WATER SOFTENING

Notes about principles and plants

The scale

The water available from well and other sources usually contains many dissolved substances of several origin and type.
This bullettin specially concerns the presence in water of calcium and magnesium bicarbonates.
Their presence in water can cause serious problems, according to their concentration and the utilization of water.
The quantity of calcium and magnesium bicarbonates (soluble substances) are chemically balanced in water with calcium and magnesium carbonates and with carbon dioxide.
An increasing of the temperature of the water causes the developing of part of the carbon dioxide and the subsequent breaking of the previous balance. The carbon dioxide is a gas, hence the higher is the temperature of water, the lower is its solubility.
The subsequent chemical reaction produces other carbon dioxide in order to rebuilt the balance again, this way the calcium and magnesium bicarbonates are transformed in calcium and magnesium carbonates, which are less soluble substances.
The deposits of calcium and magnesium form the so called "scale".

Carbonic balance in water

$Ca(HCO_3)_2$	↔	$CaCO_3$	+	CO_2	+	H_2O
calcium bicarbonate (soluble)		calcium carbonate (less soluble)		carbon dioxide (gas not very soluble)		acqua

It is interesting to note that the breaking of the balance features already at a not very high temperature; for example whether the temperature of water is 10-15°C (50-59° F), an increasing of temperature up to 30-35° (86-95°F) can already start the reaction.

The salts of calcium and magnesium dissolved in water is the "hardness" of water.
The hardness of water is usually measured as ppm (part per million) of calcium carbonate; it is also used the French degree (°Fr), where 1 °Fr = 10 ppm of calcium carbonate.
There are many process to remove calcium and magnesium off the water; this bullettin concerns the most diffused of them, the softening by ion exchange resins.

Ion exchange resins for softening

The resins are organic substances, industrially prepared.
Their special characteristic is that they have a "mobile" functional group, it means a part chemically balanced between the resin itself and the ions dissolved in the water.

Ion balance of the resins

R-Na	+	Ca	↔	R-Ca	+	Na
resin in sodium form (regenerated)		calcium		resin in calcium form (exhausted)		sodium

When water containing calcium and magnesium flow across the resins in sodium form, they are exchanged with sodium which is released in water.
This is the purpose of the softening process: the calcium and magnesium (their carbonates cause scale) are replaced with sodium, where the sodium carbonate is perfectly soluble.

Naturally, sooner or later, the resins will not be able to replace calcium and magnesium, since there will not be any more (or a very little quantity) ions of sodium available for exchange.
This resins, without any sodium ions, is exhausted, and it is required to re-built the original sodium form to start the exchange process of softening again. It is required a regeneration of the resins.
The regeneration simply means that some water, with a very high concentration of sodium ions, flows through the resins and exchanges back sodium against calcium and magnesium, released in water.
The regeneration water is a solution of sodium chloride (common kitchen salt); it flows through the resins and is carried to drain with addiction of calcium and magnesium released from resins.

The softeners

The softeners are the equipments that allow to make the softening of the water by ion exchange process.
Simply the softener can also be an housing filled with resins; the water simply flows through the resins and is softened.
But, the softener must also allow to make the regeneration of the resins; hence there are several types of softeners, different not only for the dimensions but for the way the regeneration is featured.

The most simple softener has an opening to introduce the salt directly above the resins, afterthat water will flow through the resins to slowly dissolve the salt.
This is the most simple softener and basically the features are still always the same; now a concentrated solution of salt (brine) is drawed inside the softener by an injector, therefore using the hydraulic energy of the water itself to make the suction of brine. This way allows not to open the housing of the resins.
Now, most of the softeners are fully automatic, with several and different modes to run the regeneration:

- by time schedule, allowing to set how often and the time of day of the regeneration
- by volume, where the regeneration starts after that a pre-set quantity of water has been supplied
- a combination of both, (volume schedule but only at a pre-set time of day)

Besides, dual systems softeners are also commonly used; they allow the continuous feeding of treated water, 24 hours a day, no stop. There is always a column on service, while the other one is on regeneration or stand-by. The regeneration (ecxchange of working between the columns) is usually set by volume schedule.

Obviously, the correct selection of the automatic mode of a softener depends on the application of the softener itself.

Utilization of soft water

"Hard" water, the water containing high quantity of calcium and magnesium, causes many problems.
The most common of them surely is the scale deposits along the surface of boilers, heater exchangers, laundry machines, etc. The scale inhibits the correct thermal exchange, since it is a very good thermal insulator (the thermal conductivity of the scale is approx 1/100 of the one of the iron).
The scale makes also difficult the flowing of water along the pipes, since it reduces the size of them, can cause the block of valves, mixers, can make the corrosion easier.
Besides, hardness of water can have a reaction with chemicals in many chemical industrial process.

It must also be noted that utilization of hard water for washing makes rough and coarse the clothing and the hair, makes dry the skin because the scale can clog the pores, makes different the taste of meals and drinks. Besides, it is required to use larger quantity of soaps and detergents for washing and laundry machines.
For this last point, it can be sublined that the utilization of soft water allows a shockly reduction in the quantity of detergent used and therefore a shorter quantity of waste, as a sure advantage for environmental protection.

Wherever the hard water can cause problems, the utilization of soft water can be recommended.
As residential utilization, drinking water can also be softened, with "hygienical" advantages (taste of meals and drinks, smoothness of the cloths), but also to protect the household plants (heating system, laundries,etc).
Local laws in many countries have special regulations or restrictions concerning the softening of drinking water, but is is generally allowed everywhere.
It is obvious that the softening of water must not be confused as "purification" of water, as sometimes happens. The softening of water does not change any characteristics of water, included the total salinity, except the contents of calcium and magnesium, which is replaced by sodium.

HOW TO SELECT A SOFTENER

The correct selection of a softener should be made according to both the following features

flow rate – cycle

Max flow rate
Usually expressed in m³/h. (for US system 1 m³/h = 4.4 GPM)
It identifies the max flow rate of water the softener can supply, with acceptable pressure drop (see also pressure drops table, in special catalogue of each softener).
A flow rate by far higher than the stated max flow, increases the pressure drop and can also shockly reduce the exchange capacity of the softener.
The flow rate of a softener depends on many factors, such as dimensions of the vessel, size of the connections and distribution systems, volume of the resins.

Cycle
Usually expressed in m³ x °Fr. (cubic meter per French degree). It identifies the exchange capacity of the softener. It simply means the quantity of water (in m³) the softener can treat for each °Fr of hardness of raw water, between two regeneration.
As above mentioned 1° Fr = 10 ppm as $CaCO_3$.
German degree is also used (1°G = 1,78°Fr = 17,8 ppm as $CaCO_3$)

Example: a softener, whose cycle is 150 m³ x °Fr, can treat average 5 m³ of water at 0°Fr, if the hardness of raw water is 30°Fr. (150: 30 = 5)
Whether the hardness is 50°Fr, the same softener could treat only 3 m³ of water, between two following regeneration (150: 50 = 3).

The cycle of all Nobel softeners is the number part of the mark indentifying the model (i.e. Nobel mod. AS 150/SV, the cycle is 150 m³ x °Fr).

Operating cycle
The cycle of the softener should be selected according to the automatic control; see also Technical Information RI11_I "How to select the control for a water treatment unit".
The time and the time/volume controlled softeners allow to set the regeneration not more often than one regeneration a day; while the duration time of regeneration is average 90 minutes.
It is obvious that the minimum cycle of a softener, regardless of the flow rate, should be calculated according to the water consumption during 24 hours, that means a regeneration every day.

Duplex softener

Duplex softener includes 2 lines of softening alternately working (one line always on service, one line on regeneration/stand-by).
They are used when a no-stop flow of treated water is required, or when the required max flow is not so high, and instead a very high cycle is required, due to a continuous flow or high hardness. The correct selection of a duplex system should be made according to an operating cycle not less than 8 hours per column, and according to correct flow rate.

Residual hardness

Sometimes a residual hardness in outlet water is required, usually for drinking water applications. Since the softeners exchange completely all the hardness the water contains, the treated water is to be blended with a proper quantity of untreated water.
Some of NOBEL softeners (AS/A and AC/A) are already equipped with a built-in blending valve; for some others (AC/T - AC/SV - AS/T - AS/SV) this valve is available as optional.
For other models the residual hardness can be set just adjusting a proper gate valve along the blending (by-pass) line.

Notes to the selecting guide

The flow rate of a softener depends on the size of the vessel, the connections etc. but also on the volume of resins of the softener.
The cycle of a softener depends on the quantity of resins the unit contains and the regenerant level (quantity of salt used for the regeneration). The cycle of a softener can be easily increased simply increasing the regenerant level of the resins, but over a recommended level, the exchange capacity of the resins is not more proportional; furthermore the life of the resins can be reduced.

The cycle of all NOBEL softeners as well as the flow rate and regeneration leve are designed according to resins manufacturer recommendation for highest exchange capacity and longest operating life of the resins.

Some examples of selection

Below some of the most common application of the softener are listed, with a guide to selection.

Heating system

This system are closed ones, hence it is not expected a continuous refill of new water.
The selected softener should be able to fill the system without any regeneration, so only the cycle of the softener is to be calculated, regardless of the flow rate.
It is obvious that the capacity of the system (almost approximate), is required in order to make a correct selection, according to the following:

m^3 x ºFr = cc (m^3 x ºFr)

m^3	**=**	quantity of water contained in the system
ºFr	**=**	hardness of raw water in °Fr
cc	**=**	cycle of the required softener (m^3 x ºFr)

See also the RI11_I Technical Information "How to select the control for a water treatment unit" bullettin for the selection of the control.
According to the characteristics of the heating system, it is suggested to use the most simple and cheapest control for the softener (time schedule control). Indeed this softener is not expected to be regenerated often, but only once and a while, as push-button control (semi-automatic working).
Sometimes, expecially for large capacity system, it could be suggested to instal a volume control unit (AS/METER), with a cycle approximately 50 % of the whole required capacity. Indeed AS/Meter units are fully automatic by volume schedule, and with a special valve that shut-off the outlet line during the regeneration. At the end of the regeneration, the system turns automatically on service and starts again to supply soft water.

Steam boiler feed water

The softener must be selected in order that the feed water of the boiler will be always softened.
Hence the unit should be selected according to the cycle, first, and then according to the flow rate.
As above, the cycle will be calculated as: **m³ x ºFr = cc (m³ x ºFr)**

m³ = quantity of water contained in the system
ºFr = hardness of raw water in °Fr
cc = cycle of the required softener (m³ x ºFr)

For the feed water of steam boiler it will be completed as follows:

$$\textbf{cc (m}^3\textbf{ x ºFr)} = \textbf{t/h x h x ºFr x } \frac{(100 - \%)}{100} \textbf{ x 1.1}$$

t/h = steam production of the boiler
h = working hours per day of the boiler
% = condensate recovery (% of the production of steam per hour)

The production (**t/h)** of the boiler can be also calculated as $\textbf{t/h} = \frac{\text{(power) } \textbf{kcal/h}}{\textbf{600000}}$

Example
We assume to select a softener for a steam boiler, production 4 t/h, working 8 hours/day, and a condensate recovery of 60 %. The hardness of raw water is 30ºFr.

hence:

$$\textbf{cc (m}^3\textbf{ x ºFr)} = \textbf{4 x 8 x 30 x } \frac{(100 - 60)}{100} \textbf{ x 1.1 = 422}$$

The suitable softener should have a minimum cycle of 422 m³ x ºFr in order to warrant the supplying of treated water for almost one day of working.

After identified the suitable softener (for this case model Nobel AS450) we have to check if the flow rate of this model is equal or higher than the value t/h x 1.1.
It must be noted that the softener should have a cycle by-far higher than the one calculated as above. It will avoid troubles in the future, owing to longer working time per day, increasing of the hardness of raw water, different uses of steam and reduced recovery of condensate.
It is suggested to use an unit with volume control (AS/METER).

Note: whether the boiler is expected to work 24 hours a day, naturally a dual system softener (**AS/V Duplex** for example) should be provided. Each line of the unit should have a cycle suitable to supply treated water for approximately 12 hours.

Drinking water (#)

RESIDENTIAL BUILDING
SELECTION TABLE (SEDIMENT FILTER & SOFTENER) FOR DRINKING WATER

HARDNESS ↓ °Fr		NUMBER OF FLAT FOR BUILDING																						
		1	2	3	4	5	6	7	8	9	10	11 12	13 15	16 18	19 22	23 26	27 31	32 36	37 42	43 48	49 54	55 61	61 65	66 72	73 80
	<20	**A**	**A**	**B**	**B**	**B**	**C**	**C**	**D**	**D**	**D**	**E**	**E**	**EE**	**EE**	**EE**	**EE**	**F**	**F**	**G**	**G**	**G**	**H**	**H**	**H**
21	25	**I**	**J**	**K**	**K**	**L**	**M**	**M**	**N**	**N**	**O**	**P**	**Q**	**Q**	**R**	**S**	**S**	**T**	**T**	**U**	**W**	**W**	**W**	**V**	**V**
26	30	**I**	**J**	**K**	**K**	**L**	**M**	**M**	**N**	**N**	**O**	**P**	**Q**	**Q**	**R**	**S**	**S**	**T**	**T**	**U**	**W**	**W**	**W**	**V**	**V**
31	35	**I**	**J**	**K**	**K**	**L**	**M**	**M**	**N**	**N**	**O**	**P**	**Q**	**Q**	**R**	**S**	**S**	**T**	**T**	**U**	**W**	**W**	**W**	**V**	**V**
36	40	**I**	**J**	**K**	**L**	**L**	**M**	**M**	**N**	**N**	**O**	**P**	**Q**	**Q**	**R**	**S**	**S**	**T**	**T**	**U**	**W**	**W**	**W**	**V**	**V**
41	45	**J**	**J**	**K**	**L**	**L**	**M**	**N**	**N**	**N**	**O**	**P**	**Q**	**Q**	**R**	**S**	**S**	**T**	**T**	**U**	**W**	**W**	**W**	**V**	**V**
46	50	**J**	**K**	**L**	**L**	**M**	**N**	**N**	**N**	**O**	**P**	**P**	**Q**	**R**	**R**	**T**	**T**	**U**	**U**	**W**	**V**	**V**	**Z**	**Z**	**Z**
51	55	**J**	**K**	**L**	**M**	**M**	**N**	**N**	**N**	**O**	**P**	**Q**	**R**	**R**	**T**	**T**	**T**	**U**	**U**	**W**	**Z**	**Z**	**Z**	**Y**	**Y**
56	60	**J**	**K**	**L**	**M**	**M**	**N**	**N**	**N**	**O**	**P**	**Q**	**R**	**R**	**T**	**T**	**T**	**U**	**U**	**W**	**Z**	**Z**	**Y**	**Y**	**Y**

KEYS DESCRIPTION

A = **FCP 050**	B = **FCP 070**	C = **FCP 090**	D = **FCP 120**	E = **FCP 180**
F = **FS 200**	G = **FS 300**	H = **FS 400**	EE = 2 x **FCP 180**	

I = **FCP 070** + **AC 60/A (*)**	J = **FCP 070** + **AC 90(*)**	K = **FCP 070** + **AC 150(*)**
L= **FCP 070** + **AS 210(*)**	M = **FCP 090** + **AS 300(*)**	N = **FCP 120** + **AS 450(*)**
O = **FCP 120** + **AS 600(*)**	P = **FCP 120** + **AS 800(*)**	

Q (Q1)=**FCP 180** + **AS 1055(*)**	or Q (Q2)= **FCP 180** + **AM 900(*)**
R (R1)= **FCP 180** + **AS 1350(*)**	or R (R2)= **FCP 180** + **AM 900(*)**
S (S1)= 2 x **FCP 180** + **AS 1355(*)**	or S (S2)= 2 x **FCP 180** + **AM 1200(*)**
T (T1)= 2 x **FCP 180** + **AS 1955(*)**	or T (T2)= 2 x **FCP 180** + **AM 1800(*)**
U (U1)= 2 x **FCP 180**+ **AS 3000(**)**	or U (U2)= 2 x **FCP 180**+ **AM 2700(**)**
W (W1)= 2 x **FCP 180** + **AS 4300(**)**	or W (W2)= 2 x **FCP 180** + **AM 3300(**)**
V = **FS 300** + **AM 4200(**)**	
Y = **FS 400** + **AM 6600(**)**	
Z = **FS 400** + **AM 5400(**)**	

Notes: # local laws in some countries do not allow any treatment of drinking water.
(*) CL 90i automatic resins sterilization system.
(**) CL 180i automatic resins sterilization system.

Whether the hardness is below 20 °Fr, filtration only is recomended, according to European Directive standard mentioning a value of 15°Fr as recommended hardness of drinking water.

The above suggested solutions can be modified according to the below notes:

key	A	as alternative filter FCR 35-3/4” or FTA 050 or FTA 050/A
key	B	as alternative filter FCR 35-1” or FTA 070 or FTA 070/A
key	C	as alternative filter FTA 090 or FTA 090/A
key	D	as alternative filter FTA 120 or FTA 120/A
key	E EE	as alternative filter FTA 180 or FTA 180/A
key	I	as alternative filter FCR 35-1” or FTA 070 or FTA 070/A
key	J K	as alternative filter FCR 35-1” or FTA 070 or FTA 070/A compact softeners AC available as AC/AT - AC/AV - AC/T - AC/SV; besides, correspondent AS series models can be used (AS/AT - AS/AV - AS/T - AS/SV).
key	L	as alternative filter FCR 35-1” or FTA 070 or FTA 070/A Softeners AS available as AS/AT - AS/AV - AS/T - AS/SV
key	M	as alternative filter FTA 090 or FTA 090/A Softeners AS available as AS/AT - AS/AV - AS/T - AS/SV
key	N O P	as alternative filter FTA 120 or FTA 120/A Softeners AS available as AS/A2T - AS/A2V - AS/T - AS/SV
key	Q R S T U W	as alternative filter FTA 180 or FTA 180/A Softeners AS available as AS/A3T - AS/A3V - AS/T - AS/V Softeners AM available as AM/T - AM/V - AM/DT - AM/DV
key	V Z Y	Softeners AM available as AM/T - AM/V - AM/DT - AM/DV

Note: The above table is based on an assumed consumption of 250 liters/person per day and 4 persons/flat; the peak flow rate is calculated on a max flow of 1000 l/h per flat and average contemporaneous flow correction factor.
The above estimated consumptions and data are supplied as directions only, they are influenced by many factors and are subject to change according to local conditions, plants, available water and else.

The above table concerns residential buildings only, and are not applicable for hotels, residences etc., where many other factors influence the selection.

Water heater (for sanitary use)

The below directions and suggestions concerns central water heating system for residential buildings.
As usual the selection of a proper suitable softener should take in consideration both flow rates and cycle of the softener.
It is suggested to select the softener according to the flow rate first, and then check that the correspondent cycle of selected model is suitable for the application.
The flow rate must be calculated the usual way (pumps, nos of flats, bathroom etc.); usually the flow rate required for a central water heater system is approx 35 % of the flow rate calculated for drinking water (where both cold and hot water are included).
The softener should have a max flow rate equal or higher than the calculate one. After that, check that the cycle of the softener is suitable to supply treated water for a minimum of 1 day, even it is suggested an operating cycle of 2 days at least.

Example:
We assume to select a softener for a system, the flow rate of which is calculated of 4.0m³/h.
The hardness of available raw water is 30ºFr.
The selected softener could be model AS 450, and now the cycle should be checked if suitable, as usual: **$m^3 \times {}^oFr = cc\ (m^3 \times {}^oFr)$**

m^3 = quantity of water contained in the system
ºFr = hardness of raw water in °Fr
cc = cycle of the required softener (m^3 x ºFr)

and reversing it $$m^3 = \frac{cc\ (m^3 \times {}^oFr)}{{}^oFr} = \frac{450}{30} = 15$$

The selected unit can treat approx 15 m³ of water between 2 regenerations. It should be checked if this quantity is enough for 2-3 days.
Whether the unit is not suitable, proceed for the higher model and so on.
Concerning the control (see also RI11_I "How to select the control for a water treatment unit"), it is suggested to choice a time/volume control (i.e. models AS/SV or AS/V or AM/V or AM/DV) in order that the regeneration runs after that the pre-set quantity of water has been supplied, but at a pre-set time of day.

This bullettin is provide only as general directions about the principles and applications of water softening.

Apply Nobel Service or Technical Centers for further informations about special application.