

هدف از این مقاله مدل سازی ریاضی تحلیل عملکرد برج های خنک کننده بسته و تعیین اثر پارامترهایی چون دمای آب اسپری شده ، دمای آب خنک شونده و همچنین مشخصات هوای جریان یافته، در سرتاسر برج است. تاثیر نسبت جرمی آب اسپری شده به هوا نیز که اثر مهمی بر روی کارایی برج دارد، مورد بررسی قرار گرفته و نحوه تغییرات عملکرد برج نسبت به آن تعیین شده است. تغییرات ضریب لوییس در طول برج نیز برای اولین بار بطور دقیق محاسبه شده و مقدار متوسطی برای آن توصیه شده است. همچنین اثر جهت ورود و نحوه توزیع آب خنک شونده نیز مورد بررسی قرار گرفته است.

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Parker

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$$m_s + m_a = (m_s + dm_s) + m_a (\omega_a + d\omega_a) \quad \text{ABCD} \quad (1)$$

$$dm_s = -m_a d\omega_a \quad (2)$$

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$$m_s = (m_s + dm_s) + \alpha_m (\omega_s - \omega_a) dA \quad \text{AMND} \quad (3)$$

^ Steady State
^ Drift Loss

$$dm_s = -\alpha_m (\omega_s - \omega_a) dA \quad ()$$

$$m_a d\omega_a = \alpha_m (\omega_s - \omega_a) dA \quad ()$$

$$m_w C_w dT_w = -U_o (T_w - T_s) dA \quad ()$$

$$m_a dh_a = [\alpha_m (\omega_s - \omega_a) h_{fg} + \alpha_{ca} (T_s - T_a)] dA \quad ()$$

$$h = C_{ma} T + \omega h_{fg} \quad ()$$

$$T_s - T_a = [h_s - h_a - h_{fg} (\omega_s - \omega_a)] / C_{ma} \quad ()$$

$$Le_f = \alpha_{ca} / \alpha_m C_{ma} \quad () \quad ()$$

$$m_a dh_a = \alpha_m [h_{fg} (\omega_s - \omega_a) (1 - Le_f) + Le_f (h_s - h_a)] dA \quad ()$$

$$m_a dh_a + m_s dh_{fs} + h_{fs} dm_s + dm_s dh_{fs} + m_w dh_w = 0 \quad ()$$

$$h_{fs} = C_s T_s \quad h_w = C_w T_w$$

$$m_s C_s dT_s = -m_a dh_a - C_s T_s dm_s - m_w C_w dT_w \quad ()$$

$$() \quad () \quad () \quad () \quad ()$$

$$\left\{ \begin{aligned} \frac{dm_s}{dA} &= -\alpha_m (\omega_s - \omega_a) \\ \frac{d\omega_a}{dA} &= \frac{\alpha_m}{m_a} (\omega_s - \omega_a) \\ \frac{dT_w}{dA} &= -\frac{U_o}{m_w C_w} (T_w - T_s) \\ \frac{dh_a}{dA} &= \frac{\alpha_m}{m_a} [h_{fg} (\omega_s - \omega_a)(1 - Le_f) + Le_f (h_s - h_a)] \\ \frac{dT_s}{dA} &= -\frac{m_a}{m_s C_s} \cdot \frac{dh_a}{dA} - \frac{T_s}{m_s} \cdot \frac{dm_s}{dA} - \frac{m_w C_w}{m_s C_s} \cdot \frac{dT_w}{dA} \end{aligned} \right. \quad ()$$

[] Bosnjakovic ◦

$$Le_f = 0.9078 \left[\left(\frac{\omega_s - \omega}{\omega + 0.622} \right) / \ln \left(\frac{\omega_s + 0.622}{\omega + 0.622} \right) \right] \quad ()$$

(α_m) (α_c)

[] Treybal Parker

$$\alpha_m = 0.049 G_a^{0.905} \quad ()$$

$$\alpha_c = 704 (1.39 + 0.022 T_s) \left(\frac{\Gamma}{D} \right)^{1/3} \quad ()$$

U_o

$$\frac{1}{U_o} = \frac{1}{\alpha_w} \left(\frac{D}{d} \right) + \frac{D}{2K_{tube}} \ln \left(\frac{D}{d} \right) + \frac{1}{\alpha_c} \quad (17)$$

[] Kays ($Re < \alpha_w$)

$$Nu = 3.66 + \frac{0.104 (Re_w Pr_w (d/L))}{1 + 0.016 (Re_w Pr_w (d/L))^{0.8}} \quad ()$$

($< Re <$)

[] Dreyer

:

$$Nu = \frac{(f/8)(Re_w - 10^3)Pr_w(1 + (d/L)^{0.67})}{1 + 12.7(f/8)^{0.5}(Pr_w^{0.67} - 1)} \quad ()$$

:

$$f = (1.82 \log_{10} Re_w - 1.64)^{-2} \quad ()$$

$< Re_w <$ $l < Pr_w <$ $< d/L <$: ()

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$$\varepsilon = \frac{T_{win} - T_{wout}}{T_{win} - T_{wbin}}$$

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$$Le_f = \alpha_{ca} / \alpha_m C_{ma}$$

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A : مساحت (m^2)

C : ظرفیت گرمایی ویژه ($kJ/(kg K)$)

C_{ma} : ظرفیت گرمایی ویژه هوای مرطوب ($kJ/(kg \text{ dry air } (K))$)

d : قطر داخلی لوله

D : قطر خارجی لوله

f : ضریب اصطکاک داخل لوله

G : دبی حجمی هوا ($\text{kg}/(\text{s m}^2)$)

h : آنتالپی (kJ/kg)

h_{fg} : آنتالپی تبخیر (kJ/kg)

h_{fs} : آنتالپی مایع اشباع اسپری (kJ/kg)

h_g : آنتالپی بخار آب در دمای صفر درجه سلسیوس (kJ/kg)

h_s : آنتالپی اشباع هوای مرطوب در دمای آب اسپری (kJ/kg)

K_{tube} : ضریب رسانایی گرمای لوله ($\text{W}/(\text{m K})$)

L : طول لوله در هر ردیف (m)

Le_f : ضریب لوییس

m : دبی جرمی (kg/s)

Nu : عدد ناسلت

Pr : عدد پرانتل

r : نسبت جرم آب اسپری شده به جرم هوا

Re : عدد رینولدز

T : دما ($^{\circ}\text{C}$)

T_{db} : دمای خشک هوا ($^{\circ}\text{C}$)

T_{wb} : دمای مرطوب هوا ($^{\circ}\text{C}$)

U_o : ضریب انتقال گرمای کلی (W/K)

α_c : ضریب انتقال گرمای جابجایی آب اسپری نسبت به لوله ($\text{W}/(\text{m}^2 \text{K})$)

α_{ca} : ضریب انتقال گرمای جابجایی آب اسپری نسبت به هوا ($\text{W}/(\text{m}^2 \text{K})$)

α_m : ضریب انتقال جرم ($\text{kg}/(\text{m}^2 \text{s})$)

α_w : ضریب انتقال گرمای جابجایی آب داخل لوله ($\text{W}/(\text{m}^2 \text{K})$)

Γ : دبی جرمی آب بر واحد طول لوله ($\text{kg}/(\text{m s})$)

\mathcal{E} : ضریب کارایی برج

ω : نسبت رطوبت هوای مرطوب (kg_w/kg_a)

زیر نویسها

a : هوا

in : ورودی

calc : محاسباتی

out : خروجی
 s : آب اسپری
 w : آب داخل لوله

جدولها

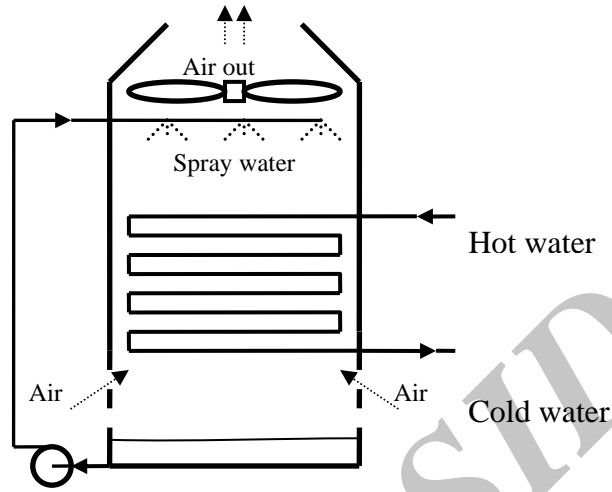
جدول ۱-

Supply air			Cooling water				Spray water			Error
V_a m^3/s	T_a $^{\circ}C$	RH %	m_w kg/s	$T_{w\ in}$ $^{\circ}C$	$T_{w\ out(ex)}$ $^{\circ}C$	$T_{w\ out}$ $^{\circ}C$	m_s kg/s	$T_{s(ex)}$ $^{\circ}C$	T_s $^{\circ}C$	(%)
0.48 ^a	16.07	50	0.4	18.54	15.67	15.82	1.37	15.10	15.54	3.87
0.48 ^a	21.33	43	0.6	21.18	19.15	19.20	1.38	18.56	18.78	1.45
0.48 ^b	20.70	45	0.8	20.38	18.90	18.95	1.38	18.10	18.40	1.92
1.08 ^a	26.19	47	0.4	23.96	20.82	20.78	1.37	20.37	20.50	0.83
1.08 ^a	19.71	46	0.6	18.01	15.89	15.97	1.38	15.33	15.52	1.74
1.08 ^b	13.03	87	0.8	15.86	14.35	14.55	1.38	13.85	14.10	3.20
1.36 ^a	19.74	43	0.4	17.77	14.78	14.83	1.38	14.30	14.53	1.95
1.36 ^a	32.50	30	0.6	23.86	21.84	21.77	1.37	21.43	21.36	0.65
1.36 ^a	16.21	94	0.8	18.99	17.39	17.70	1.38	16.79	17.25	4.52

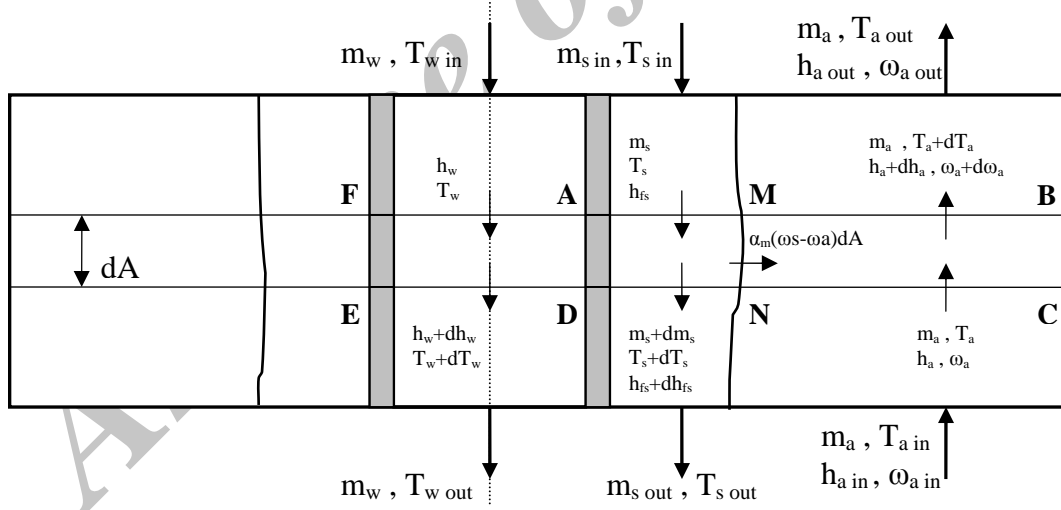
^a Ali Ala Hassan [22] , ^b Saffa Riffat, A.Oliveira, J.Facao, G.Gan, and P.Doherty [21]

$T_{db,out}$	$T_{wb,out}$	T_s	$T_{w,out}$
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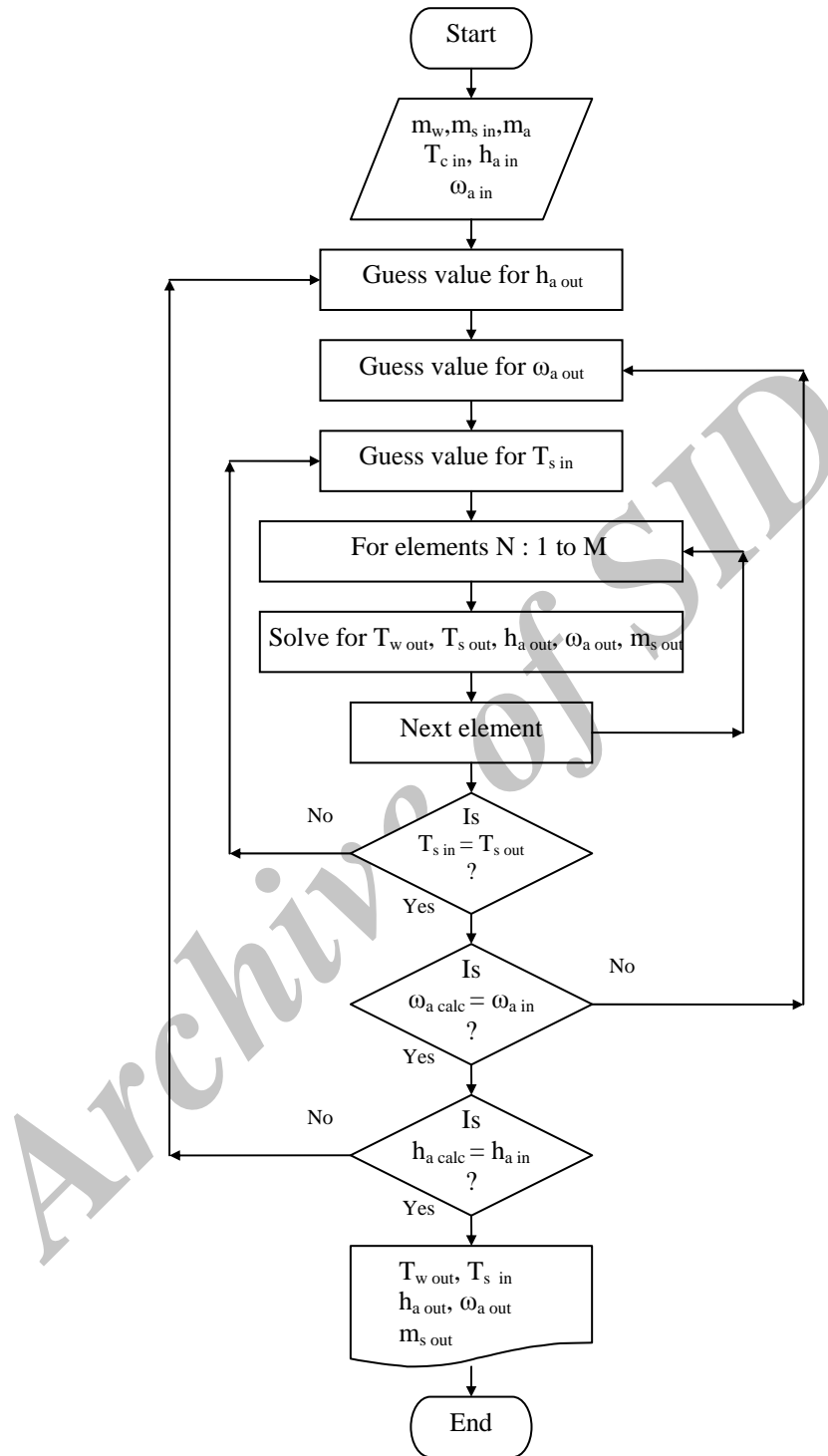
r (kg/s)	۰/۶	۱/۰	۱/۴	۱/۸	۲/۲
$T_{w\ out}$ (C) Cross Sys.	۳۴/۰۲	۳۳/۸۴	۳۳/۸۱	۳۳/۸۲	۳۳/۸۴
$T_{w\ out}$ (C) Parallel Sys.	۳۴/۹۷	۳۴/۷۹	۳۴/۷۳	۳۴/۷۱	۳۴/۷۳



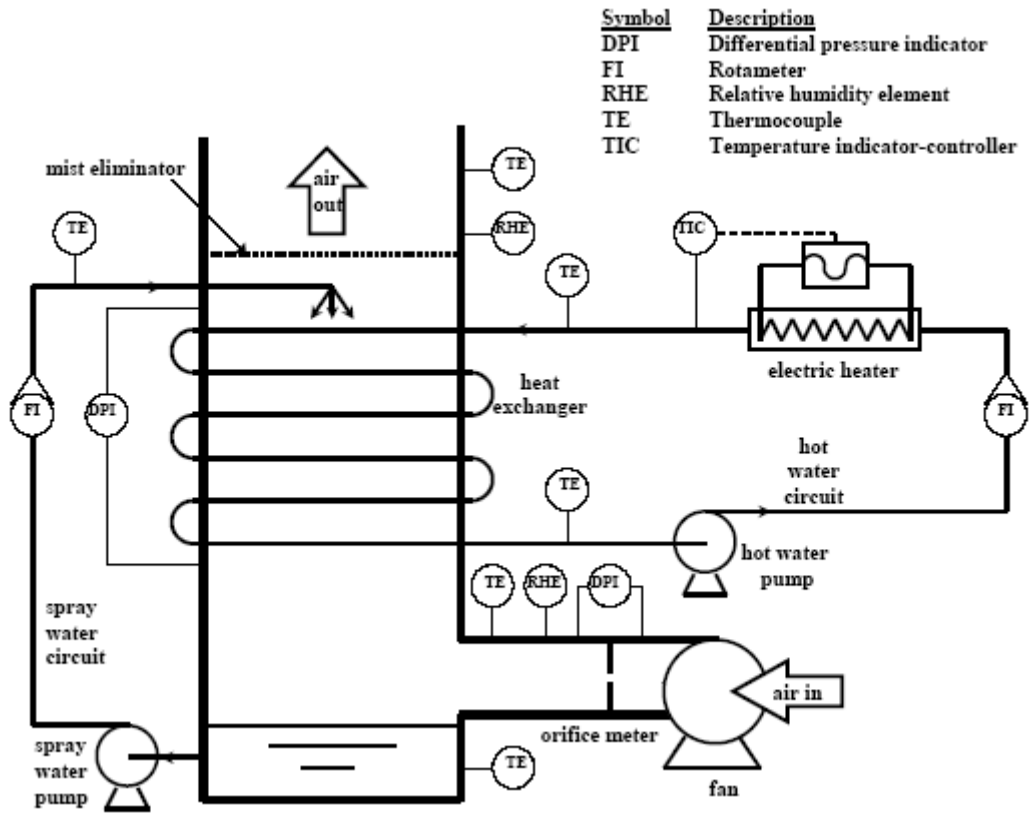
شکل ۱-



شکل ۲- نمای شماتیکی از المان در نظر گرفته شده داخل برج

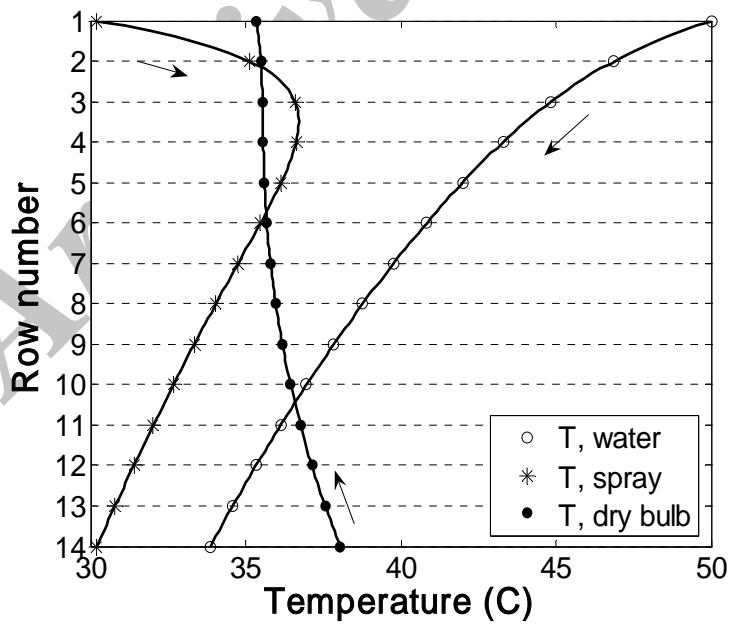


شکل ۳ -

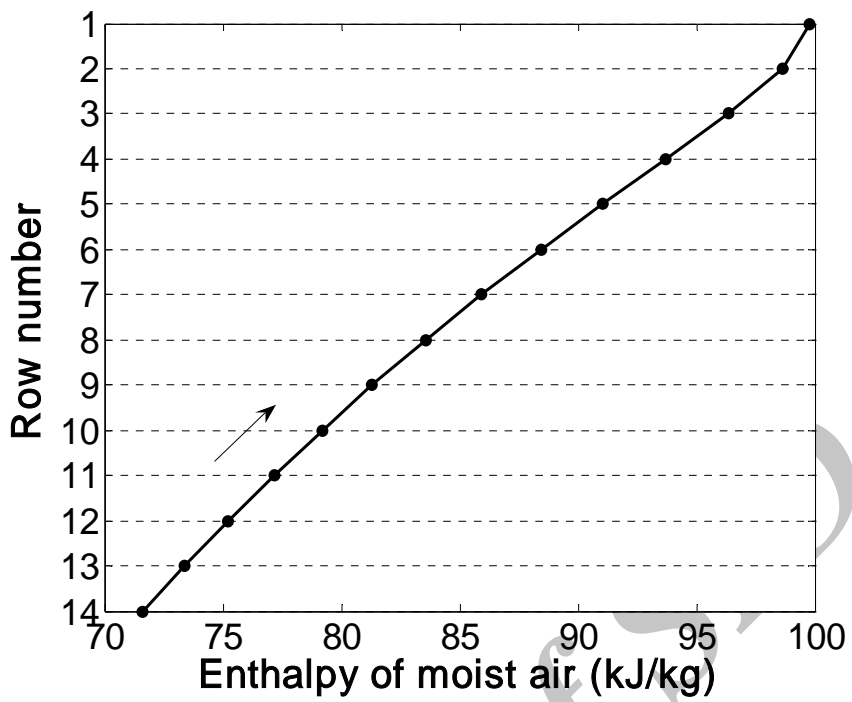


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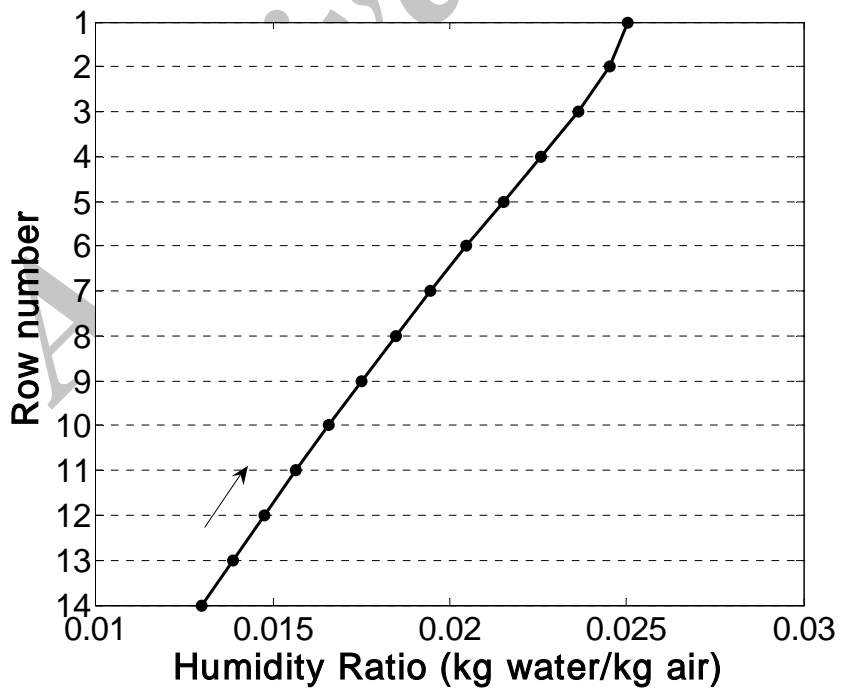
شکل ۴ -



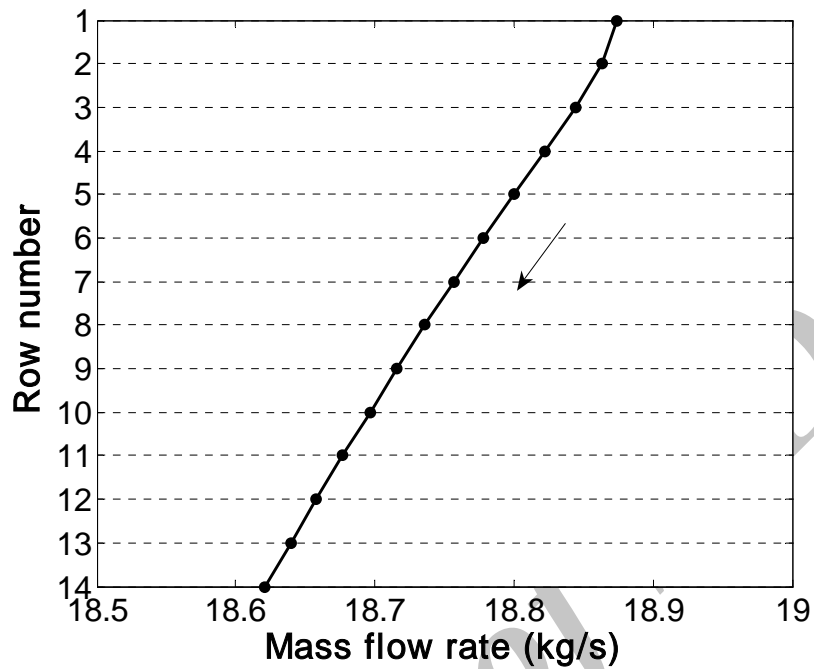
شکل ۵ -



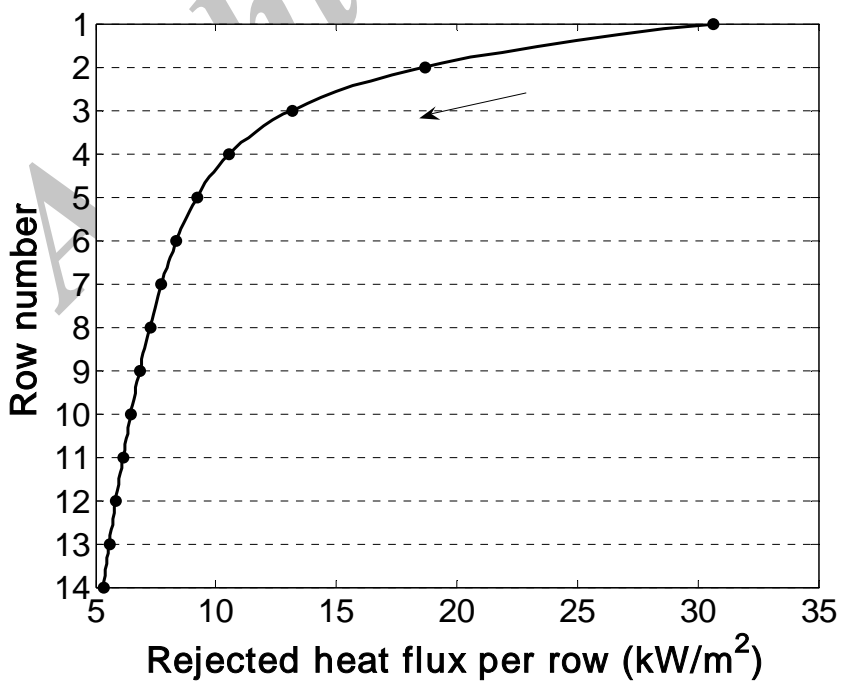
شکل ۶ -

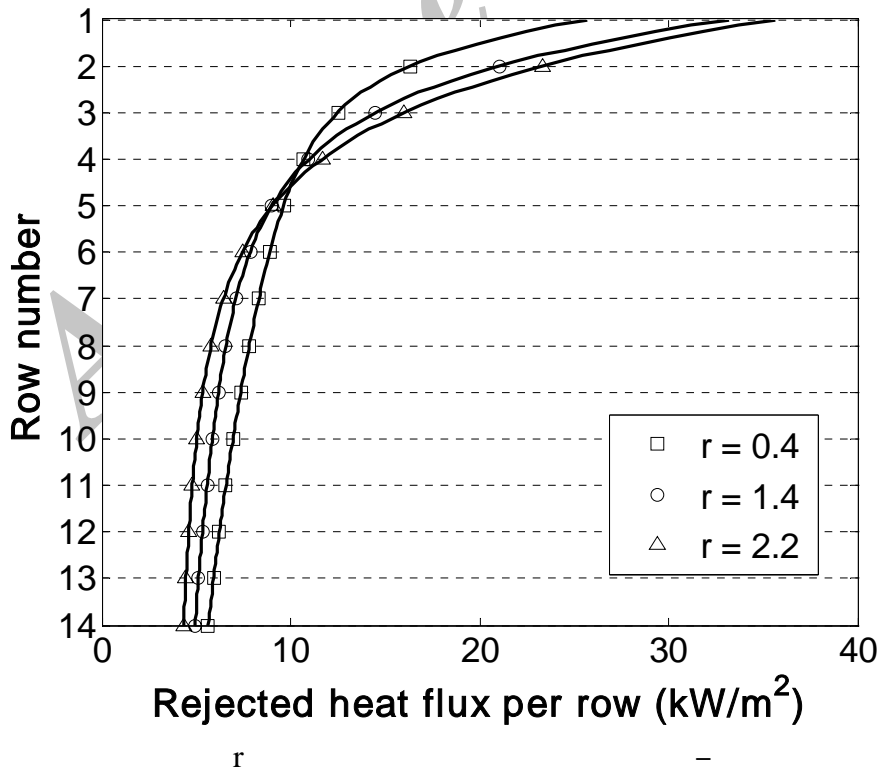
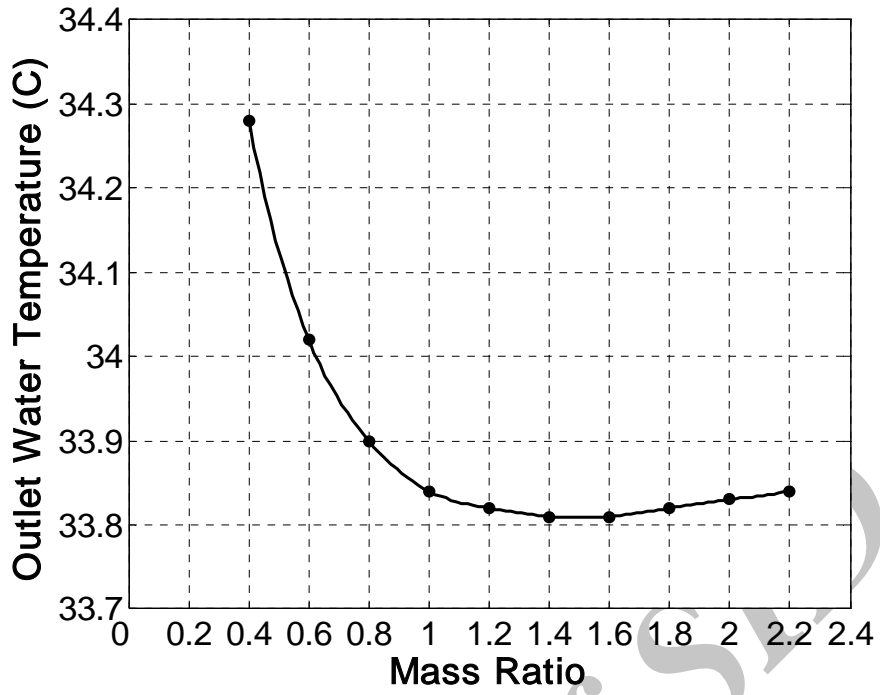


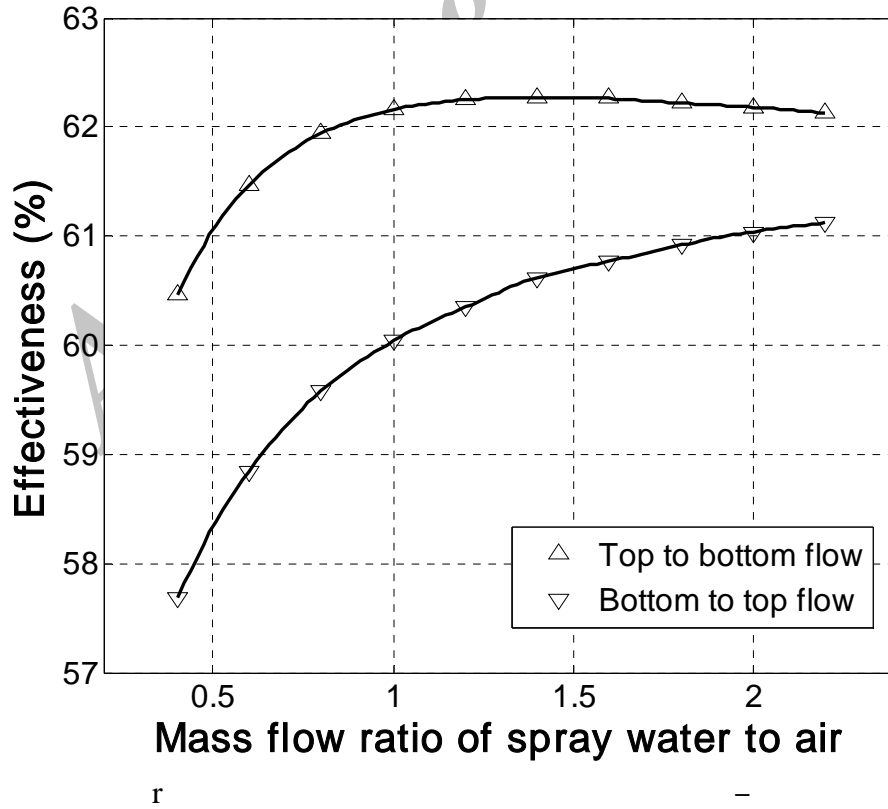
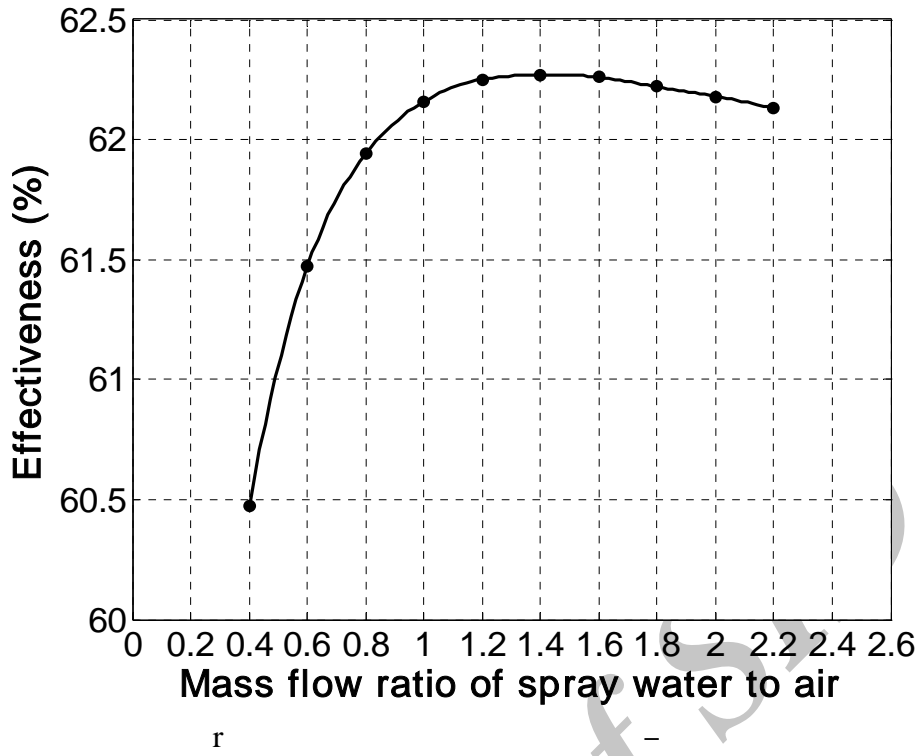
شکل ۷ -

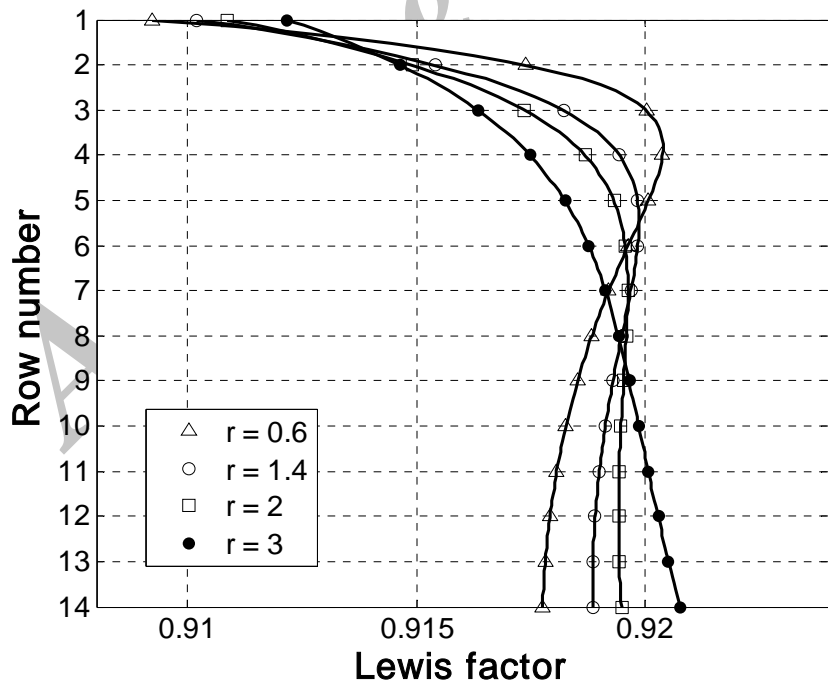
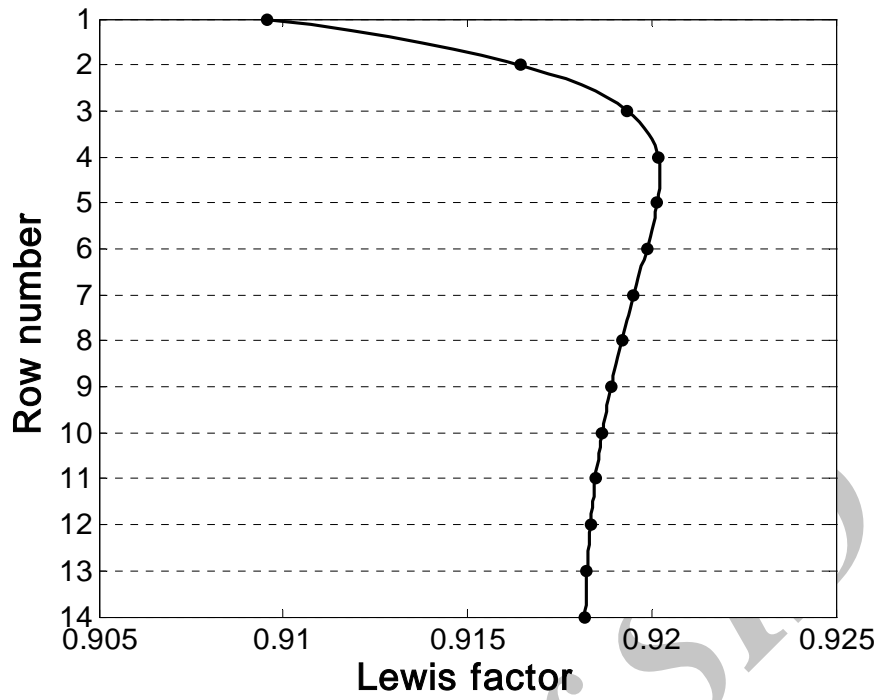


شکل ۸ -

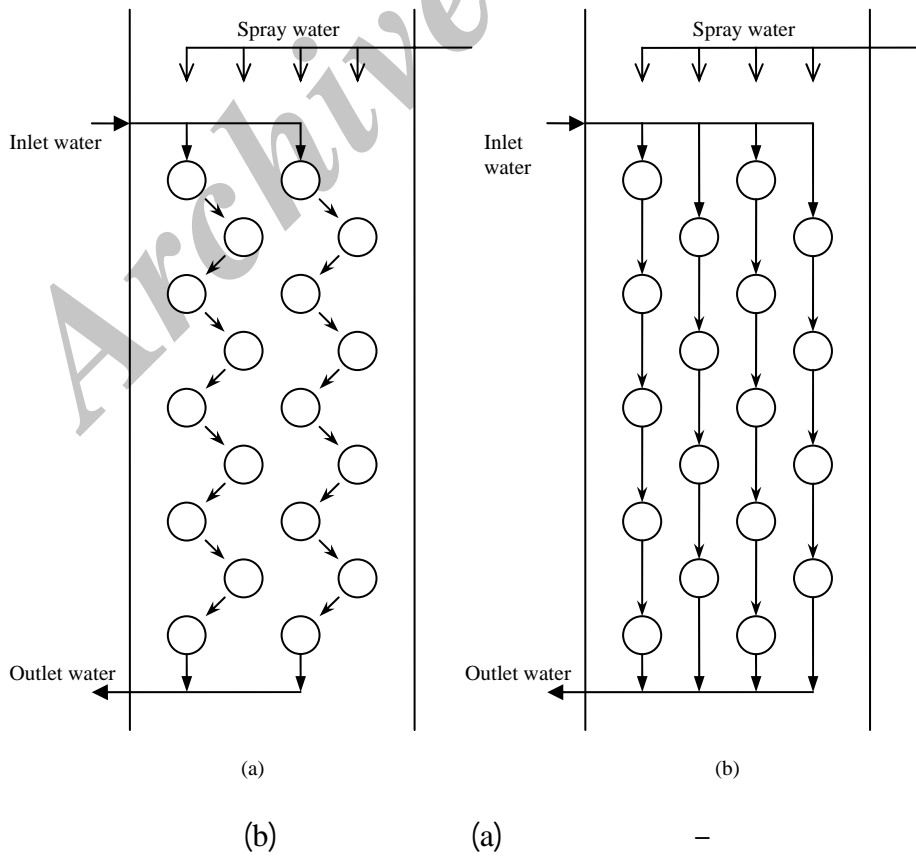
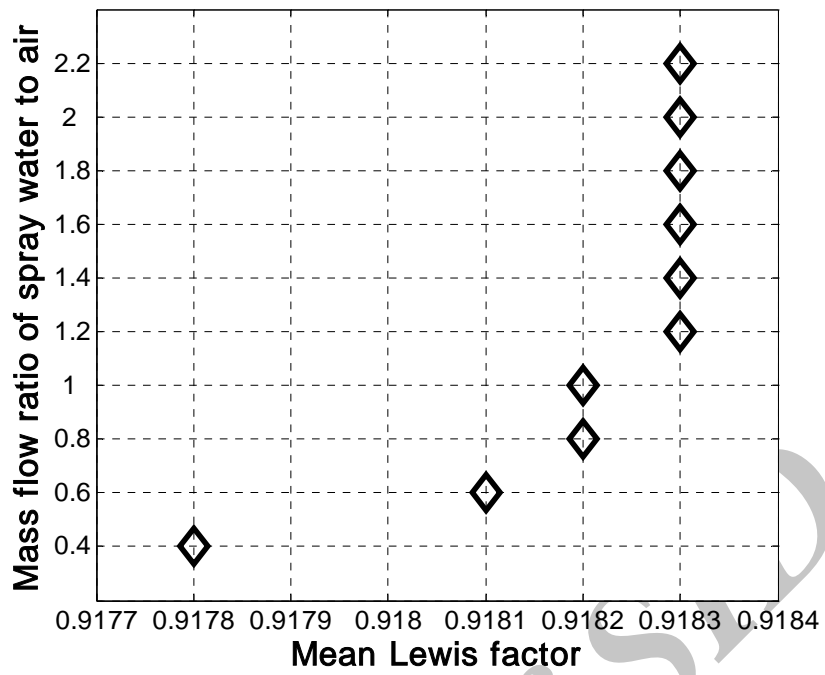


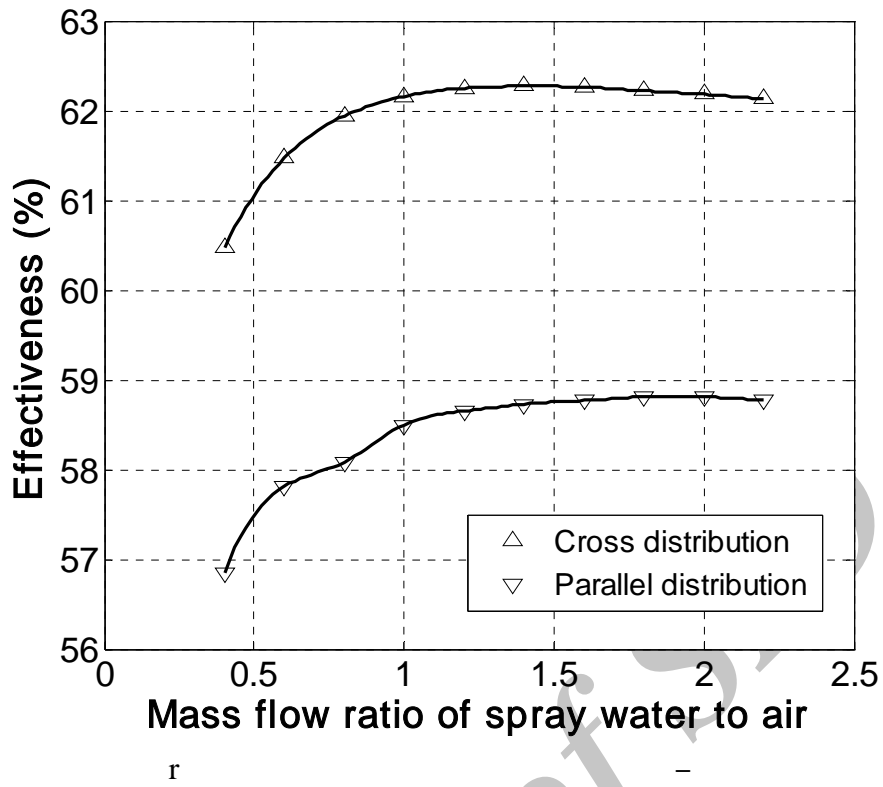






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Abstract

A mathematical modeling of heat and mass transfer in close cooling towers is presented to determine the effect of such parameters as sprayed water temperature, process water temperature and air conditions through the tower. Effect of spray water to air mass flow ratio, which is an important parameter in tower performance, is investigated and tower effectiveness variation with it is determined. For the first time, variation of Lewis number through the tower is calculated and an average value for it is recommended. Also the effect of process water entry direction and method of distribution is investigated.

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