During operation, the calcium and magnesium ions are removed in reactions similar to the following reaction. Z is the zeolite anion. The resulting sodium compounds are soluble.

$$\left\{\begin{matrix}\text{Ca}\\\text{Mg}\end{matrix}\right\}\left\{\begin{matrix}(HCO_3)_2\\SO_4\\Cl_2\end{matrix}\right\} + Na_2Z$$

$$\rightarrow \left\{\begin{matrix}2NaHCO_3\\Na_2SO_4\\2NaCl\end{matrix}\right\} + \left\{\begin{matrix}\text{Ca}\\\text{Mg}\end{matrix}\right\}Z \qquad 7.67$$

Typical characteristics of an ion exchange unit are expressed per 1000 grains of hardness removed.[16]

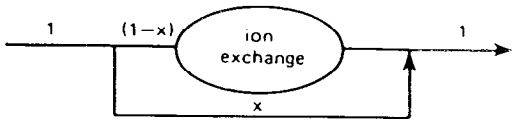
- exchange capacity: 3000 grains hardness/ft^3 zeolite for natural; 5000–30,000 (20,000 typical) for synthetic.
- flow rate: 2 to 6 gpm/ft^3 (2 gpm/ft^3 standard)

  6 gpm/ft^2 of filter bed
- backwash flow: 5 to 6 gpm/ft^2
- salt dosage: 5 to 20 pounds/ft^3. Alternatively, 0.3 to 0.7 pound of salt per 1000 grains of hardness removed
- brine contact time: 25 to 45 minutes
- depth of ion exchange bed: 2 ft (minimum) to 9 ft (maximum)

[16] 1000 grains of hardness is also known as a *kilograin*.

Example 7.20

A municipal plant receives water with a total hardness of 200 mg/l. The designed discharge hardness is 50 mg/l. If an ion exchange unit is used, what is the bypass factor?



Let x be the bypass factor. Since the water passing through the ion exchange unit is reduced to zero hardness,

$$(1 - x)0 + x(200) = 50$$
$$x = 0.25$$

J. TURBIDITY REMOVAL

Coagulants can be based on aluminum (e.g., aluminum sulfate, sodium aluminate, potash alum, or ammonia alum) or iron (e.g., ferric sulfate, ferrous sulfate, chlorinated copperas, or ferric chloride). If significant hydrolysis of iron and aluminum salts is ignored, the re-

Table 7.24
Types of Synthetic Exchange Materials

type of resin	drained density lbm/ft^3	operating pH range	regeneration	characteristics
strong acid	49–53	0–14	excess strong acid	high exchange rates; are stable; low swelling; long life, up to 20 years or more; can split strong and weak salts
weak acid	45	7–14	weak or strong acid	capacities double of strong acid; resistant to chlorine and other oxidants; high (90%) swell; not effective for electrolytic salt cations
strong base	45	0–14	excess strong base	irreversibly fouled by humic acids from decaying vegetation; can split strong or weak salts; less stable than cation resins (life less than 3 years); can remove silica; often used with food processing
weak base	32	0–6	weak or strong base	resistant to organic fouling; does not remove CO_2 or silica; capacity double of strong base; can remove color
intermediate base	43	0–14	strong base	can absorb CO_2 silica and phenol. Useful as substitutes for weak base resins in multiple-bed processes