MODELLING OF VARIATION WITH TIME OF FLOW OF MEMBRANE DESALINATION PERMEATORS: B10 AND B9 CASES

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INTRODUCTION:

A desalination plant by reverse osmosis is formed mainly by modules, like the B9 case for brackish water desalination, and B10 case for seawater desalination. These types of permeators which are the more used in the desalination plants in the world [1], [2], are formed by hollow fine fibre membrane made from aramid polymer (polyamid) manufactured by the Dupont Company and currently by the Company Toyobo (Japan) [3].

The design and the calculation of the reverse osmosis desalination plants, pass by the good evaluation of the modules flow, with operation pressure, with feed water temperature and also with time (operation life of modules). We note that the permeator flow decreases progressively during her operation and functioning. By consequence, the permeator flow is equal to its flow under the standard conditions of operation (tested at the laboratory) corrected by three factors [4], [5], [6], [7], [8], [9]: a pressure correction factor PCF, a temperature correction factor TCF, and the membrane flux retention coefficient MFRC. As the only factor which depends on time; it is the MFRC, the study of the flow variation with time consists to the study and the modelling of MFRC during the operation life of permeators.

The MFRC values given by the supplier tables [4], [5], [6], allow only one tiresome manual calculation at the end of the first, the third and the fifth year of exploitations of permeators.

The existing mathematical models to calculate the MFRC enables us to estimate it as well as the flow only at the end of the lifetime permeators (theoretically five years) [10], [11], [7].

For certain cases of exploitation, and like it is also mentioned by the supplier, these permeators can function a long time under good conditions out the theoretical lifetime: 7 to 10 years [12], [13]; the Tunisian experiment show it. In this case, it is of primary importance to have a tool of forecast of the permeator flow out of lifetime (> 5 years).

The objective of this paper is to work out a reliable and effective mathematical model for the calculation of the permeateur flow (modules) of membrane desalination, through the modelling of the MFRC. To arrive at that, we must work out the mathematical models of MFRC behaviour, with pressure and temperature at the end of the first and the third year for the two cases: B9 and B10 permeators. For that of MFRC behavior at the end of the fifth year; they already exists [10], [11], [7].

MEANS AND METHODS:

The flow of a permeator (module) of membrane desalination of B10 and B9 types, is given as being the product of four parameters [4], [5], [6]: The pressure correction factor PCF, The temperature correction factor TCF, The membrane flux retention coefficient MFRC and Initial permeator capacity at standard test conditions. The only parameter which depends on time is MFRC. The tables giving the MFRC, gives measurements for nine values of temperature and seven values of pressure –only four values of pressure for the B9 permeators, - at the end of the first, the third and the fifth year of operation [4], [5], [6]. We follow in this work, the same base of methodology that we worked out, used and published in preceding work to study the behavior of the MFRC (Metaiche and al.. (2003) [10], Metaiche and al.. (2003) [11]), we will pass by: 1- Study and modelling of MRFC behavior with the pressure at constant temperature, and with the temperature at constant pressure.The more adapted model is :MFRC = F (P) = $A.e^{B.P}$. 2- To calculate the values of A and B. 3- Study and modelling of A and B behaviour with the temperature: A= F (t) and B = F (t). The more adapted model is the polynomial type, in the form: A = $a_1.t^3 + b_1.t^2 + c_1.t + d_1$ and B = $a_2.t^3 + b_2.t^2 + c_2.t + d_2$. 4- To calculate the values of the coefficients: a_1, b_1, c_1, d_1, a_2, b_2, c_2 and d_2 . 5- To draw the model MFRC = F (P, T) at the end of the first year. 6- To take again the preceding steps for the end of the third and the fifth year. 7- To calculate the values of the coefficients a_1, b_1, c_1, d_1, a_2, b_2, c_2 and d_2 . 8- To study and model the variation with time (number of years of operation) of a_1, b_1, c_1, d_1, a_2, b_2, c_2 and d_2 coefficients. 9- To draw and form finally the model MFRC = F (P, T, N); N: it is the number of years.

RESULTS AND DISCUSSION:

*** B 10 permeators case:** MFRC = $(A_1.t^3 + B_1.t^2 + C_1.t + D_1).e^{(\alpha_1.t^3+\beta_1.t^2+\gamma_1.t+\theta_1).10^{-3}.P}$

P: pressure in Psi , T: the temperature in °C, n: it is the number of years of operation. With:

A_1 = (0,1676.n ^{2} - 2,3640.n - 24,0380).10 $^{-6}$.

B_1 = (0,6708.n + 12,1270).10 $^{-4}$.

C_1 = (-0,0005.n ^{2} - 0,0317.n - 0,5764).10 $^{-2}$.

D_1 = (-0,0006.n ^{2} + 0,0069.n + 1,0587.

α_1 = (-0,0409.n ^{2} + 0,7160.n + 11,949).10 $^{-6}$.

β_1 = (0,0385.n ^{2} – 0,5963.n - 8,6164).10 $^{-4}$.

γ_1 = (0,00485.n ^{2} - 0,0356.n - 0,048).10 $^{-2}$.

θ_1 = 0,00102.n ^{2} – 0,0109.n - 0,0961.

*** B-9 permeators case:** MFRC = $(A_2.t^3 + B_2.t^2 + C_2.t + D_2).e^{(\alpha_2.t^3+\beta_2.t^2+\gamma_2.t+\theta_2).10^{-3}.P}$

P: pressure in Psi, T: the temperature in °C, n: it is the number of years of operation. With:

A_2 = (0,07106.n ^{2} - 0,46645.n + 0,5005).10 $^{-6}$.

B_2 = (-0,0516.n ^{2} + 0,3262.n - 0,384).10 $^{-4}$.

C_2 = (0,0096.n ^{2} - 0,0598.n + 0,0714).10 $^{-2}$.

D_2 = -0,0003.n ^{2} + 0,0018.n + 0,9973.

α_2 = (-1,4635.n – 35,934).10 $^{-6}$.

β_2 = (0,0844.n ^{2} – 0,0885.n + 11,654).10 $^{-4}$.

γ_2 = (-0,0166.n ^{2} + 0,0324.n - 1,8823).10 $^{-2}$.

θ_2 = 0,00238.n ^{2} – 0,0234.n - 0,1718.

The errors made on the estimate of all coefficients, are lower than 3‰. By the use of the same steps of the method that we already published in the articles: «Mathematical modeling of desalination parameters: one stage reverse osmosis case» [14], «New approach for computation of RO desalination parameters» [15] and « Nouvelle méthode pour le calcul des centrals de dessalement par osmose inverse» [16].

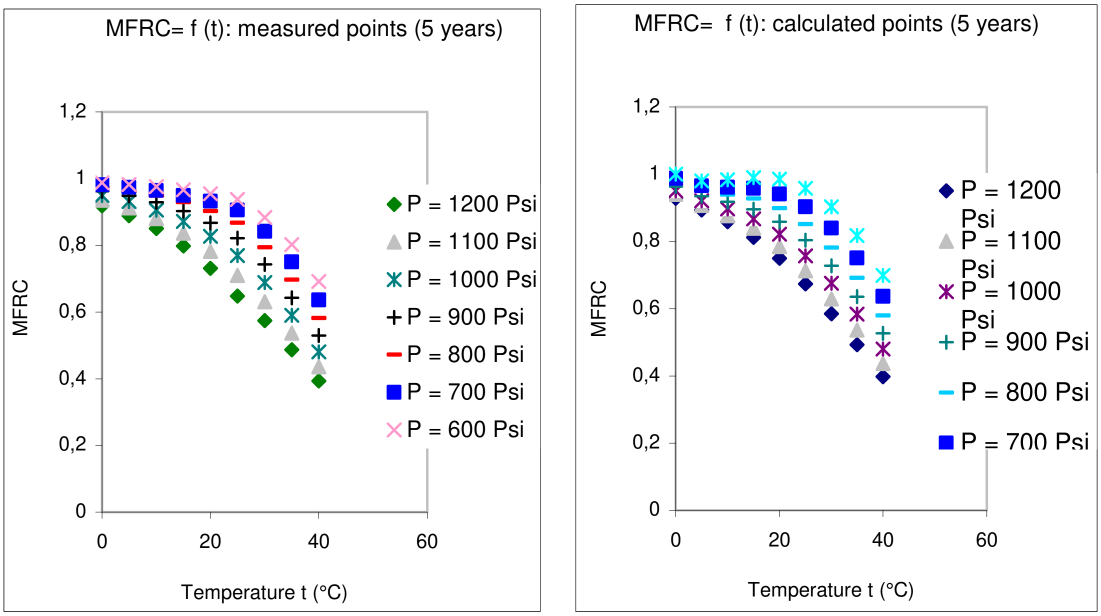

Figure 1 : The curves MFRC = f(t), B10 permeators case.

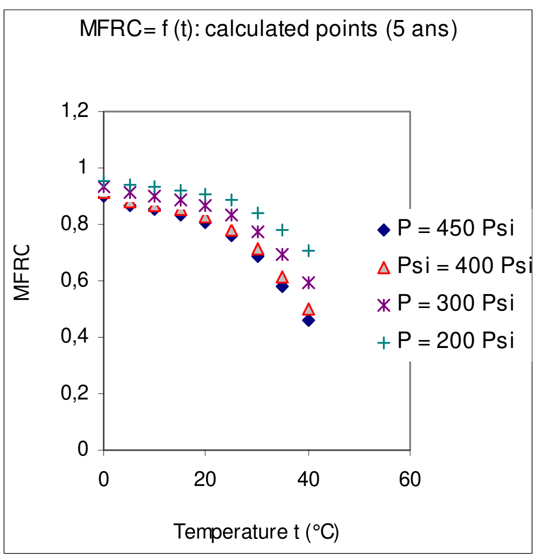

Figure 2 : The curves MFRC = f (t) , B9 permeators case.

CONCLUSION:

A long and complicated work was carried out; test of 1019 mathematical models, i.e. to also evaluate 1019 coefficients of correlation, and to choose most powerful at each stage. And by consequence, to calculate a more significant number of coefficients, by the means of the data-processing programs which we have to work out for these ends. A computational model of permeator flow for reverse osmosis desalination (sea waters and water brackish), reliable and effective is elaborate. The production of a RO desalination plant can be evaluated automatically in any moment of exploitation. The error analysis showed that the model that we established is very quite representative and reliable. This model which is formed by nine equations, does not prove practical for numerical calculations, but -and as all other stages of calculation of desalination systems is carried out on computers and PC- it is very useful, and its role is of primary importance for automatic calculations, and forms an important tool in the programming work data-processing. The importance of the model carried out for work of optimization of desalination systems, is

certain, because it is obvious now, that the unrolling of this calculations type, is carried out neither starting from the tables nor with the hand.
We add at the end that, to know the production of a desalination system under the various conditions and constantly at the exploitation, can better converge works which aims at reducing the costs more.

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