Water and Slurry Introduction

There are three states of all mater: gaseous, liquid or solid and each state are determined by its own temperature and pressure. The best known example of a substance with the three states is water, which in temperatures and pressures can exist as steam, water and ice.

Fluids

Liquids and gases are called fluids because they can flow and can take the shape of any container into which they are entered. However, there are still great differences between liquids and gases. A liquid can have separating upper and lower surfaces with other liquids – if they do not mix – or with gases but a gas cannot have a separating surface with another gas. Some liquids mix with other liquids (water and wine) some do not (water and oil). All gases mix with each other and some gases can dissolve in some liquids. Liquids are virtually incompressible whereas gases are compressible.

Many physical, chemical or other properties identify all substances. In pumping we are mainly concerned with properties associated with mass. A force imparts acceleration to a mass. Weight, as a particular form of force, imparts gravitational acceleration to a mass. For easy comparison of various materials, we usually express their masses relative to a unit volume. This physical property is called Density ρ [kg/m3]. Occasionally density is expressed in tonnes per cubic meter [t/m3] or kg per liter [kg/L], which is numerically equal.

Liquids

The most common liquid handled by centrifugal pumps is water. At normal ambient pressure and at freezing point (0℃), water and ice have densities of 999 and 895 kg/m3 respectively, which explain why ice floats on water. At the same pressure but at boiling point (100℃), water and saturated steam has densities of 957 and 0.590 kg/m3 respectively, which shows that water expands approximately 1600 times after boiling. The most common solid material handled by centrifugal pumps is silica in the form of sand or rock, whose density is around 2650 kg/m3.

Very often we express unit mass of a material by its Specific gravity or SG, a dimensionless number, which we obtain by dividing the density of the material by the density of water. For this particular purpose, we usually take the density of water as 1000 kg/m3 and so the SG of any material is simply equal to its density divided by 1000. By this reasoning, the SG of water is 1 and that of silica is 2.65.

SLURRIES

In solids handling by pumping, we mix some solid matter with some liquid carrier to form a slurry, i.e. a mixture of liquid and solid particles, large or small. In calculations associated with slurry pumping in this Manual we use the following symbols: the SG of the solids is S, the SG of the liquid is Sw. The SG of the mixture is Sm. Often mixtures of solids and liquids can be treated as an equivalent fluid with the same SG=Sm. Two additional parameters are used, namely Concentration of solids in the mixture by weight Cw [%] and Concentration of solids in the mixture by true volume Cv [%]. The word true is often omitted. To understand its meaning, consider the following:

A hollow cube with sides D has a volume of D3. A solid sphere of diameter D has a volume of 0.52D3 and would take up 52% of the cube's volume. If eight smaller spheres were added with centers at the corners of the cube and touching the large sphere the volume of the portions of these spheres inside the cube would be 0.20D3 and the combined volume of the nine spheres would be 72% of the cube. A progressive similar fitment of smaller spheres of correct number and size would make their combined volumes quickly converge to an asymptotic value of around 74%. If we had spheres of the same diameter or if we had solid particles of various shapes and sizes, the true volumes filled would vary from 50% to 80%. For loose sand it is around 73%.

There are, as we have seen, five inter-related variables, which we use with slurries. on next page lists all the equations for calculating any one of the variables from other known values. For water use Sw=1.

Divide all Cw and Cv values by 100 – if expressed as percentages (%) – before using them in
the tabulated equations.

Specific Gravity and Concentration Equations for Slurries

Sw = S(SmCw–Sm) /(SmCw-S) = (SCv–Sm) / (Cv–1) = S[Cv(Cw–1)] / [Cw(Cv– 1)]
S = SwCw(Cv–1) / [Cv(Cw-1)]= Sw+(Sm–Sw) / Cv = SwCw / (Cw–1+Sw/Sm)
Sm = Sw / [1–Cw(1–Sw/S)] = Sw+Cv(S–Sw) = Sw(Cv–1) / (Cw–1)
Cw = S(Sm–Sw) / [Sm(S– = SCv / [Sw+Cv(S–Sw)] = 1+Sw(Cv–1) / Sm
Cv = (Sm–Sw) / (S–Sw) = Sw / (Sw–S+S/Cw) = 1+Sm(Cw–1) / Sw

For any slurries, when any three of the five variables tabulated at left are known, the fourth and
fifth may be calculated from the equations shown. Another useful – and possibly surprising – equation is: Cw/Cv = S/Sm

As can be readily seen, this equation is independent of liquid density Sw and it holds true for
solids mixed with any liquid. In other words, when the ratio Cw/Cv for a slurry has been given a
value, the ratio S/Sm must have the same value and the specific gravity of the liquid Sw can then be changed at will without affecting the said value. The equation is used to calculate any one of its four variables when the other three are known.