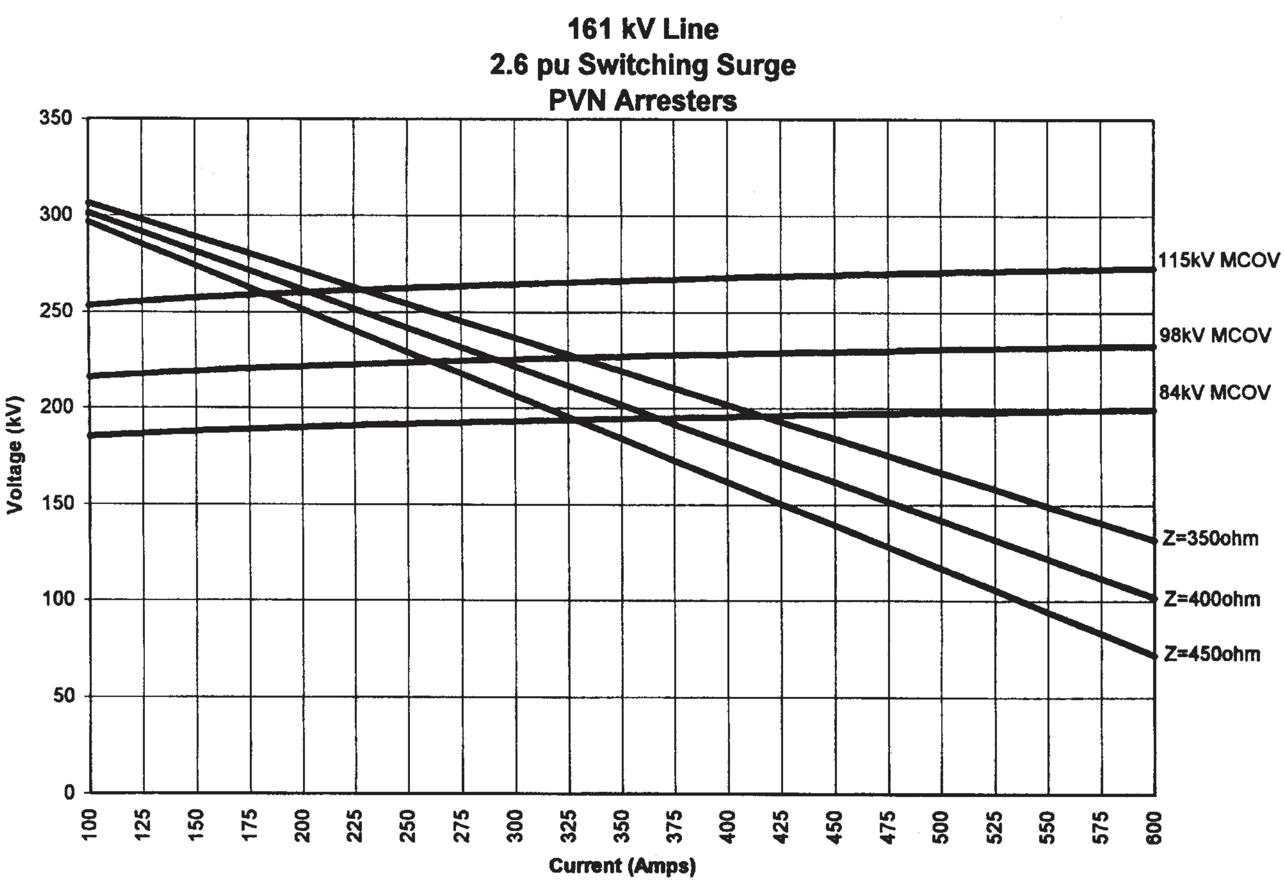
161 kV Line
2.6 pu Switching Surge
PVN Arresters
Voltage (kV)
Current (Amps)
115kV MCOV
98kV MCOV
84kV MCOV
Z=350ohm
Z=400ohm
Z=450ohm
350
300
250
200
150
100
50
0
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
525
550
575
600

NOTE: Because Hubbell has a policy of continuous product improvement, we reserve the right to change design and specifications without notice.

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573-682-5521 Fax 573-682-8714 http://www.hubbellpowersystems.com

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UNITED STATES • 210 N. Allen • Centralia, Mo 65240 • Phone: 573-682-5521 • Fax: 573-682-8714 • e-mail: hpsliterature@hps.hubbell.com
CANADA • 870 Brock Road South • Pickering, Ontario L1W 1Z8 • Phone: 905-839-1138 • Fax: 905-831-6353 • e-mail: infohps@hubbellonline.com
MEXICO • Av. Coyoacan No. 1051 • Col. Del Valle • 03100 Mexico, D.F. • Phone: 52-55-9151-9999 • Fax: 52-55-9151-9988 • e-mail: vtasdf@hubbell.com.mx