Dow
Water & Process Solutions

DOWEX™ MARATHON™ Industrial Water Softening

Ion Exchange Resins

Engineering Information

General Information

DOWEX™ MARATHON™ C, DOWEX MARATHON C-10 and DOWEX MARATHON MSC are uniform particle sized strong acid cation exchange resins in the sodium form which are specially suited for water softening applications. The resins are based on a styrene-divinylbenzene copolymer matrix with sulfonic acid functional groups.

DOWEX™ MARATHON™ C is a high capacity, gel-type exchange resin specifically designed to give high throughput and economical operation in both water and non-water applications.

DOWEX™ MARATHON™ C-10 is a higher cross-linked, gel-type exchange resin specifically designed to be used under more stringent conditions of higher temperature and oxidation.

DOWEX™ MARATHON™ MSC is a highly cross-linked macroporous resin with high porosity giving excellent chemical and thermal stability. The resin is therefore particularly suited for hot process industrial softening and for the most highly mechanically stressed or oxidative systems, such as those containing >1 ppm free Cl_2.

Because of their uniform particle size, these resins offer a number of advantages compared to conventional polydispersed resins. The small uniform bead size results in rapid exchange kinetics during operation, more complete regeneration of the resin and faster, more thorough rinse following regeneration. The uniform bead size regenerates more efficiently resulting in lower hardness leakage and higher operating capacity. This results in lower operating costs and reduced waste disposal. The outstanding physical strength of DOWEX MARATHON C and DOWEX MARATHON C-10 resins makes them far more resistant to bead breakage than conventional gel resins.

This brochure gives detailed engineering information on the resins to allow operational capacities and hardness leakages to be calculated for different water qualities at different levels of regeneration and designs to be made for co-flow and counter-flow industrial softeners.

Physical and Chemical Properties

		DOWEX™ MARATHON™ C	DOWEX™ MARATHON™ C-10	DOWEX™ MARATHON™ MSC
Matrix		Styrene-DVB	Styrene-DVB	Styrene-DVB
Type		Gel	Gel	Macro
Ionic form as delivered		Na^+	Na^+	Na^+
Total exchange capacity, min.	eq/L	2.0	2.2	1.7
	kgr/ft^3 as $CaCO_3$	43.7	48.1	37.1
Water content	%	42 - 48	40 - 45	44 - 50
Mean particle size	µm	585 ± 50	580 - 680	550 ± 50
Uniformity coefficient, max.		1.1	1.1	1.1
Total swelling ($Na^+ \rightarrow H^+$)	%	8	7	4
Whole uncracked beads	%	95 - 100	95 - 100	95 - 100
Particle density	g/mL	1.28	1.31	1.28
Shipping weight**	g/L	820	845	800
	lbs/ft^3	51	53	50

Recommended Operating Conditions	DOWEX™ MARATHON™ C	DOWEX™ MARATHON™ C-10	DOWEX™ MARATHON™ MSC
Maximum operating temperature	120°C (250°F)	130°C (265°F)	150°C (300°F)
pH range	0 - 14	0 - 14	0 - 14
Bed depth, min.	800 mm (2.6 ft)	800 mm (2.6 ft)	800 mm (2.6 ft)
Flow rates:			
Service/fast rinse	1 – 6 gpm/ft^3 (5 – 50 BV/hr)	–	1 – 6 gpm/ft^3 (5 – 50 BV/hr)
Service/demineralizing and softening	–	12 - 50 m/h (5 - 20 gpm/ft^2)	–
Service/sodium or amine cycle polishing	–	38 - 75 m/h (15 - 30 gpm/ft^2)	–
Backwash	see Figure 1a	see Figure 1b	see Figure 1c
Co-current regeneration/displacement rinse	1 - 10 m/h (0.4 - 4 gpm/ft^2)	1 - 10 m/h (0.4 - 4 gpm/ft^2)	1 - 10 m/h (0.4 - 4 gpm/ft^2)
Counter-current regeneration/displacement rinse	5 - 20 m/h (2 - 8 gpm/ft^2)	5 - 20 m/h (2 - 8 gpm/ft^2)	5 - 20 m/h (2 - 8 gpm/ft^2)
Total rinse requirement	2 - 5 Bed volumes	2 - 5 Bed volumes	3 - 6 Bed volumes
Regenerant	1 - 8% H_2SO_4, 4 - 8% HCl, or 8 - 12% NaCl	1 - 8% H_2SO_4, 4 - 8% HCl, or 8 - 12% NaCl	1 - 10% H_2SO_4, 4 - 8% HCl, or 8 - 12% NaCl

** As per the backwashed and settled density of the resin, determined by ASTM D-2187.

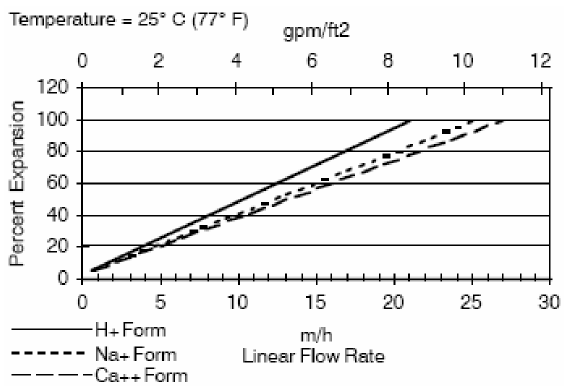
Hydraulic Characteristics

Bed Expansion

Under the upflow conditions of backwashing, the resins will expand their volume (see Figures 1a-1c). Such expansion allows the re-grading of the resin, fines removal and avoids channeling during the subsequent service cycle. At the same time, accumulated particulate contamination is removed.

For an efficient backwash a uniform bead resin requires less flow to expand to the same height as a conventional polydispersed resin of the same average particle size. Due to the smaller and more uniform bead size of the DOWEX™ MARATHON™ resins, an expansion of around 60-80% is normally sufficient to remove particulate matter from the resin bed, thereby reducing the backwash flow rate required even further. Due to the absence of fine beads in the uniform resin, the risk of resin loss during backwashing is reduced.

Figure 1a. Backwash expansion data for DOWEX MARATHON C resin

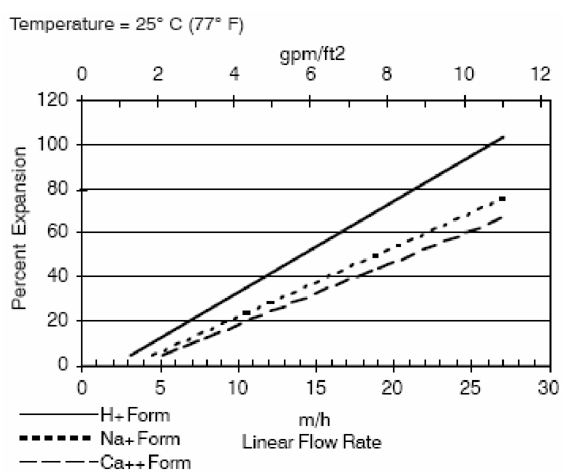


For other temperatures use:

$F_T = F_{77°F} [1+ 0.008 (T_{°F} -77)]$, where $F \equiv gpm/ft^2$

$F_T = F_{25°C} [1+ 0.008 (1.8T_{°C} - 45)]$, where $F \equiv m/h$

Figure 1b. Backwash expansion data for DOWEX MARATHON C-10 resin

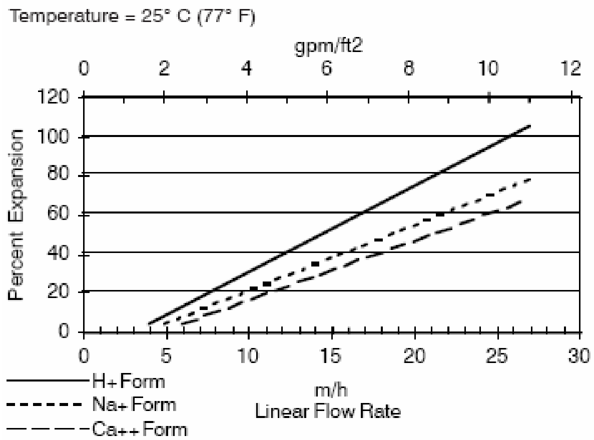


For other temperatures use:

$F_T = F_{77°F} [1+ 0.008 (T_{°F} -77)]$, where $F \equiv gpm/ft^2$

$F_T = F_{25°C} [1+ 0.008 (1.8T_{°C} - 45)]$, where $F \equiv m/h$

Figure 1c. Backwash expansion data for DOWEX™ MARATHON™ MSC resin



For other temperatures use:

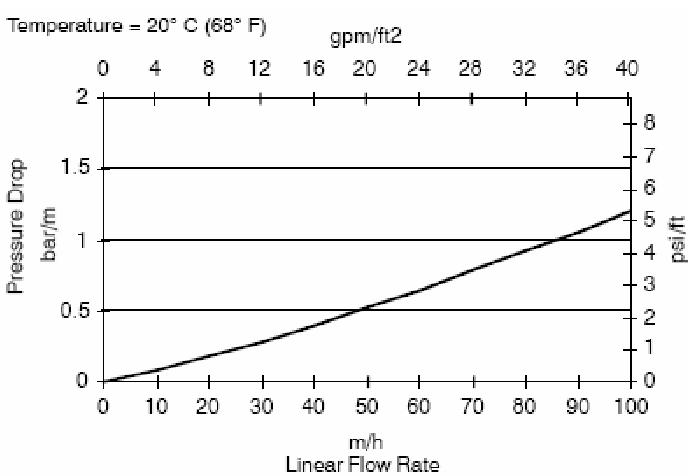
$F_T = F_{77°F}\,[1 + 0.008\,(T_{°F} - 77)]$, where $F \equiv gpm/ft^2$

$F_T = F_{25°C}\,[1 + 0.008\,(1.8T_{°C} - 45)]$, where $F \equiv m/h$

Pressure Drop Data

The pressure drop across a resin bed can vary depending on a number of factors. These include resin type, bead size, interstitial space (bed voidage), flow rate, temperature and bed contamination. The data in Figures 2a, 2b and 2c relates the pressure drop per unit bed depth to both flow velocity and water temperature for DOWEX™ MARATHON™ C, DOWEX MARATHON C-10 and DOWEX MARATHON MSC resins. Depending on the degree of bed classification, the smaller beads in conventional polydispersed resins may fill the interstitial spaces between the larger beads, thereby increasing the head loss. Compared to conventional resins, uniform beads have a higher voidage which compensates for the smaller mean bead diameter, resulting in similar head loss characteristics for DOWEX MARATHON resins as for conventional resins.

Figure 2a. Pressure drop data for DOWEX MARATHON C resin

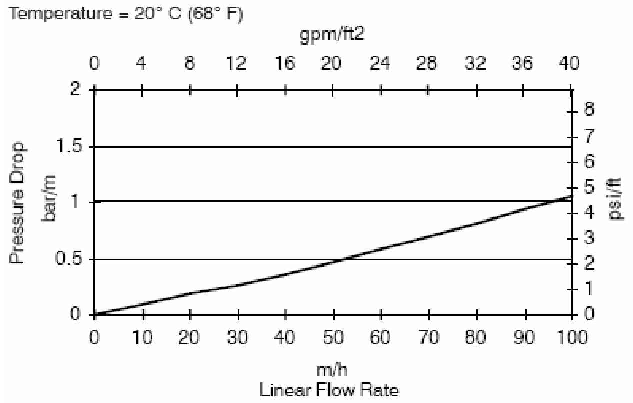


For other temperatures use:

$P_T = P_{20°C} / (0.026\,T_{°C} + 0.48)$, where $P \equiv bar/m$

$P_T = P_{68°F} / (0.014\,T_{°F} + 0.05)$, where $P \equiv psi/ft$

Figure 2b. Pressure drop data for DOWEX™ MARATHON™ C-10 resin

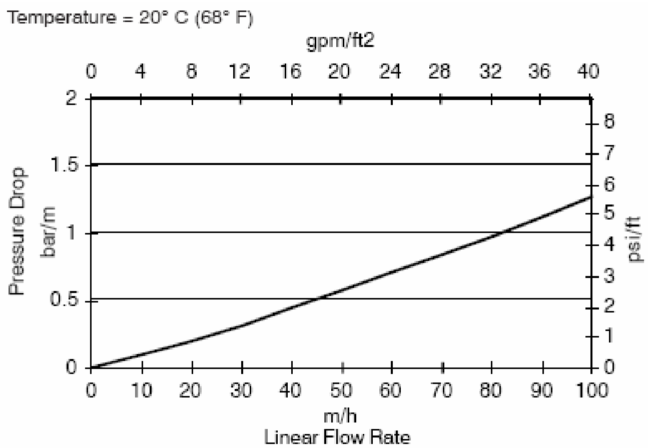


For other temperatures use:

$P_T = P_{20°C} / (0.026\, T_{°C} + 0.48)$, where P ≡ bar/m

$P_T = P_{68°F} / (0.014\, T_{°F} + 0.05)$, where P ≡ psi/ft

Figure 2c. Pressure drop data for DOWEX MARATHON MSC resin



For other temperatures use:

$P_T = P_{20°C} / (0.026\, T_{°C} + 0.48)$, where P ≡ bar/m

$P_T = P_{68°F} / (0.014\, T_{°F} + 0.05)$, where P ≡ psi/ft

Resin operation in the sodium cycle

The exchange capacity of the resins when used in the sodium cycle depends upon the following:

- allowable residual hardness in the treated water (leakage)
- analytical characteristics of the raw water
- operating conditions, such as regeneration level

The level of hardness leakage is shown in Figures 3a-3c as a function of raw water total dissolved solids (TDS expressed as salinity in ppm $CaCO_3$) and at different resin regeneration levels.

Concentrations of ionic species in water may be expressed in different units in different countries. The following table gives the conversion factors for commonly encountered units to milliequivalents/litre (meq/L) and ppm $CaCO_3$.

	ppm $CaCO_3$	meq/L
1 grain/U.S. gallon	17.1	0.342
ppm $CaCO_3$	1.0	0.020
1 English degree	14.3	0.285
1 French degree	10.0	0.200
1 German degree	17.9	0.357
kgr/ft^3	2,288	45.8

Multiply by the conversion factor to obtain ppm $CaCO_3$ or meq/L. Divide by the conversion factor to obtain the different units from numbers expressed as ppm $CaCO_3$ or meq/L.

Softener design for co-flow and counter-flow operation

The methodology for designing a co- or counter-flow plant is to determine the resin operating capacity based on one reference set of operating conditions and then to apply correction factors for the specific conditions of the design. The reference conditions are:

- Linear flow of 12 m/hr (5 gpm/ft^2) or 16 bed volumes/hr
- Temperature 20°C (68°F)
- 500 ppm TDS feed
- 75 cm (30") resin bed depth
- 10% NaCl regenerant at 25 minutes contact time
- Capacity TH endpoint of 3% (15 ppm $CaCO_3$) for co-flow operation

Before proceeding with the design, consideration should be made of the particular conditions applying to the softener (e.g. temperature, oxidants) which may impact the choice of resin (see resin descriptions above). A description of how to make a design in given below:

<u>Co-flow design</u>

1. From Figures 3a-3c, determine the level of regenerant required for the particular water feed TDS to give an acceptable hardness leakage.
2. Use Figure 4 to determine the resin operating capacity at that level of regeneration.

Figure 3a. Hardness leakage in co-flow operation for DOWEX™ MARATHON™ C

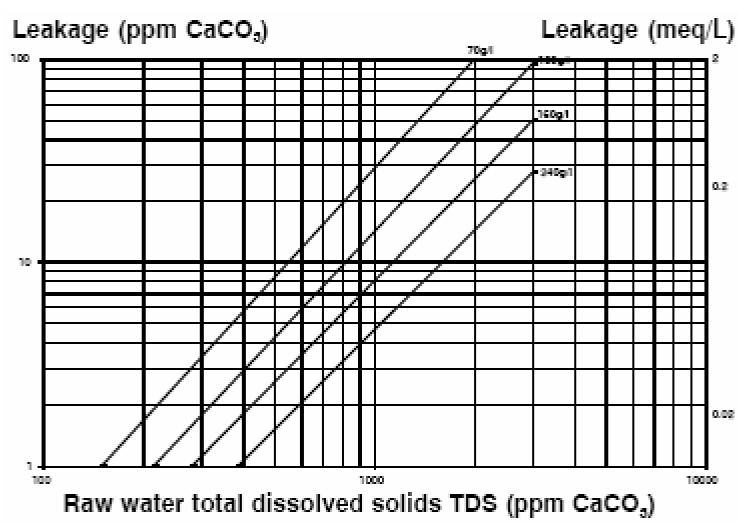


Figure 3b. Hardness leakage in co-flow operation for DOWEX™ MARATHON™ C-10

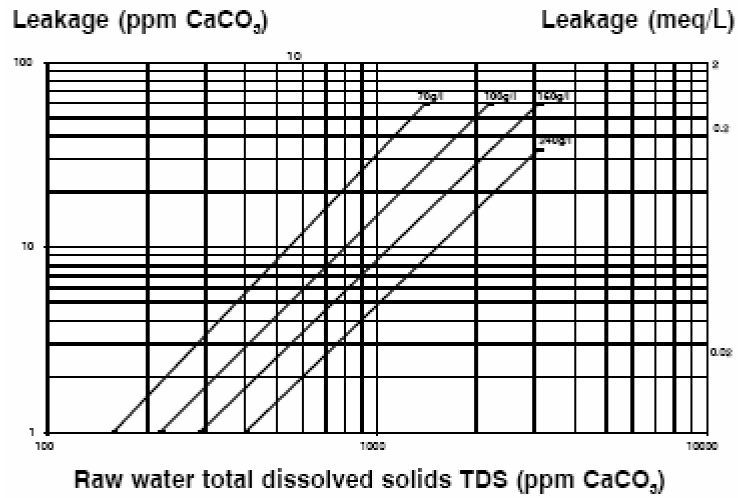


Figure 3c. Hardness leakage in co-flow operation for DOWEX MARATHON MSC

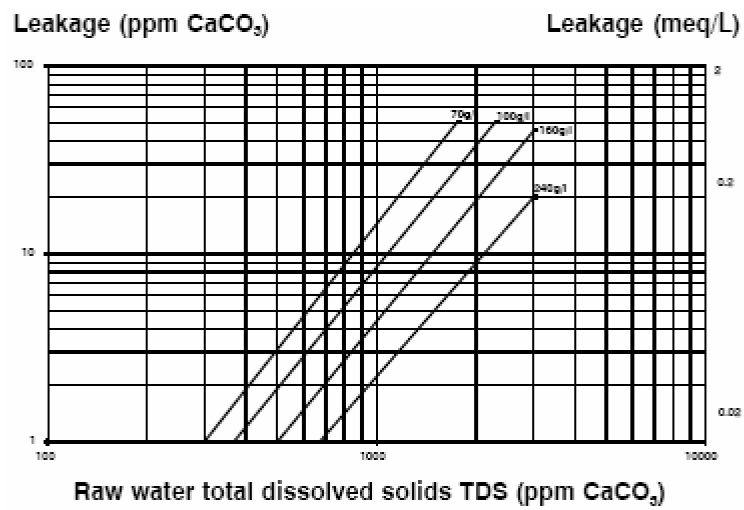
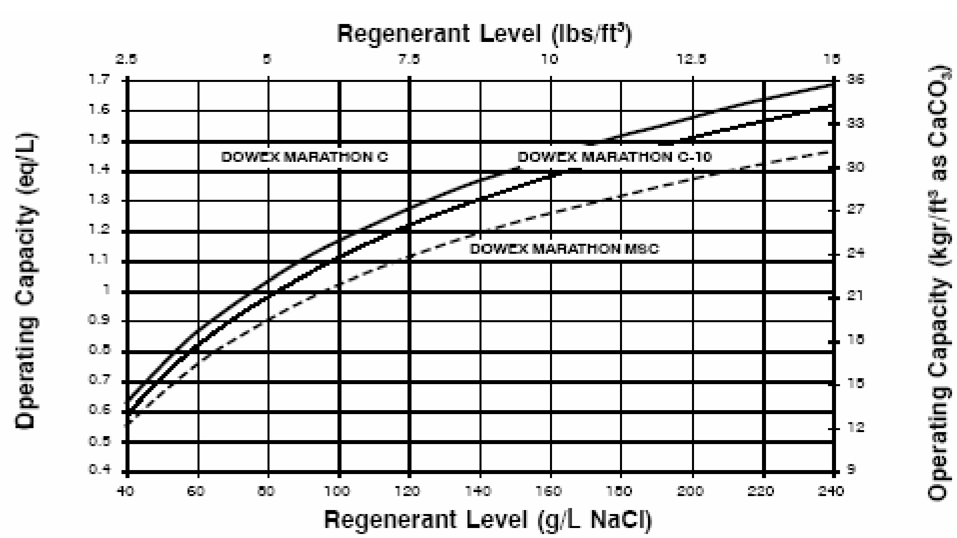


Figure 4. Operating capacity of DOWEX MARATHON resins for water softening



To design at other conditions, correction factors should be applied to the operating capacity curve as described below:

3. Correct the operating capacity for feed water TDS using Figure 5.
4. Correct the operating capacity for feed temperature using Figure 6.
5. Correct the operating capacity for %Na/TH in feed using Figure 7.
6. Correct the operating capacity for TH end-point (if desired) using Figure 8.

Figure 5. Correction of operating capacity for feed TDS

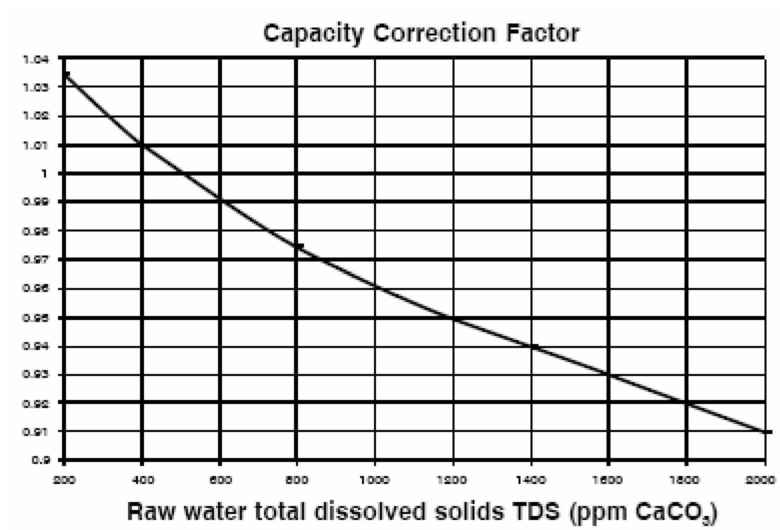


Figure 6. Correction of operating capacity for feed temperature

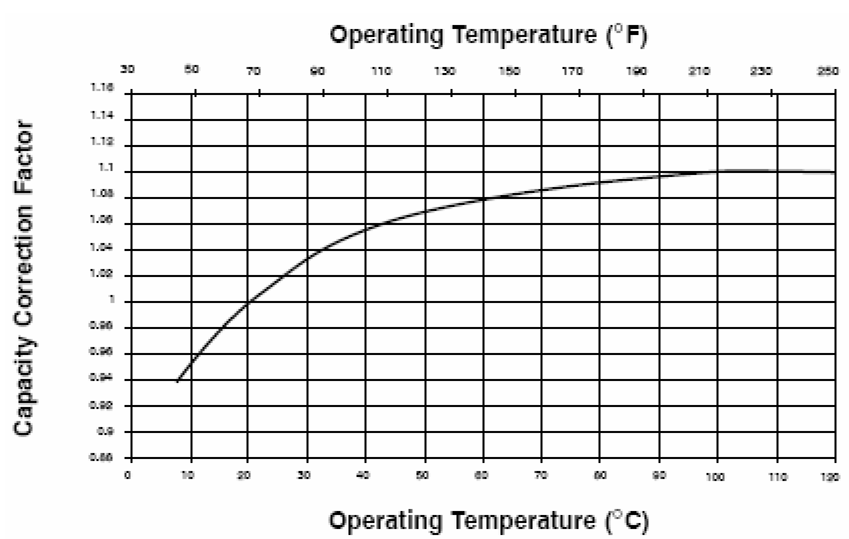


Figure 7. Correction of operating capacity for %Na in feed

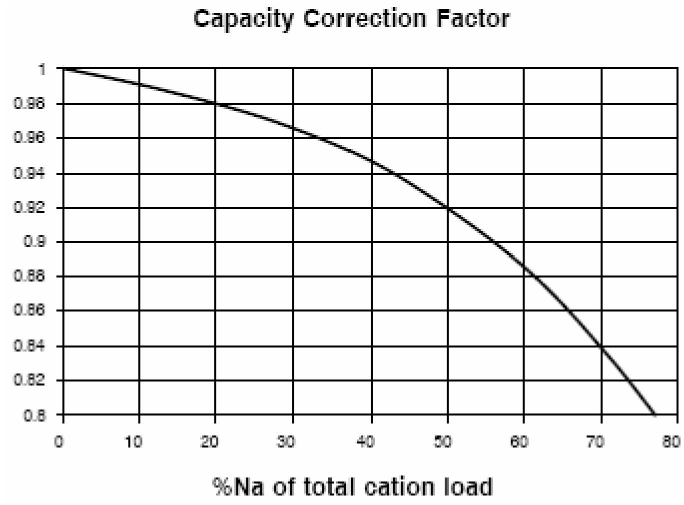
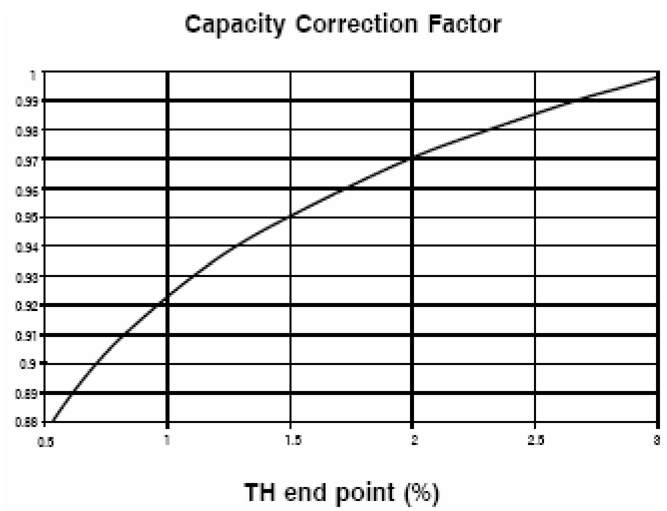


Figure 8. Correction of operating capacity for TH end point



From the calculated resin operating capacity above, apply capacity safety factors (if desired) and determine the resin volume required to produce the desired plant throughput. Design of the vessel dimensions is described as follows:

7. Choose a vessel dimension to give a service flow rate between 5 and 50 m/hour (2-20 gpm/ft^2). With an increase in flow rate there is an increase in hardness leakage, which may be contained within certain limits by reducing service exchange capacity. This operating capacity correction is given in Figure 9. Correct the operating capacity for flow rate and adjust the resin volume accordingly.
8. The resin bed height correction is given in Figure 10. Leakage and capacity data presented here are based on resin bed depths of 75 cm (30"), the minimum depth recommended. Average leakage for the run is lower for deeper beds due to continually improving water during exhaustion. The capacity correction factors are shown for up to 300 cm (10 ft) beds.

Modification of the vessel dimensions should be made by iteration using Figures 9 and 10 until the final design is obtained.

Figure 9. Correction of operating capacity for flow rate

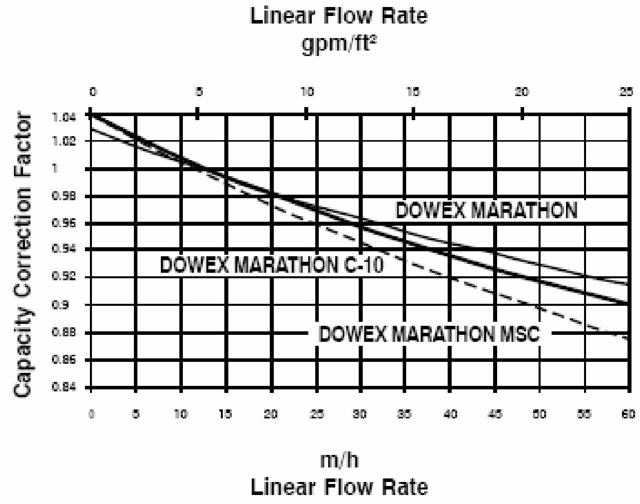
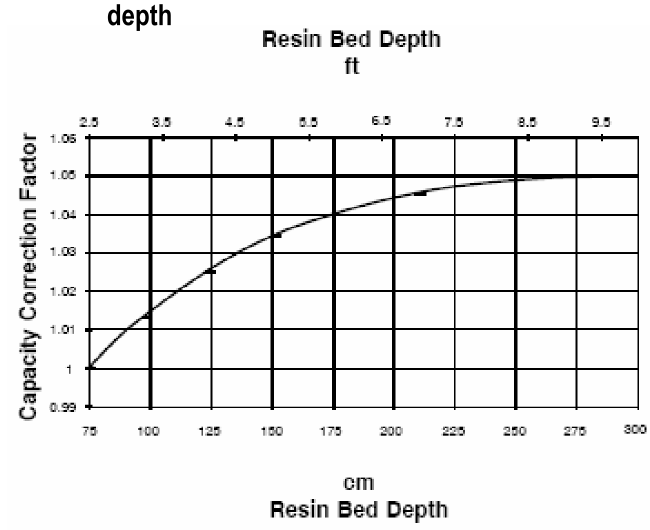


Figure 10. Correction of operating capacity for resin bed depth



Counter-current design

Leakage data presented in Figures 3a-3c are based on co-current operation. In designing counter-flow softening systems, leakages are very low (expect <1 ppm $CaCO_3$), so Figures 3a-3c are not used.

The operating capacities for counter-flow can be taken as the same as for co-flow, so Figures 4-10 above can be applied using the same methodology. Note that Figure 8 is not relevant for counter-flow operation. In general, maximum salt efficiency is obtained at lower regeneration levels, while maximum capacity results from higher levels. The designer must balance these considerations.

Operating Conditions

In addition to the information given above, some further guidelines on design and operation of a softener unit are included below:

Concentration of regenerant solution
Other operating conditions being equal, the highest exchange capacity values are attained by utilizing 10-12% solutions of sodium chloride.

Regeneration contact time
It is advisable to adopt a contact time of at least 30 minutes. When particular characteristics of the raw water to be decalcified impose the use of regeneration levels higher than 200 g/L (12.5 lbs/ft^3) of NaCl (100% basis), a longer contact time is advisable (about 45 minutes).

Rinse procedure
The excess regenerant and regeneration derivative products are removed by rinsing with raw water after flow of the regenerant solution through the exchanger. In conditions of efficient column drainage, the rinse requirements of raw water are 3-6 BV.

Calcium-magnesium ratio
The reported data are based on a calcium-magnesium ration of 2/1 (67% of total hardness as calcium). As percent calcium increases from 67 to 100%, capacity decreases 5%. As calcium decreases from 67 to 33%, capacity increases by 5%, with hardness leakage increasing 15 to 20%. Below 33% calcium, both capacity and leakage increase at a faster rate.

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Notice: Oxidizing agents such as nitric acid attack organic ion exchange resins under certain conditions. This could lead to anything from slight resin degradation to a violent exothermic reaction (explosion). Before using strong oxidizing agents, consult sources knowledgeable in handling such materials.