Aquatronica®
AQUARIUM CONTROL SYSTEMS

Measuring salt levels in a marine aquarium

The salt concentration in the water is a fundamental parameter for the survival of fish and invertebrates in a marine aquarium.
There are numerous ways of expressing the concentration of these salts in the tank, which vary depending on the measurement method and the unit of measurement used. The only way to determine concentration electronically is to measure the conductivity of the water. As a result, all the electronic instruments available on the market measure this parameter, which may then be used to calculate the other parameters required indirectly. The instruments most commonly used for this measurement are as follows:

Instrument	Parameter measured	Relative unit of measurement
Conductivity cells	Conductivity	mS/cm
Swing arm hydrometer	Specific gravity (+ salinity)	adimensional (+PSU/ppt)
Floating hydrometer	Specific gravity	adimensional
Refractometers	Specific gravity (+ salinity)	adimensional (+PSU/ppt)

These instruments are based on different physical and chemical principles and give results expressed with different units of measurement depending on the parameter actually measured by the instrument: conductivity, salinity, specific gravity or density.
These values may be converted to and from one another using special tables. However, it is important to note that there are a number of variables that must also be taken into account, the most important of which being temperature.

Conductivity

Conductivity is an electrical parameter that varies in proportion with the concentration of mineral salts dissolved in the water (in other words salinity) and with the mobility of these salts (which depends on temperature and pressure). This value is electrically measurable and is expressed in mS/cm (milliSiemens per centimetre) or μS/cm (microSiemens per centimetre).
There are many different types of cells (probes) for measuring this value, which differ in the number of electrodes and the material used for their construction.
As temperature strongly influences the measurement, the Aquatronica system features an automatic compensation function, meaning that no correction using mathematical formulas or tables is necessary. The result read on the instrument's display is the conductivity measured in the aquarium water corrected for a reference temperature of 25°C. This means that the value read may be compared against any other reading taken with an instrument using a reference temperature of 25°C. If the value shown on the display was the effective conductivity, in other terms, the conductivity effectively measured in the aquarium, converting the value into other units of measurement would be very complicated and easily susceptible to error.

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Automatic temperature compensation is performed not just during reading but also when calibrating the instrument. This means that the calibration solution may be left at ambient temperature during calibration without having to bring the temperature to 25°C before starting.
Once the measurement in mS/cm has been taken, this may be used to determine the corresponding density, salinity and specific gravity (see the table at the end of this document, which is based on a reference temperature of 25°C).

Salinity

Salinity (S) may basically be defined as the total concentration of solids (salts) dissolved in a liquid. The salinity of seawater, where the predominant salt is NaCl (sodium chloride), is approximately 35 ppt (parts per thousand), equating to 35g of salt in every 1000g of water.
Measurements in ppt may be equated to measurements in PSU (practical salinity units), which is defined in terms of the ratio between the electrical conductivity of the sample solution and that of a reference solution of KCl (potassium chloride) (32.43g/Kg, 15°C, 1 atm).

Density and Specific Gravity

Density (d) is a physical-chemical parameter representing the ratio between the mass and the volume of a liquid or, put more simply, the volume occupied by a given mass of matter. This parameter is usually expressed in g/l (grams/litre). For a reef aquarium, this value should be maintained at approximately 1.023 g/l.

Generally, a liquid or a gas expands in volume as its temperature increases, and contracts as its temperature decreases. Water differs slightly from this general rule in that it contracts in volume (and therefore increases in density) gradually as temperature decreases, but only down to 3.98°C. At this temperature, water reaches its maximum density (approximately 1), and it then starts to expand in volume as temperature decreases further. It is, of course, common knowledge that ice is less dense than water as a similar mass of ice occupies a larger volume.

From this rule, it is patently clear that the temperature at which the density is measured is a very important parameter that must be considered in order to obtain correct, repeatable and reliable results.
Specific gravity (SG), also known and relative density, is defined as the ratio between the density of a sample solution at a given temperature and that of a standard solution at a given temperature.

There are a number of different standard temperatures which may be used: such as 3.98°C, 15°, 20°C or 25°C for example.
The SG of a water sample with a salinity of 35 varies depending on which standard is chosen as the reference (see table below).

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Standard	SG	Range
d $^{4}/_{4}$	1.0278	1.027-1.029
d $^{15.6}/_{15.6}$	1.0269	1.026-1.028
d $^{20}/_{20}$	1.0266	1.026-1.028
d $^{25}/_{25}$	1.0264	1.025-1.028
d $^{15.6}/_{4}$	1.0259	1.025-1.027
d $^{20}/_{4}$	1.0248	1.024-1.026
d $^{25}/_{4}$	1.0234	1.022-1.025

In the term "d $^{20}/_{4}$", for example, the number 20 indicates the water T at which the density is measured, whereas the number 4 indicates the water temperature relative to the density against which the measurement is compared.

NB: It is very easy to confuse these two parameters because they are expressed with numbers that may appear similar but are in fact very different. For example, the density and specific gravity values for a theoretical salinity of 35 ppt are:

Density = approx. 1,023 g/l
Specific gravity = approx. 1.026

While it may be easy to oversee the distinction between the decimal point and comma, they significantly change the order of magnitude of the measurement.

Measurement instruments

Instruments for measuring ***conductivity*** are generally electronic circuits of varying complexity processing a signal generated by a ***conductivity cell.***

Figure 1) Conductivity cell

The electronic circuit passes a small alternating current through a small sample of water contained in the cells.
By measuring the resistance to the flow of electrons offered by the water, the instrument can determine the amount of current conducted and, therefore, the conductivity.

Figure 2) Floating hydrometer

Specific gravity (SG) is measured with ***Floating hydrometers***.
These instruments make use of the Archimedes Principle: a body immersed totally or partially in a fluid receives an upward thrust called the buoyancy force, which is equal to the weight of a mass of water of the same shape and volume as the immersed part of the body. Put more simply, the body is pushed upward with a force equal to the weight of the volume of liquid displaced.

As a consequence, if the weight of the floating object and the displaced volume of liquid are known, the density of the liquid can be determined, and the hydrometer uses this principle. At the top of the instrument is a reference scale from which the SG value can be read in relation to how much the instrument itself floats.
As with density, temperature also significantly influences the SG reading.

Hydrometers are calibrated at a standard temperature (usually 20 or 25°C), and the reading must be corrected in reference to this temperature in order to ascertain the correct SG value. The value effectively measured by the floating instrument will not be the real value because the aquarium temperature will certainly not be the same as the instrument calibration temperature. The relative tables (supplied together with the instrument) must be referenced, reading off the correct SG value relative to the actual aquarium temperature. If the aquarium temperature is the same as the instrument calibration temperature, no correction is necessary. However, bear in mind that even a difference of 1 °C is significant.

In addition to the standard temperature, another variable in the system is the sample temperature: the hydrometer itself may vary slightly in density in relation to the temperature and give incorrect results at any T other than the specific reference temperature. Unfortunately, there are no tables for correcting this effect, which varies in relation to the material from which the instrument is made. Another reason why the sample T is important is that the sample itself changes density in relation to T: for instance, the density of water with a salinity of 35 changes from 1.028 g/cm^3, if read at 3.98°C, to 1.025 g/cm^3 if read at 20°C. The density at a typical temperature for a marine aquarium is approximately 1.023 g/cm^3.

It is therefore clear that the results obtained with this instrument can only be considered reliable if it is used in the conditions for which it was designed, otherwise there is a risk of basing aquarium maintenance on incorrect data. Even using instruments with temperature compensation will, in reality, not always guarantee consistently correct results.
Another type of commercially available instrument is the ***swing arm hydrometer***. These are filled with a given volume of liquid, and the correct SG value is read from the movement of the arm against a reference scale. The principle behind these instruments and the variables influencing the reading are the same as those for floating hydrometers.
Of the two types, however, floating hydrometers are perhaps preferable, as they are easier to clean to remove any encrustations which may distort the results.

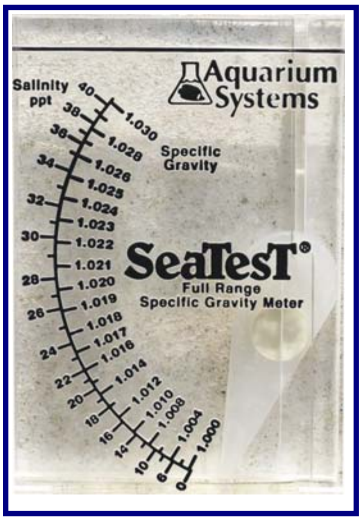

Figure 3) Swing arm hydrometer

Figure 4) Refractometer

The issue of temperature must also be considered when using ***refractometers***.

These are based on a completely different physical principle: the refraction of light (not to be confused with reflection or diffraction). Refraction is the deflection in the path of light as it passes from one physical medium to another as a result of the different propagation speeds of the two materials.

When light passes from a medium with a certain density (air) to another of different density (water), refraction occurs.

A few drops of saline water placed on the prism – just enough to cover it completely – are enough to significantly change the direction of the light. The refracted light projects a line on a scale. The greater the salinity, the higher this line appears on the scale.

Most refractometers feature an SG scale alongside a salinity scale in ppt/PSU.

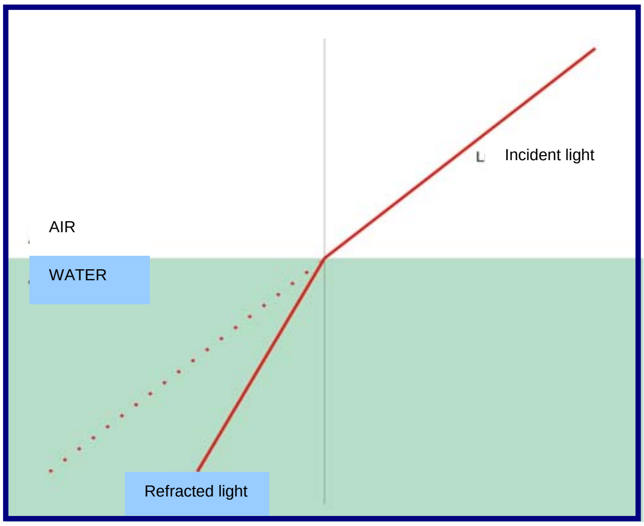

Figure 5) Light refraction

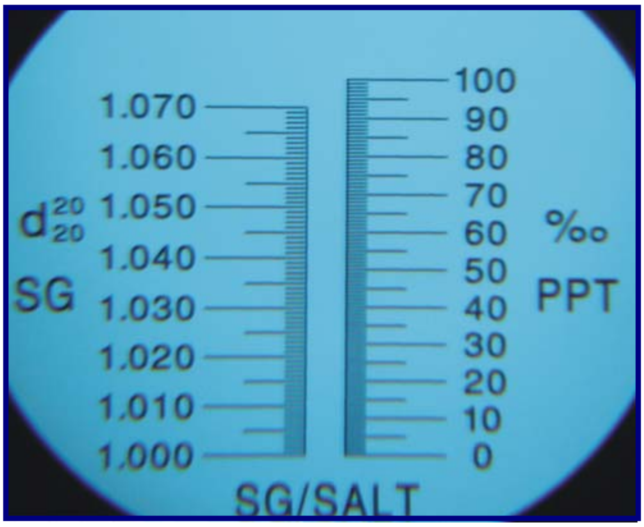

Figure 6) Scale on a refractometer

Here too, it is very important to use the instrument correctly, considering both the temperature of the sample and the calibration temperature for the instrument (e.g. $d^{20}/_{20}$).

Even ATC instruments (with automatic temperature compensation) exhibit some temperature dependency with large differences (which is why these instruments must not be kept in very warm or very cold places). This dependency can be demonstrated by simply measuring the water in your aquarium with a refractometer before and after placing it for a few minutes in a cold place, such as the refrigerator. You will see that the reading changes significantly.

One must also remember to calibrate the refractometer with the specific solution supplied or using distilled or double-distilled water.

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Conclusions

From the above, it is clear that in order to ensure accurate, reliable and repeatable results, working correctly and precisely is indispensable. One must be fully aware of any variables in the system that may significantly influence the measurements made. It is therefore best to use the conductivity reading made with the relative probe as a basis and then convert this measurement into salinity expressed in PSU (the Aquarium Controller comes ready equipped with the capability to convert between different units of measurement). If you need to compare the results obtained with measurements made with other instruments, take all the factors described previously into account and take all measures necessary to ensure comparability between readings, paying particular attention to the temperature at which measurements are made.

The Aquatronica technical team will be happy to answer any of your queries on this topic. For further information, please email us at: service@aquatronica.com

The following is a conversion table between the different parameters described above:

DENSITY CONVERSION TABLE (Reference Temperature = 25°C)			
Conductivity (mS/cm)	**Density (g/l)**	**Salinity (ppt/PSU)**	**Specific Gravity**
40 ms/cm	1016.2 g/l	25.5 ppt/psu	1.0187
40.5 ms/cm	1016.5 g/l	25.9 ppt/psu	1.0190
41 ms/cm	1016.7 g/l	26.2 ppt/psu	1.0193
41.5 ms/cm	1017 g/l	26.6 ppt/psu	1.0195
42 ms/cm	1017.3 g/l	26.9 ppt/psu	1.0198
42.5 ms/cm	1017.5 g/l	27.3 ppt/psu	1.0201
43 ms/cm	1017.8 g/l	27.7 ppt/psu	1.0204
43.5 ms/cm	1018.1 g/l	28.0 ppt/psu	1.0206
44 ms/cm	1018.4 g/l	28.4 ppt/psu	1.0209
44.5 ms/cm	1018.6 g/l	28.7 ppt/psu	1.0212
45 ms/cm	1018.9 g/l	29.1 ppt/psu	1.0214
45.5 ms/cm	1019.2 g/l	29.5 ppt/psu	1.0217
46 ms/cm	1019.4 g/l	29.8 ppt/psu	1.0220
46.5 ms/cm	1019.7 g/l	30.2 ppt/psu	1.0223
47 ms/cm	1020 g/l	30.5 ppt/psu	1.0225
47.5 ms/cm	1020.3 g/l	30.9 ppt/psu	1.0228
48 ms/cm	1020.5 g/l	31.3 ppt/psu	1.0231
48.5 ms/cm	1020.8 g/l	31.6 ppt/psu	1.0234
49 ms/cm	1021.1 g/l	32.0 ppt/psu	1.0236
49.5 ms/cm	1021.4 g/l	32.4 ppt/psu	1.0239
50 ms/cm	1021.6 g/l	32.7 ppt/psu	1.0242
50.5 ms/cm	1021.9 g/l	33.1 ppt/psu	1.0245
51 ms/cm	1022.2 g/l	33.5 ppt/psu	1.0248
51.5 ms/cm	1022.5 g/l	33.8 ppt/psu	1.0250
52 ms/cm	1022.8 g/l	34.2 ppt/psu	1.0253
52.5 ms/cm	1023 g/l	34.6 ppt/psu	1.0256
53 ms/cm	1023.3 g/l	34.9 ppt/psu	1.0259
53.5 ms/cm	1023.6 g/l	35.3 ppt/psu	1.0262
54 ms/cm	1023.9 g/l	35.7 ppt/psu	1.0264
54.5 ms/cm	1024.2 g/l	36.1 ppt/psu	1.0267
55 ms/cm	1024.4 g/l	36.4 ppt/psu	1.0270
55.5 ms/cm	1024.7 g/l	36.8 ppt/psu	1.0273
56 ms/cm	1025 g/l	37.2 ppt/psu	1.0276
56.5 ms/cm	1025.3 g/l	37.6 ppt/psu	1.0278
57 ms/cm	1025.6 g/l	37.9 ppt/psu	1.0281
57.5 ms/cm	1025.9 g/l	38.3 ppt/psu	1.0284
58 ms/cm	1026.1 g/l	38.7 ppt/psu	1.0287
58.5 ms/cm	1026.4 g/l	39.1 ppt/psu	1.0290
59 ms/cm	1026.7 g/l	39.6 ppt/psu	1.0293
59.5 ms/cm	1027 g/l	39.8 ppt/psu	1.0296
60 ms/cm	1027.3 g/l	40.2 ppt/psu	1.0299