Dow
Liquid Separations

DOWEX
Ion Exchange Resin

DOWEX MAC-3 Engineering Information

July 2003

DOWEX MAC-3 Weak Acid Cation Exchange Resin

General Information

DOWEX* MAC-3 resin is a high capacity, macroporous weak acid cation exchange resin with excellent regeneration efficiency, very good resistance to osmotic shock and good chemical and physical stability. The resin is based on a polyacrylic-divinylbenzene matrix containing carboxylic acid functional groups. The resin is available in four grades:

DOWEX MAC-3: standard grade for use in single beds.

DOWEX MAC-3 PS: specially graded for use in packed bed counter-current regeneration systems.

DOWEX UPCORE* MAC-3: specially graded for use in the packed bed, counter-current, up-flow regeneration UPCORE system.

In water treatment applications, DOWEX MAC-3 is very effective in removing calcium and magnesium at nearly 100% chemical efficiency. Due to the weak acid functionality, DOWEX MAC-3 removes temporary hardness (calcium and magnesium associated with the water alkalinity) but not the permanent hardness (hardness associated with free mineral acidity, FMA):

$$Ca^{++} (HCO_3^-)_2 + 2 (R\text{-}COO^- H^+) \rightarrow (R\text{-}COO^-)_2 Ca^{++} + 2H_2O + 2CO_2$$

$$Mg^{++} (HCO_3^-)_2 + 2 (R\text{-}COO^- H^+) \rightarrow (R\text{-}COO^-)_2 Mg^{++} + 2H_2O + 2CO_2$$

Where as:
$Ca^{++} (Cl^-)_2 + 2 (R\text{-}COO^- H^+)$ or $Mg^{++}SO_4^{--} + 2 (R\text{-}COO^- H^+)$
does not proceed.

In addition to water treatment, this resin can be used for a variety of applications including wastewater and the recovery of metals. DOWEX MAC-3 can be supplied on request for use in food and potable water applications in accordance with health authority guidelines or requirements for TOC (Total Organic Carbon). In such cases, a recommendation is given for resin conditioning before use.

Guaranteed Sales Specifications		**H^+ form**
Total exchange capacity, min.	eq/l	3.8
	kgr/ft^3 as $CaCO_3$	83.0
Bead size distribution range†		
0.3 mm – 1.2 mm, min. (50 mesh – 16 mesh)	%	90

† For additional particle size information, please refer to the Particle Size Distribution Cross Reference Chart (Form No. 177-01775).

Typical Physical and Chemical Properties		**H^+ form**
Water content	%	44 – 50
Whole beads	%	95 – 100
Total swelling ($H^+ \rightarrow Ca^+$)	%	15
Particle density	g/ml	1.18
Shipping weight	g/l	750
	lbs/ft^3	47

Recommended Operating Conditions	
Maximum operating temperature	120ºC (250ºF)
pH range	5 – 14
Bed depth, min.	800 mm (2.6 ft)
Flow rates:	
Service/fast rinse	5 – 50 m/h (2 – 20 gpm/ft^2)
Backwash	See figure 1
Regeneration/displacement rinse	1 – 10 m/h HCl (0.4 – 4 gpm/ft^2), 5 – 20 m/h H_2SO_4 (2 – 8 gpm/ft^2)
Rinse	5 – 20 m/h (2 – 8 gpm/ft^2)
Total rinse requirement	3 – 6 bed volumes
Regenerant	1 – 5% HCl or 0.5 – 0.8% H_2SO_4

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Hydraulic Characteristics

Backwash Expansion

Backwash expansion data for DOWEX MAC-3 is given in Figure 1. The resin is normally operated in co-flow mode and is backwashed for a short time before each regeneration to regrade and to discharge resin particles that may be trapped in the collecting strainers. An expansion of around 80 – 100% for 15 minutes is recommended to remove particulate matter from the resin bed. Depending on the quality of the inlet water, the resin may require a longer backwash (20 – 30 minutes) to clean the resin of accumulated contamination.

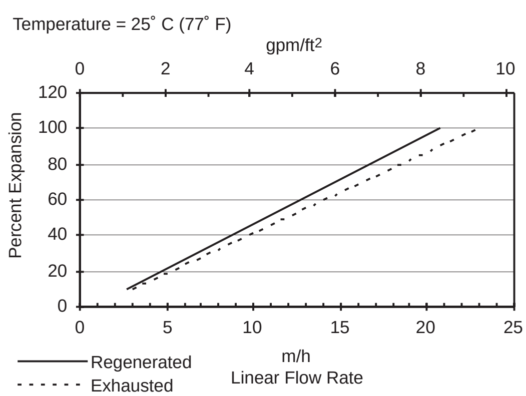
After regeneration and before the final rinse, the resin may also be backwashed for 1 minute before commencing the service flow in order to release the pressure built up on the bed surface due to resin expansion. The resin volume change during the operational cycle is substantial, and may be nearly 10% if the resin is operated to full exhaustion. This means that the backwash flow must be reduced by about 10% if the bed is backwashed in the regenerated condition.

Pressure Drop

The pressure drop across a resin bed can vary depending on a number of factors. These include resin type, bead size and distribution, interstitial space (bed voidage), flow rate and temperature. Plant geometry can also affect overall head loss and the head loss in strainers surrounded by resin may be considerable. These factors should be included in engineering calculations.

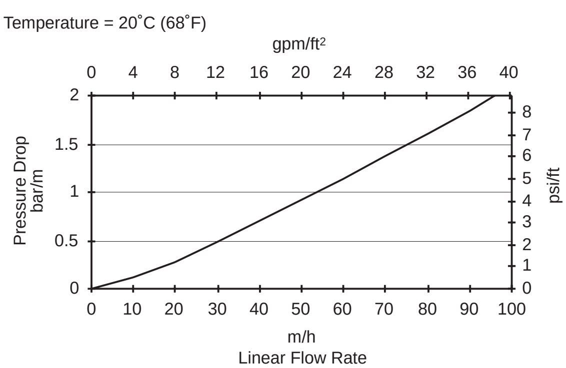
The data in Figure 2 shows the pressure drop per unit bed depth as a function of both flow velocity and water temperature for the standard grade resin (0.3 – 1.2 mm). These figures refer to new resin after backwashing and settling and should be considered indicative. The total head loss of a unit in operation will also depend on its design. It is substantially affected by the contribution of the strainers surrounded by the resin. Due to their narrower particle size distributions, DOWEX MAC-3 PS and DOWEX UPCORE MAC-3 can exhibit ~5% lower pressure drop characteristics than those illustrated in Figure 2.

Figure 1. Backwash expansion vs. flow rate



For other temperatures use:
$F_T = F_{25°C}$ (1+0.008 (1.8$T_{°C}$ - 45)), where F ≡ m/h
$F_T = F_{77°F}$ (1+0.008 ($T_{°F}$ - 77)), where F ≡ gpm/ft²

Figure 2. Pressure drop



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

Operating Characteristics

The recommended operating conditions in the table shown on page 2 are intended as a guide and should not be found restrictive. The kinetics of DOWEX MAC-3 are such that regeneration with either HCl or H_2SO_4 does not affect the resin capacity and regeneration times are minimized. It is important to note however, that when using H_2SO_4 as regenerant, the concentration of calcium sulfate produced will greatly exceed its solubility. The resultant supersaturation is acceptable as long as the regeneration is performed according to certain guidelines: it is recommended to regenerate with not greater than 0.8% sulfuric acid and to ensure that the acid passes through in less than 30 minutes. It is also important to rinse the acid out immediately.

Operating Processes

DOWEX MAC-3 may be used alone or in combination with other resins in a variety of processes.

Partial Demineralization (Dealkalization) using DOWEX MAC-3 alone
This is a very effective process involving DOWEX MAC-3 on its own to remove temporary hardness and the corresponding alkalinity (if a degasser is installed downstream of the resin). In this combination, the resin usually operates in co-flow regeneration and at nearly 100% chemical efficiency.

As the resin capacity is affected by the kinetics, flow changes or water changes which cause early resin exhaustion will result in slight loss of capacity. Ideally, the amount of acid used to regenerate should then also be reduced, but this is usually not possible and the resin becomes over-regenerated. The resultant pH of the treated water is affected, especially at the beginning of the operational cycle (see Figure 3). The pH variation can be reduced if the pH is raised by adding approximately 5 – 10 mg/l of NaOH to the degassed water sump (see Figure 4). The other alternative is to monitor the in-line addition of NaOH with a pH instrument. With sufficient storage of final treated water (as in a cooling tower sump), degassing occurs naturally and the problem does not arise.

It the total calcium and magnesium in the feed exceed the alkalinity (as equivalents), they will be removed up to the level of alkalinity present. Under these circumstances, no sodium bicarbonate is present and the resin capacity is high (see Figure 9A curves with hardness/alkalinity ratio >1).

If alkalinity exceeds calcium and magnesium, then sodium bicarbonate is present and a reduction in capacity of the weak acid cation resin will occur, due to the presence of sodium ions, although only if it is necessary to remove the sodium (Figure 9A curves with hardness/alkalinity ratio <1).

Figure 3.

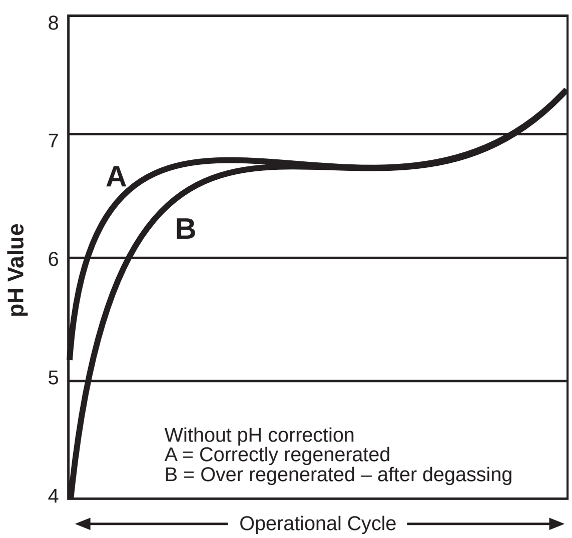
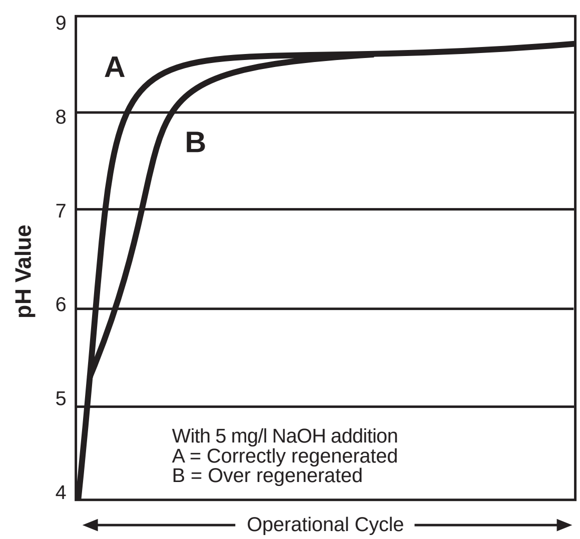


Figure 4.



Full Demineralization using DOWEX MAC-3 with a Strong Acid Cation Resin
To remove all cations in a full demineralization plant, a strong acid cation resin is placed downstream of DOWEX MAC-3. This combination of weak and strong cation exchange resins is particularly suitable for treating hard, alkaline waters and almost 100% chemical efficiency is obtainable. If the water contains a large percentage of sodium, however, nearly the same efficiency may be obtained by a correctly designed counter-current cation unit alone using DOWEX MARATHON* C.

By using DOWEX MAC-3 with a strong acid cation, the normal alkalinity end-point of the resin can be exceeded and the leakage picked up by the strong acid cation. In this overrun condition, the total performance of the DOWEX MAC-3 increases due to additional capacity utilization of the resin.

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If the feed hardness/alkalinity ratio is >1, the total performance of the DOWEX MAC-3 exceeds that shown in the capacity graph in Figure 9, and may even approach the total capacity of the resin. This is illustrated in Figure 5. If the alkalinity/hardness ratio is >1, the overall capacity of DOWEX MAC-3 is reduced if sodium bicarbonate has to be removed, but overrunning will still result in additional weak acid cation resin capacity and its performance is shown in Figure 6. However, at a certain point the sodium bicarbonate will leak through.

Figure 5. Hardness > Alkalinity

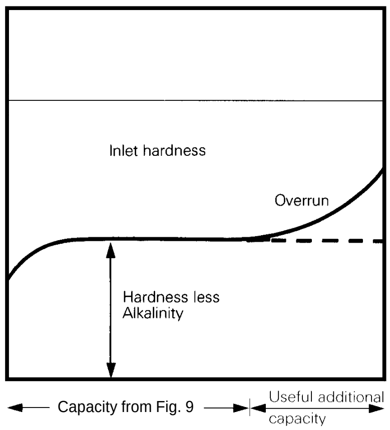
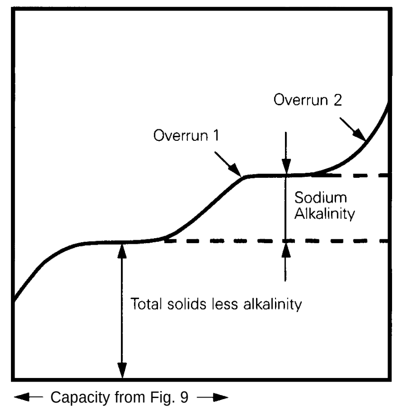


Figure 6. Alkalinity > Hardness



In contrast to weak acid cations, the capacity of strong acid cation resins e.g. DOWEX MARATHON C, can increase in the presence of sodium bicarbonate, so the omission of the weak acid cation resin might be considered if the hardness/alkalinity ratio in the feed is below 0.8.

There are two main designs for a combination of weak and strong cation resins. The first is to have DOWEX MAC-3 in a separate unit followed by a plant containing a strong acid cation resin, e.g. DOWEX MARATHON C. The water first passes through the DOWEX MAC-3 and then through the strong acid cation resin. If HCl is used as regenerant, it can be passed in series through both vessels in the opposite direction (see Figure 7). With H_2SO_4, it is advisable to dilute the acid to <1% after the strong acid cation, or else regenerate the two resins separately (e.g. in co-flow).

The other arrangement is a layer of DOWEX MAC-3 on top of a bed of DOWEX HGR-W2 or DOWEX MONOSPHERE* 650C in the same vessel. The resin is preferably regenerated up-flow and operated down-flow, i.e. counter-current (Figure 8). In order to prevent $CaSO_4$ precipitation, the whole bed should either be regenerated with <1% concentration of H_2SO_4, (which decreases the capacity of the strong acid resin) or provision for acid dilution at the resin boundary should be made. This is facilitated if a separating nozzle plate is installed in the vessel.

Figure 7. Separate unit

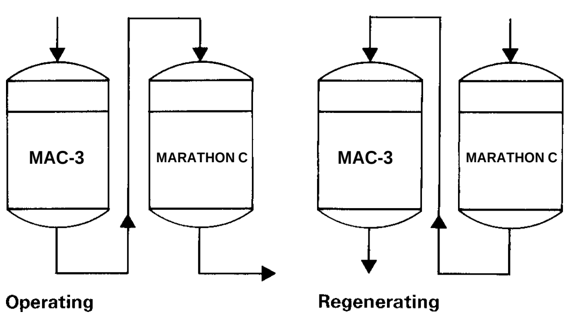
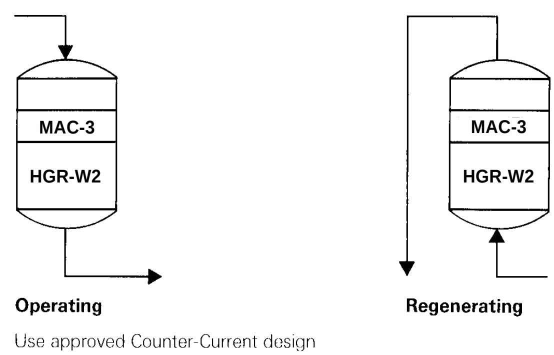


Figure 8. Layered bed



Due to the increased complexity of the layered bed option, it may be worthwhile to consider a strong acid cation resin alone operating in counter-current regeneration as an alternative. This can be so chemically efficient that the combination of the weak acid layer may not yield a substantial advantage. Nevertheless, there are occasions when it is appropriate to install and the combination of DOWEX MAC-3 and DOWEX HGR-W2 or DOWEX MONOSPHERE 650C is ideal, providing an adequate separation of the resins can be maintained.

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Co-current Operational Capacity Data

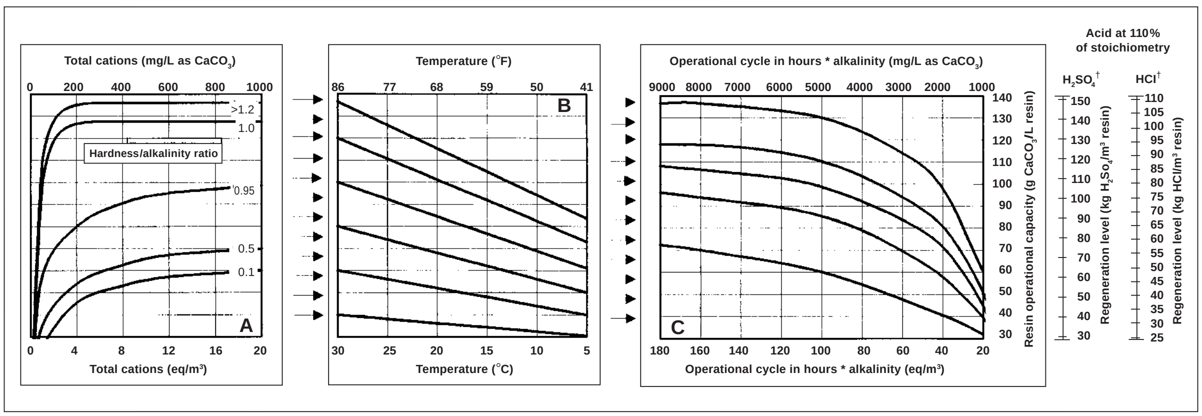
Instructions:

1. Locate a point on the ordinate of graph A from total cations and ratio of hardness to alkalinity (usually 1.0 or more).
2. Transfer the ordinate from graph A horizontally to graph B and follow the guidelines of graph B to locate a new point on the ordinate according to the water temperature.
3. Transfer the ordinate point from graph B horizontally to graph C and follow the guidelines to a new ordinate point according to the hours of the operational cycle times the alkalinity. Now read off the capacity.

Definition:

Hours of the operational cycle means the number of hours from the delivery of treated water to the time of breakthrough. It does not include the time taken to regenerate or the overrun time.

Figure 9. Co-current operational capacity data



†Divide by 16.03 to convert from kg acid/m³ resin to lb acid/ft³ resin

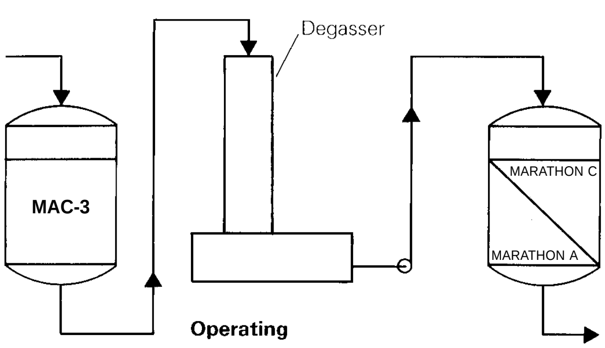
Full Demineralization using DOWEX MAC-3 with a Mixed Bed Plant

This type of combination plant (Figure 10) is an alternative to full demineralization using counter-current cation and anion plants. The decision on which type of plant to install depends on a number of factors, including the detailed engineering of the mixed bed plant.

In this system, it is usual to have a small amount of strong acid cation resin such as DOWEX MARATHON C mixed with the DOWEX MAC-3 to produce an acid water at the beginning of the operational cycle to ensure there is no salt splitting on the mixed bed plant.

It is not normal procedure to use series regeneration of the acid from the mixed bed plant to the DOWEX MAC-3 as the detailed design can give rise to flow difficulties. Although in theory the series use of the acid is perfectly feasible.

Figure 10. With a mixed bed plant



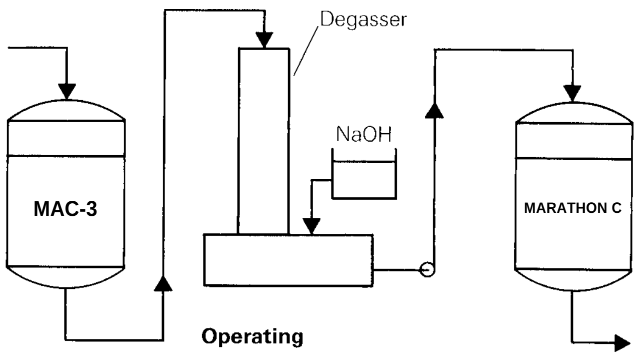
Regenerate each resin separately

Alkalinity and Hardness Removal (DOWEX MAC-3 with a Sodium Exchanger)
This is an excellent process for producing water of very low hardness and low alkalinity (Figure 11). It has been used for nearly 40 years for feed water to low pressure boilers and cooling systems. The analysis of the treated water closely resembles treated water from a cold lime soda water softener.

The treated water alkalinity should be 20 – 40 mg/l and the hardness less than 5 mg/l, but only the reduction in alkalinity will reduce the total solids.

The pH can be adjusted at will, usually about 9.0 for low-pressure boilers and 7.8 for cooling systems.

Figure 11. With a sodium exchanger



Regenerate both units in normal manner using common salt (NaCl) for sodium exchanger

Special Applications
The special selectivity characteristics of DOWEX MAC-3 resin make it suitable for a wide range of applications. Some examples are given here.

It is increasingly standard practice to design ion exchange plants so that the waste acid effluent of the cation stage is used to neutralize the waste alkali from the anions. However, the total wastewater with these chemicals may be quite large and above effluent discharge limits. One method to treat this waste is to pass it through a bed of DOWEX MAC-3 and then add a small amount of caustic soda to raise the pH, e.g. to 7.5. This can be achieved by installing sensing equipment.

Another interesting aspect of weak acid cation ion exchange technology has been noticed by beer manufacturers who wish to control magnesium content. As an example, if 60% calcium and 20% magnesium are present in the feed and the alkalinity is 80%, then calcium and magnesium will be removed, but not to the same extent throughout the operational cycle. At the beginning of the cycle, more magnesium will be removed and less calcium, while at the end the position will be reversed. If two or more units are working in parallel and are out of step, then a constant calcium/magnesium ratio can be obtained.

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† Toll-free telephone number for the following countries: Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom

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.