Error Analysis of Heat Transfer for Finned-Tube Heat-Exchanger Test-Board[1]

Yongpan Chen Jili Zhang
Doctoral Candidate Ph.D. Professor
School of Municipal & Environmental Eng, Harbin Institute of Technology
Harbin P. R. China, 150090
cyp257@126.com

Abstract: In order to reduce the measurement error of heat transfer in water and air side for finned-tube heat-exchanger as little as possible, and design a heat-exchanger test-board measurement system economically, based on the principle of test-board system error analyses and design, the equation of measurement error of heat transfer in air side and water side about orifice meter for the finned-tube heat-exchanger was obtained. This paper studies the major factors that may influence the largest admitted measurement error of measurement instruments for heat transfer in water and air side, and analyzes the degree that water temperature and pressure measurement influence heat transfer in water side, and the degree that wet bulb temperature difference measurement influences heat transfer in air side. Finally, this paper indicates that the key problem of reducing heat transfer in water side is water temperature measurement of the in-out pipe of heat-exchanger, and wet bulb temperature difference is a key to decrease the heat transfer in air side for finned-tube heat-exchanger. This paper gives a theoretical instruction for designing the measurement system of a finned-tube heat-exchanger test-board

Key words: finned-tube heat-exchanger; test-board; heat transfer; error analysis.

1. INTRODUCTION

A Finned-Tube Heat-exchanger is a key component of an air handling unit for treating the temperature and humidness of air, the heat transferring performance of which influences the capability of treating air and supplying energy. Some studies have been published to research the performances of Finned-Tube Heat-exchanger, such as the heat transferring performance[1-2]. Fig.1 provides the structure of the Finned-Tube Heat-exchanger Test-board[3]. This board contains four parts, such as air pretreating section (shown as component 1 and 2 in Fig.1), air measuring section (shown as component 3 in Fig.1), testing section (shown as component 6 in Fig.1), and water pretreating section. In testing section, the in-air dry temperature is restricted within 18~28 ，the in-air wet temperature is restricted within 16~20 , in-water temperature is restricted within 5~10 , in-air velocity is restricted within 1~4m/s.

By regulating the heater and humidifier of the air pretreating section, the air performances in front of the testing section could be controlled. By measuring the air dry temperature, air wet temperature, and the air volume, the heat transfer in air side for finned-tube heat-exchanger could be obtained. By measuring the change of water temperature and water velocity, some performances could be educed such as the heat transfer in water side, water resistance. The heat transfer is calculated indirectly from several performances, whose precision will affect final precision. According to final measuring precision, we have to analysis and confirm each sub precision of measurements, and design total monitoring system economically. Since the temperature difference about in-out pipe of the heat-exchanger is low, especially in cooling working station, the temperature error of in-out pipe for heat-exchanger affects the measurement of the heat transfer in water side for finned-tube heat-exchanger. So It is difficult to select temperature instrument. Then, based on introducing briefly about basic principle of test-board error analysis, this paper analyses the main factors which influences the measuring precision of the heat transfer in water side,

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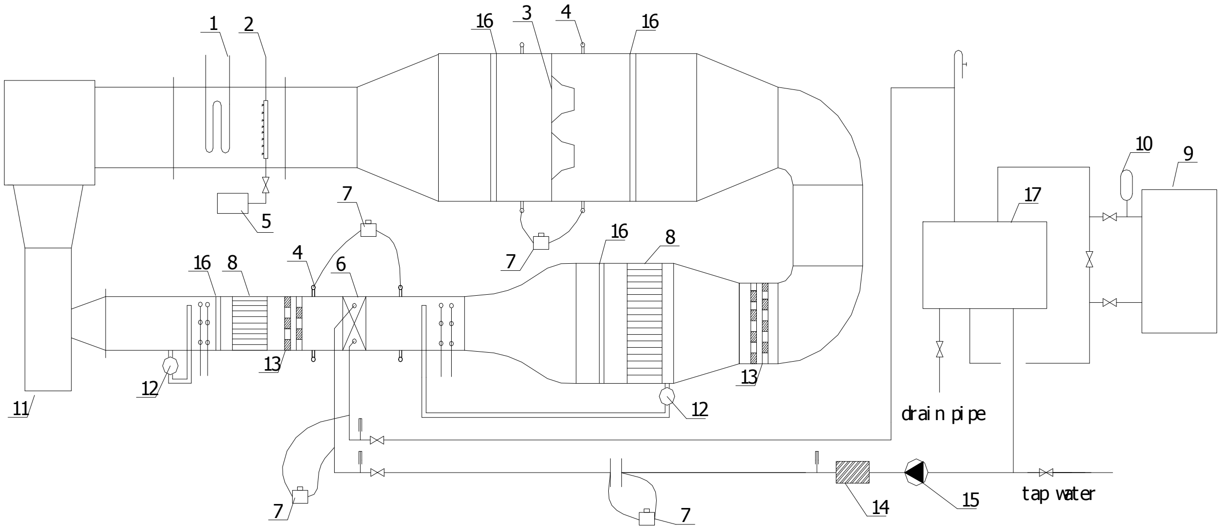

Fig.1 The structure of Finned-tube heat-exchanger test-board

1-heater 2-humidifier 3-muzzle 4-pressure hoop 5-boiler 6-sample 7- pressure difference transmitter 8-rectifying unit 9-heat pump 10-constant pressure container 11-fan 12-sampling fan 13-air admixture 14-micro-adjustment for water temperature 15-recycle pump 16-rectifying mesh 17-water container

analyses how to reduce the measurement error, and gives theory Introduction for designing finned-tube heat-exchanger test-board measurement system.

2. BASIC PRINCIPLE OF TEST-BOARD ERROR ANALYSIS

Physical parameters could be gained directly or indirectly. Indirect physical parameter can be gained by using corresponding function with direct physical parameter. The final measurement error depends on item error. So error analysis must be done to determine specific measurement scheme and item error according to the final measurement error[4-5].

If $y=f(x_1, x_2, \ldots, x_n)$, we assume that each error element is random parameter and incoherent, then the following can be gotton:

$$\delta_y = \sqrt{D_1^2 + D_2^2 + \cdots + D_n^2} \quad (1)$$

where δ_y means max limiting error; D_i item error of the function; $D_i = \frac{\partial f}{\partial x_i}\delta_i$, i=1, 2, ……, n, δ_i item limiting error.

By equation (1), if max limiting error δ_y is a setting value, D_i and δ_i must satisfy equation (2).

$$\sqrt{D_1^2 + D_2^2 + \cdots + D_n^2} \le \delta_y \quad (2)$$

D_i is random parameter as long as max limiting error δ_y is satisfied. Then we can gain the following basic principle for error design.

Firstly, item error is distributed according to the principle of equal error action. The principle of equal error action means that each D_i is equal, as

$$D_1 = D_2 = \cdots = D_n = \frac{\delta_y}{\sqrt{n}} \quad \text{and} \quad \delta_i = \frac{\delta_y}{\frac{\partial f}{\partial x_i}\sqrt{n}}.$$

Secondly, item error can be adjusted according to different difficult grade of measuring parameter. By equation (1), some parameters which can be measured easily could satisfy item limiting error request like a cork. However it is difficult for other parameters which need expensive instrument. Since D_i includes differential coefficient and item limiting error, δ_i can be regulated so that the error of parameters which can be measured easily is much little assuring that D_i is constant. But the error of parameters which can be measured difficult is not changed or enlarged as long as final limiting error δ_y is satisfied.

Finally, if the max limiting error δ_y regulated is not satisfied, certain item error has to be reduced so that the max limiting error is met. If the max limiting error δ_y regulated is less than permissible error, certain item error may be enlarged to decrease the measurement difficult.

3. THE RELATIVE ERROR OF HEAT TRANSFER IN WATER SIDE WITH ORIFICE METER

Heat transfer in water side:

$$Q_{\rm w} = c_{\rm pw}\rho_{\rm w}V_{\rm w}(t_{\rm w2}-t_{\rm w1})$$

where $Q_{\rm w}$ means the heat transfer in water side, kW; $c_{\rm pw}$ the water specific heat, kJ/(kg•□); $\rho_{\rm w}$ the water density, kg/m^3; $V_{\rm w}$ the water flow, m^3/s; $t_{\rm w1}$ in water temperature, □;$t_{\rm w2}$ out water temperature, □.

Then the max absolute error of heat transfer in water side can be expressed as:

$$|\delta Q_{\rm w}| = \rho_{\rm w}c_{\rm pw}\sqrt{(t_{\rm w2}-t_{\rm w1})^2(\delta V_{\rm w})^2+V_{\rm w}^2(\delta t_{\rm w1})^2+V_{\rm w}^2(\delta t_{\rm w2})^2}$$

where $\delta Q_{\rm w}$, $\delta V_{\rm w}$, $\delta t_{\rm w1}$, $\delta t_{\rm w2}$ means individually the max absolute error of heat transfer in water side, water flow, in-water temperature, out-water temperature. So the max relative error of the heat transfer in water side can be written as:

$$E(\delta Q_{\rm w}) = \frac{|\delta Q_{\rm w}|}{Q_{\rm w}} = \sqrt{\left(\frac{\delta V_{\rm w}}{V_{\rm w}}\right)^2+\frac{(\delta t_{\rm w2})^2+(\delta t_{\rm w1})^2}{(t_{\rm w2}-t_{\rm w1})^2}} \quad (3)$$

where E($\delta Q_{\rm w}$) means the max relative error of heat transfer in water side.

By equation (3), the max relative error of heat transfer in water side is composed of water flow error ($\delta V_{\rm w}$), in-water temperature error($\delta t_{\rm w1}$), and out-water temperature error($\delta t_{\rm w2}$). The water flow is gained depending on standard orifice meter and digital pressure difference transmitter. Then the water flow error δV_w is made up of orifice meter error and digital pressure difference transmitter error. The flow with orifice meter can be calculated as:

$$V_{\rm w} = 1.11072\alpha\varepsilon d^2\sqrt{\frac{\Delta P_{\rm w}}{\rho_{\rm w}}}$$

where α means orifice coefficient of flow; ε orifice coefficient of expansion correction; d center diameter of the orifice, m; $\Delta P_{\rm w}=P_1-P_2$ pressure difference, Pa. So max absolute error of water flow error $\delta V_{\rm w}$ is:

$$\delta V_{\rm w} = 1.11072\alpha\varepsilon d^2\frac{\delta P_{\rm w}}{2\sqrt{\Delta P_{\rm w}\rho_{\rm w}}}$$

where $\delta P_{\rm w}$ means the max absolute error of digital pressure difference transmitter.

The max relative error of water flow caused by pressure difference transmitter is shown as:

$$E(\delta V_{\rm w1}) = \frac{\delta V_{\rm w}}{V_{\rm w}} = \frac{\delta P_{\rm w}}{2\Delta P_{\rm w}}$$

Because of the measurement error of the orifice meter, the max relative error of water flow is expressed as:

$$E(\delta V_{\rm w}) = \sqrt{(E\delta V_{\rm w1})^2+(E\delta V_{\rm w2})^2} = \sqrt{\left(\frac{\delta P_{\rm w}}{2\Delta P_{\rm w}}\right)^2+(E(\delta V_{\rm w2}))^2} \quad (4)$$

where E($\delta V_{\rm w2}$) means max relative error of orifice meter.

If max absolute error of water temperature difference$\delta t_{\rm w1}$ equals $\delta t_{\rm w2,}$ and $\delta t_{\rm w}$, combining equation (3) and (4), the max relative error of heat transfer in water side can be expressed as:

$$E(\delta Q_{\rm w}) = \frac{|\delta Q_{\rm w}|}{Q_{\rm w}} = \sqrt{\left(\frac{\delta P_{\rm w}}{2\Delta P_{\rm w}}\right)^2+(E(\delta V_{\rm w2}))^2+2(\frac{\delta t_{\rm w}}{t_{\rm w2}-t_{\rm w1}})^2} \quad (5)$$

4. The FACTOR ANALYSIS OF THE MAX LIMITING RELATIVE ERROR OF HEAT TRANSFER IN WATER SIDE AND SETTLEMENT OF INSTRUMENT ERROR

If the max limiting relative error of heat transfer in water side $E(\delta Q_{\rm W})$ less than ε, according to the principle of equal error action, by equation (5), the max instrument limiting error of heat transfer in water side can be expressed as:

$$\begin{cases} \dfrac{\delta P_{\rm w}'}{2\Delta P_{\rm w}} \le \dfrac{\varepsilon}{\sqrt{3}} \\ E(\delta V_{\rm w2}') \le \dfrac{\varepsilon}{\sqrt{3}} \\ \dfrac{\sqrt{2}\delta t_{\rm w}'}{t_{\rm w2}-t_{\rm w1}} \le \dfrac{\varepsilon}{\sqrt{3}} \end{cases}$$

$$\begin{cases} \delta P_{\mathrm{w}}^{'} \le \dfrac{2\varepsilon}{\sqrt{3}} \Delta P_{\mathrm{w}} \\ E(\delta V_{\mathrm{w2}}^{'}) \le \dfrac{\varepsilon}{\sqrt{3}} \\ \delta t_{\mathrm{w}}^{'} \le \dfrac{\varepsilon}{\sqrt{6}} (t_{\mathrm{w2}} - t_{\mathrm{w1}}) \end{cases} \quad (6)$$

where $\delta P'_{\mathrm{W}}$ means the limiting absolute error of digital pressure difference transmitter, kPa; $E(\delta V'_{\mathrm{w2}})$ the limiting relative error of orifice meter; $\delta t'_{\mathrm{W}}$ the limiting relative error of thermometer, □; if $\varepsilon=0.04$, $\dfrac{\varepsilon}{\sqrt{3}}$ =2.3%. From equation (6), we can gain the following:

1) The relative error of orifice meter is independent of the working station, and 2.3 percent of relative error can be satisfied easily.

2) The limiting absolute error of digital pressure difference transmitter is coherent with pressure difference. If pressure difference is lower, the absolute error of digital pressure difference transmitter is much lower, viz. instrument with high degree of accuracy. So we should design the pressure difference scope of orifice meter in reason. If the measuring range of orifice meter is 10kPa and precision of 0.3 percent, then minimum pressure difference is 652Pa which is realized easily.

3) The limiting absolute error of thermometer is coherent with temperature difference. For the thermometer whose absolute error is 0.1℃, to satisfy the limiting error, the temperature difference is greater than or equal to 6.13℃, which can satisfy requirement at heating station, but not satisfy at cooling station.

We know that it is easy to realize the measuring error of orifice meter and digital pressure difference transmitter, but difficult for limiting error of instrument of water temperature. Then, it is too difficult to assign the error by equation (5) according to the principle of equal error action. So the item error in equation (5) must be regulated. In the test-board, we choose the orifice meter whose relative error is 0.01, thermometer whose absolute error is 0.1℃, and digital pressure difference transmitter whose absolute error is 30Pa. If ΔP_{w} is not less than 3.68℃ which can be realized at heating and cooling station, $E(\delta Q_{\mathrm{w}})$ is less than or equal to 4%.

5. THE INFULUENCE OF WATER TEMPERATURE AND PRESSURE DIFFERENCE MEASUREMENT ERROR ON HEAT TRANSFER IN WATER SIDE

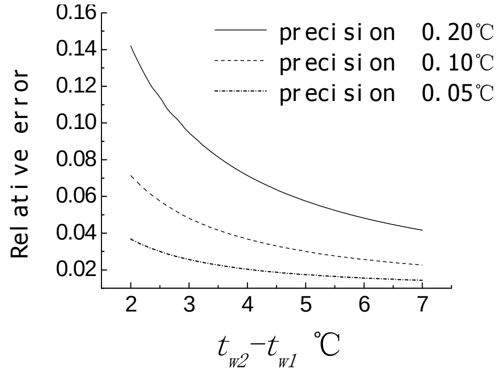

Fig.2 Curve of relative error Changes by temperature difference

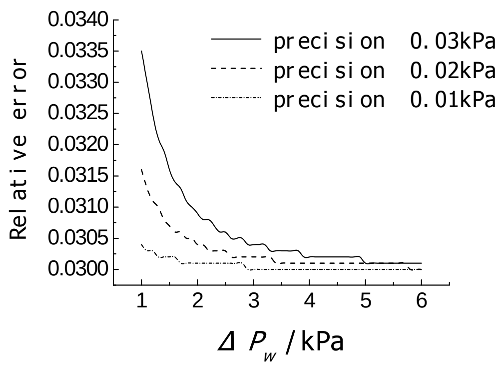

Fig.3 Curve of relative error changes by pressure difference

By equation (5) we know that, the relative error of standard orifice meter is independent of the working condition. It also has little influence to do with the measuring error of heat transfer in water side. Contrarily, the relative error of digital pressure difference transmitter and thermometer has its influence to the final error when the working condition changes. For the water system, thinking about the gap of order between ΔP_{w} and δP_{w} (generally the former one is 10^2 times larger than the latter one) , however, δt_{W} and t_{w2}-t_{w1} get only several times disparities between them. Obviously, in equation (5) the test error of water temperature has larger influence on the overall test error than pressure test error. To check this influence degree in quantity, we calculate the influence of relative error in water side heat exchange amount when temperature difference between inlet and outlet port is 2~7°C and pressure difference between back and forth of orifice meter is 3kPa, and temperature difference is 5℃ and pressure difference is 1~6 kPa. The result is shown in Fig.2 and Fig.3.

By Fig.2 and Fig.3 we know, the relative error of heat transfer in water side tested by instruments with different precision reduces when temperature difference between inlet and outlet port increases, the error reduces when pressure difference between forth and back increases; when the precision of digital pressure difference transmitter is no more than 50Pa, its influence on relative error of heat transfer in water side is basically constant. To make the influence of inlet and outlet water temperature on the error of heat exchange amount as small as possible, the thermometer requires very high precision (the testing error is no more than 0.05°C), Otherwise, to meet the challenge of the overall testing error, we need to control the differential temperature between inlet and outlet of the heat exchanger.

6. THE RELATIVE ERROR OF HEAT TRANSFER IN AIR SIDE

6.1 Heat Transfer in Air Side:

$$Q_{\rm a} = \rho_{\rm a} V_{\rm a} \left(I_1 - I_2 \right)$$

where $Q_{\rm a}$ means the heat transfer in aid side, kW; $\rho_{\rm a}$ the dry air density, kg/m^3; $V_{\rm a}$ the air flow, m^3/s; I_1 the in air enthalpy, kJ/ kg(a); I_2 the out air enthalpy, kJ/ kg(a); Then the max absolute error of heat transfer in air side can be expressed as

$$\delta Q_a = \sqrt{\rho_a^2 (I_1 - I_2)^2 \left(\delta V_a\right)^2 + (I_1 - I_2)^2 V_a^2 \left(\delta \rho_a\right)^2 + \rho_a^2 V_a^2 \left(\left(\delta I_1\right)^2 + \left(\delta I_2\right)^2\right)}$$

So, the max relative error of heat transfer in air side can be written as:

$$E\delta Q_a = \frac{\delta Q_a}{Q_a} = \sqrt{\left(\frac{\delta \rho_a}{\rho_a}\right)^2 + \left(\frac{\delta V_a}{V_a}\right)^2 + \frac{\left(\delta I_1\right)^2 + \left(\delta I_2\right)^2}{(I_1 - I_2)^2}} \quad (7)$$

We can know, the max relative error of heat transfer in air side is composed of max relative error of dry air density, air flow and air enthalpy.

6.2 The Max Relative Error of Dry Air Density

The dry air density:

$$\rho_{\rm a} = \frac{\rho_{\rm as}}{1 + d}$$

where$\rho_{\rm a}$ means the dry air density, kg/m^3; $\rho_{\rm as}$ the wet air density, kg/m^3; d the moisture content, kg/kg(a); So the max absolute error of dry air can be written as:

$$\delta \rho_{\rm a} = \sqrt{\frac{\left(\delta \rho_{\rm as}\right)^2}{(1+d)^2} + \frac{\rho_{as}^2}{(1+d)^4}\left(\delta d\right)^2}$$

the max relative error of dry air can be written as:

$$E\delta \rho_{\rm a} = \frac{\delta \rho_a}{\rho_a} = \sqrt{\left(\frac{\delta \rho_{as}}{\rho_{as}}\right)^2 + \frac{\left(\delta d\right)^2}{(1+d)^2}} \quad (8)$$

We can know, the max relative error of dry air density is composed of the max relative error of wet air density and moisture content.

1) The max relative error of wet air density

The wet air density

$$\rho_{\rm as} = \frac{P(1+d)}{461T(0.622+d)}$$

where P means air press, Pa; T the Kelvin temperature, K; So the absolute error of wet air density is:

$$\delta \rho_{as} = \frac{1}{461T(0.622+d)} \times \sqrt{(1+d)^2(\delta P)^2 + \frac{P^2(1+d)^2(\delta T)^2}{T^2} + \frac{[(0.622+d)-(1+d)]^2 P^2 (\delta d)^2}{(0.622+d)^2}} \quad (9)$$

So the max relative wet air density can be expressed as:

$$E\delta \rho_{as} = \frac{\delta \rho_{as}}{\rho_{as}} = \sqrt{\left(\frac{\delta T}{T}\right)^2 + \left(\frac{\delta P}{P}\right)^2 + 0.143\left[\frac{\delta d}{(1+d)(0.622+d)}\right]^2}$$

2) The absolute error of air moisture content

The air moisture content is:

$$d = 0.622 \frac{P_{\rm v}}{P - P_{\rm v}}$$

where $P_{\rm v}$ means partial pressure of water vapor, Pa; So the max absolute error of air moisture content is:

$$\delta d = \frac{0.622}{(P - P_v)^2} \sqrt{P_v^2 \left(\delta P\right)^2 + P^2 \left(\delta P_v\right)^2} \quad (10)$$

3) The max absolute error of water vapor partial pressure.

The equation of water vapor partial pressure

$$P_v = P_{qb}{}' - A_1 P(t_g - t_s) \qquad (11)$$

where P'_{qb} means saturated water vapor partial pressure at wet temperature, Pa; t_g dry air temperature,℃; t_s wet air temperature,℃; A_1 const of wet bulb, and

$$A_1 = \left(597.1 + 135.1v^{-0.5} + 48v^{-1}\right) \times 10^{-6}$$

where v means air speed in sampling tube, m/s. We can get the following from equation (7):

$$\left(\delta P_{\mathrm{v}}\right)^2 = \left(\delta P_{\mathrm{qb}}{}'\right)^2 + P^2 (t_{\mathrm{g}} - t_{\mathrm{s}})^2 \left(\delta A_1\right)^2 + A_1^2 (t_{\mathrm{g}} - t_{\mathrm{s}})^2 \left(\delta P\right)^2 + A_1^2 P^2 [\left(\delta t_{\mathrm{g}}\right)^2 + \left(\delta t_{\mathrm{s}}\right)^2]$$

According to the principle of mini error editing, we can simplify the former equation as:

$$\delta P_{\mathrm{v}} = \sqrt{(\delta P_{\mathrm{qb}}')^2 + A_1^2 P^2 [(\delta t_{\mathrm{g}})^2 + (\delta t_{\mathrm{s}})^2]} \qquad (12)$$

When the dry air temperature is between 0~200℃,

$$Ln(\frac{P_{\mathrm{qb}}'}{98066.5}) = -\frac{7235.425}{T} + 0.0057T - 8.2\ln T + 65.856$$

Then

$$\delta P_{\mathrm{v}} = \sqrt{\left[\frac{7235.425}{T^2} + \frac{8.2}{T} + 0.0057\right]^2 P_{\mathrm{qb}}'^2 \left(\delta T\right)^2 + 2A_1^2 P^2 \left(\delta t_{\mathrm{g}}\right)^2} \qquad (13)$$

We substitute the equation (13) into equation (10), and gain the max absolute error of air moisture content:

$$\delta d = \frac{0.622 P_v}{(P - P_v)^2} \times \sqrt{\left(\delta P\right)^2 + \left[(\frac{7235.425}{T^2} + \frac{8.2}{T} + 0.0057)^2 P_{\mathrm{qb}}'^2 + 2A_1^2 P^2\right]\left(\delta t_{\mathrm{g}}\right)^2}$$

We can gain the max relative error of dry air density from equation (8) and (9):

$$E\delta\rho_{\mathrm{a}} = \frac{\delta\rho_a}{\rho_a} = \sqrt{(\frac{\delta T}{T})^2 + (\frac{\delta P}{P})^2 + [1 + \frac{0.143}{(0.622 + d)}]\frac{\left(\delta d\right)^2}{(1 + d)^2}}$$

6.3 The Max Relative Error of Air Flow.

The equation of air flow:

$$V_a = \alpha\varepsilon \frac{\pi d^2}{4}\sqrt{\frac{2\Delta P_a}{\rho_a}} = 1.1107\alpha\varepsilon d^2 \sqrt{\frac{\Delta P_a}{\rho_a}}$$

So the max relative error of air flow is:

$$\frac{\delta V_a}{V_a} = \sqrt{\left(\frac{\delta \Delta P_a}{2\Delta P_a}\right)^2 + \left(\frac{\delta\rho_{as}}{2\rho_{as}}\right)^2} = 0.5\sqrt{(\frac{\delta T}{T})^2 + (\frac{\delta P}{P})^2 + 0.143[\frac{\delta d}{(1+d)(0.622+d)}]^2 + \left(\frac{\delta\Delta P_a}{\Delta P_a}\right)^2} \qquad (16)$$

6.4 The Max Relative Error Of Air Enthalpy

The equation of air enthalpy:

I＝1.01tg+(2500+1.84tg)d

where tg dry air temperature, ℃; d the moisture content, kg/kg(a); So we can obtain the absolute error of air enthalpy:

$$\delta I = \sqrt{\left(1.01 + 1.84d\right)^2 \left(\delta t_g\right)^2 + \left(2500 + 1.84t\right)^2 \left(\delta d\right)^2}$$

Then

$$\frac{(\delta I_1)^2 + (\delta I_2)^2}{(I_1 - I_2)^2} = \frac{\left[\left(1.01 + 1.84d_1\right)^2 + \left(1.01 + 1.84d_2\right)^2\right]}{\left[1.01(t_{g1} - t_{g2}) + 2500(d_1 - d_2) + 1.84(t_{g1}d_1 - t_{g2}d_2)\right]^2}\left(\delta t\right)^2 + \frac{\left(2500 + 1.84t_{g1}\right)^2 + \left(2500 + 1.84t_{g2}\right)^2}{\left[1.01(t_{g1} - t_{g2}) + 2500(d_1 - d_2) + 1.84(t_{g1}d_1 - t_{g2}d_2)\right]^2}\left(\delta d\right)^2 \qquad (17)$$

We substitute the equation (14),(15) and (16) into equation (17), and gain the max relative error of heat transfer in air side for finned-tube heat-exchanger:

$$\left(E\delta Q_a\right)^2 = \frac{\left(\delta V\right)^2}{V_a^2} + \frac{\left(\delta\rho_a\right)^2}{\rho_a^2} + \frac{\left(\delta I_1\right)^2 + \left(\delta I_2\right)^2}{(I_1 - I_2)^2}$$
$$= \left(\frac{\delta \Delta P_a}{2\Delta P_a}\right)^2 + \frac{5}{4}\left(\frac{\left(\delta T\right)^2}{T_1^2} + \frac{\left(\delta P\right)^2}{P^2} + \frac{0.143}{(1+d_1)^2(0.622+d_1)^2}\left(\delta d\right)^2\right) + \frac{\left(\delta d\right)^2}{(1+d_1)^2} + \frac{\left(\delta I_1\right)^2 + \left(\delta I_2\right)^2}{(I_1 - I_2)^2}$$
$$= \left(\frac{\delta \Delta P_a}{2\Delta P_a}\right)^2 + \left[\frac{5}{4P^2} + \frac{(0.622P)^2}{(P - P_v)^4}C\right]\left(\delta P\right)^2 + (CD + E + \frac{5}{4T_1^2})\left(\delta t_g\right)^2 \qquad (18)$$

where

$$C = \frac{5}{4}\frac{0.143}{(1+d_1)^2(0.622+d_1)^2} + \frac{1}{(1+d_1)^2} + \frac{\left(2500 + 1.84t_{g1}\right)^2 + \left(2500 + 1.84t_{g2}\right)^2}{\left[1.01(t_{g1} - t_{g2}) + 2500(d_1 - d_2) + 1.84(t_{g1}d_1 - t_{g2}d_2)\right]^2}$$

$$D = \frac{(0.622P)^2}{(P - P_v)^4}\left[\left[\frac{7235.425}{T^2} + 0.00571133 + \frac{8.2}{T}\right]^2 P_{\mathrm{qb}}^2{}' + 2A_1^2 P^2\right]$$

$$E = \frac{\left(1.01 + 1.84d_1\right)^2 + \left(1.01 + 1.84d_2\right)^2}{\left[1.01(t_{g1} - t_{g2}) + 2500(d_1 - d_2) + 1.84(t_{g1}d_1 - t_{g2}d_2)\right]^2}$$

7. The FACTOR ANALYSIS OF THE MAX LIMITING RELATIVE ERROR OF HEAT TRANSFER IN AIR SIDE AND SETTLEMENT OF INSTRUMENT ERROR

According to the principle of equal error action, the test-board demand that $E(\delta Q_a)\le\varepsilon$, we adopt the following work condition: the air speed in sampling tube v equals to 5m/s, press difference out air nozzle is 410Pa, air press in room is 1.01×10^5Pa, in air dry temperature is 37.5℃, in air wet bulb temperature is 24.7℃, out air dry temperature is 17.8℃, out air wet bulb temperature is 16.9℃.

Then

$$\frac{\delta \Delta P_a'}{2\Delta P_a}\le\frac{\varepsilon}{\sqrt{3}}$$

$$\sqrt{\frac{5}{4P^2}+\frac{(0.622P)^2}{(P-P_v)^4}C}\,\delta P'\le\frac{\varepsilon}{\sqrt{3}}$$

$$\sqrt{(CD+E+\frac{5}{4T_1^2})}\,\delta t_g'\le\frac{\varepsilon}{\sqrt{3}}$$

or

$$\delta\Delta P_a'\le\frac{2\varepsilon}{\sqrt{3}}\Delta P_a$$

$$\delta P'\le\frac{\varepsilon}{\sqrt{3}\sqrt{\frac{5}{4P^2}+\frac{(0.622P)^2}{(P-P_v)^4}C}} \tag{19}$$

$$\delta t_g'\le\frac{\varepsilon}{\sqrt{3}\sqrt{(CD+E+\frac{5}{4T_1^2})}}$$

where $\delta\Delta Pa'$ means the admitted absolute error of digital differential manometer out air nozzle, Pa; $\delta P'$ the admitted absolute error of manometer ahead of nozzle, Pa; $\delta t_g'$ the absolute error of temperature, ℃. From equation (19), we can know that when ε=0.01,

$$\frac{\varepsilon}{\sqrt{3}}=0.023.$$

The admitted absolute error of digital differential manometer is relational to press difference, which demands smaller with the press difference becomes small. So we must choice proper air flow range through the air nozzle. When the measure range of digital differential manometer is 1000Pa, precision is 0.5%, then mini press difference is 108.25Pa, which can be realized easily generally.

8. THE INFULUENCE OF WET BULB DIFFERENCE MEASUREMENT ERROR ON HEAT TRANSFER IN AIR SIDE

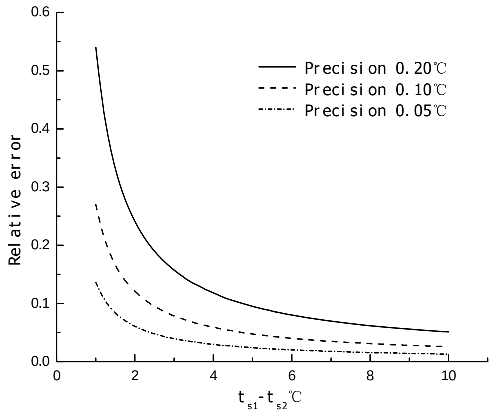

Fig.4 Curve of relative error changes by wet bulb temperature difference

By Fig. 4, we know the relative error of heat transfer in air side decreases when wet bulb temperature difference between inlet and outlet port increases, and decreases when the precision increases. So we can reduce the error from following two aspects:

1) Increasing the precision of wet bulb temperature measure. When the cooling load of finned tube heat exchanger is smaller, in order to reduce the relative error of heat exchanger in air side, we should reduce air flow to raise wet bulb temperature difference. At the same time, high precision measurement also raises the accuracy of heat transfer in air side.

2) Increasing the precision of air nozzle, which can affect the error of air density, enthalpy, and air flow.

9. CONCLUSIONS

Based on the theory of experimental error analysis and design, this paper obtains the expression of measurement error of heat transfer in water and air side of finned tube heat-exchanger, and also analysis the key element which influences the error of heat transfer. The result indicates firstly that controlling the measurement error of water temperature difference and air wet bulb temperature difference of heat exchanger is a key process, when we want to reduce the measurement error of heat transfer. Then we must analysis the error of heat transfer in water side, by allocating the measurement error of temperature and flux and pressure difference, enlarging the temperature test error properly, and deducing the error of pressure difference and orifice meter, we can ensure the overall error to meet the demand of error design, so as to select the thermometer in low cost. Secondly, we must enlarge the temperature difference in water side as possible as we can, especially in thermo-technical performance experiment of chiller, we must reduce the flow of cold water, and increase the temperature difference of cold water, so as to reduce the influence of test error of water temperature on refrigerating effect. In air side, in order to reduce the relative error of heat transfer, we must reduce air flow to raise wet bulb temperature difference, and increase the precision of air nozzle so as to increase the accuracy of air flow measurement.

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