Material balance in steam boiler

Power-Chemicals

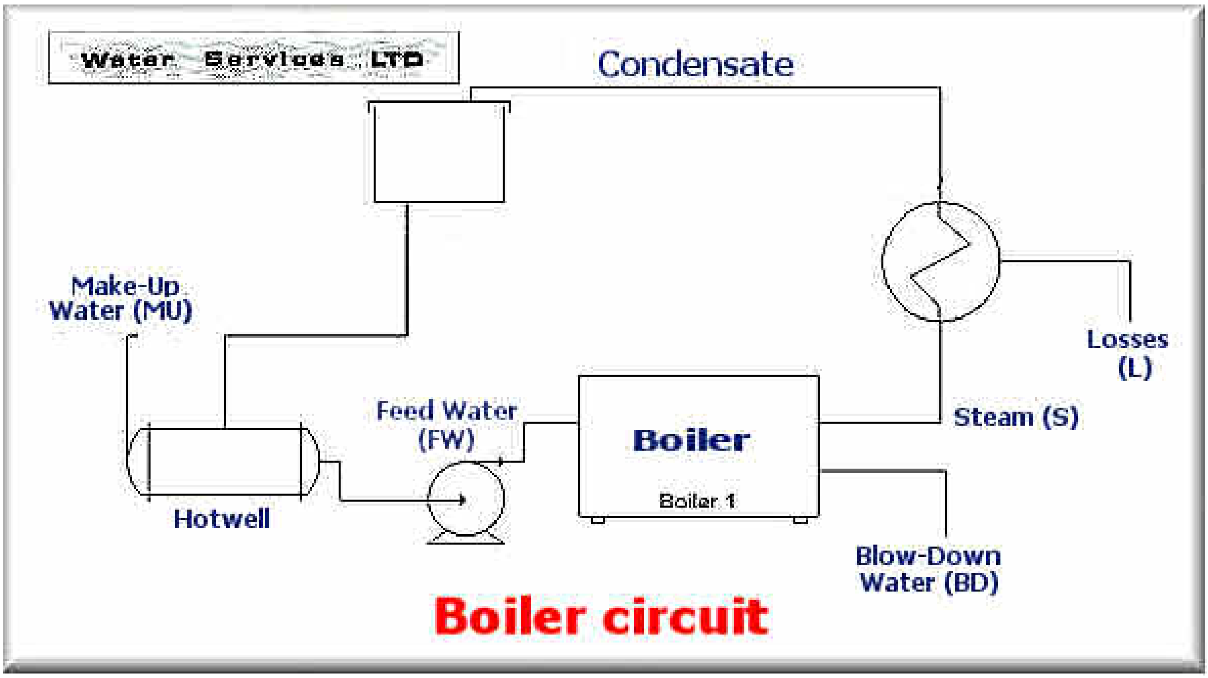
Water Services LTD

www.arvanitakis.com www.power-chemicals.com www.refinery-chemicals.com www.paper-specialities.com

tel +30 6948 518699

e mails dennis@arvanitakis.com export@power-chemicals.com

Material balance in steam boiler



A simplified flow sheet of water in boiler circuit is presented at the above sketch.

The boiler is producing steam **(S)** which is driven to the consumption. There its heat is recovered, and the steam is condensed. During this process a part of water is lost as losses **(L)** and the remaining returns to the condensate collection tank as condensate **(C)**. From the condensate collection tank is driven to the feed water tank (hotwell), maybe through deaerator.

At the hotwell is added also fresh water **(Make-up, MU)** as to cover the losses, and the mixture is fed to the boiler as feed water **(FW)**.

Feed water contains dissolved solids from make-up. As the produced steam is pure distilled water, these dissolved solids are left behind and its concentration into the boiler is increased.

As to avoid the overconcentration we deconcentrate the boiler by removing a quantity of concentrated boiler water, replacing by fresh water. This is called blow down **(BD)**.

From the drawing we can obtain the relationships:

a. FW = MU + C

b. FW = S + BD

c. MU = L + BD

The × factor.

If we define the relation :

$$MU / FW = \times$$

Then × is the participation of make up at the feed water, and can vary from zero till one.

The participation of condensate is:

$$1 - \times$$

The × is called **make-up ratio**, while **1 - ×** **is condensate ratio**.

Operators are using the terms **% make up** and **% condensate** which correspond to:

$100 * \times$ and **$100 * (1-\times)$**.

The × factor, even being hydraulic characteristic of the process, can be calculated every moment from the chemical analysis of the water.

Taking into consideration a water analysis constituent which comes into the circuit only through make-up and leaves only through blowdown and losses, is not transformed, destroyed or precipitates , like chloride ion, then its material balance for the feed water will be:

$$MU * CL_{MU} + C * CL_{C} = FW * CL_{FW}$$

or

$$MU/FW * CL_{MU} + C/FW * CL_{C} = CL_{FW}$$

or

$$\times * CL_{MU} + (1-\times) * CL_{C} = CL_{FW}$$

and finally:

$$X = \frac{CL_{FW} - CL_{C}}{CL_{MU} - CL_{C}} \qquad (d)$$

So from the water analysis of make up, feed water and condensate we can calculate the × factor from equation (d).

If there is not priming or carry-over, **$CL_C=0$.** In any case, when:

$$CL_C > CL_{MU}$$

Condensate has to be rejected.

Definition of cycles of concentration (NC & NF).

We define the **<u>Make-up cycles of concentration (NC)</u>** as::

$$NC = MU / BD \qquad (e)$$

And **NC** represents the concentration of the make-up into the boiler.

We define also the **<u>Feed-water cycles of concentration (NF)</u>** as:

$$NF = FW / BD \qquad (e.1)$$

This represents the concentration of the feed-water into the boiler.

Making the material balance for a water analysis constituent which comes into the circuit only through make-up and leaves only through blowdown and losses, is not transformed, destroyed or precipitates, like chloride ion, we can correlate **NC and NF** and calculate them from water analysis.

$$NC = \frac{MU}{BD} = \frac{CL_{BD} - CL_C}{CL_{MU} - CL_C} \quad (e.2)$$

$$NF = \frac{FW}{BD} = \frac{CL_{BD} - CL_C}{CL_{FW} - CL_C} \quad (e.2a)$$

and

$$NC = X * NF$$

We can calculate **NC** and **NF** from the chemical analysis data.

Material balance of water.

Combining the equations **(a)** till **(e.2)** we can calculate all hydraulic quantities, and close the material balance.

We are using as basic parameter the steam production **S**, and × plus **NC** which we calculate from chemical analysis.

The equations obtained are::

$$(f) \quad MU = S * \frac{\times * NC}{NC - \times}$$

$$(g) \quad BD = S * \frac{\times}{NC - \times}$$

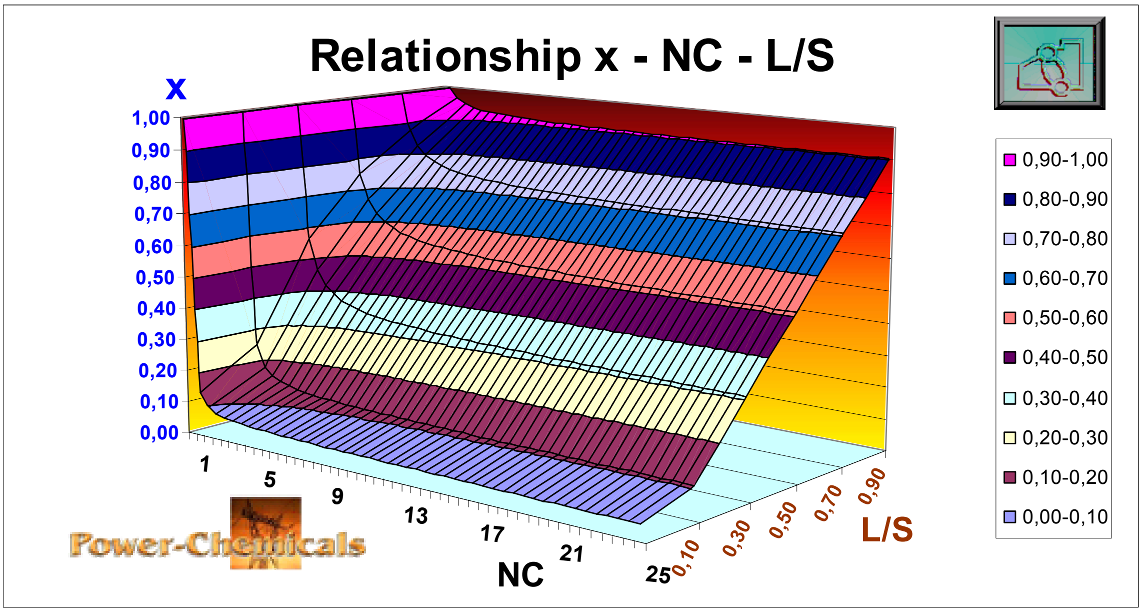
$$(h) \quad FW = S * \frac{NC}{NC - \times}$$

$$(i) \quad C = S * \frac{NC(1-\times)}{NC - \times}$$

$$(j) \quad L = S * \frac{\times*(NC-1)}{NC - \times}$$

Solving the last equation, and due to the fact that **L and S** are operational constants of our system, we obtain the relationship of × **- NC** which it is ***INDEPENDENT*** of the system, which is applied.

$$(k)\quad x = \frac{L/S * NC}{L/S + (NC - 1)}$$



Energy conservation

Blowdown is a basic energy loss in steam boiler, because high temperature water is rejected, as to de-concentrate the dissolved solids.

Our attempt has to be to decrease **BD**, as to minimize energy loss.

According the material balance, the quantity of **BD** is:

$$\textbf{(g)} \qquad BD = S * \frac{\times}{NC - \times}$$

And this relationship can be modified to:

$$\textbf{(l)} \quad BD / S = \frac{1}{[NC / \times] - 1}$$

which represents the corresponding **BD** quantity as a function of **NC** and ×.

The relationship of losses according to the material balance is:

$$\textbf{(j)} \qquad L = S * \frac{\times * (NC-1)}{NC - \times}$$

Combining above equations we conclude::

$$\textbf{(m)} \quad BD/S = [L/S] / [NC - 1]$$

Which correlates **BD/S** and **L/S**, to **NC**, means correlates operational parameters to water analysis. This correlation is presented to the following graph.