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Uncertainty Evaluation of Residential Central Air-conditioning Test System

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Abstract. According to national standards, property tests of air-conditioning are required. However, test results could be influenced by the precision of apparatus or measure errors. Therefore, uncertainty evaluation of property tests should be conducted. In this paper, the uncertainties are calculated on the property tests of Xinfei13.6 kW residential central air-conditioning. The evaluation result shows that the property tests are credible.

1. Introduction

In recent years, residential central air-conditionings have been widely used. According to *Water chilling (heat pump) packages for household and similar application* (GB18430.2)[1], specified percentage of products must be tested under standardized condition. Moreover, *The minimum allowable values of the energy efficiency and energy efficiency grades for unitary air conditioners* (GB19576)[2] stipulates new national requirements on energy efficiency limits of air-conditioning equipment. As required by these two regulations, manufacturers should build air-conditioning property testing laboratories following the requirements of *General requirements for the competence of testing and calibration laboratories* (GB/T15481)[3], and should conduct property tests on air-conditioning units. Since the testing accuracy could influence the test result directly [4], we should also assess the uncertainties in accordance with *Evaluation and Expression of Uncertainty in Measurement* (JJF1059)[5]. However, even though all air-conditioning factories are capable of conducting property tests of air-conditioning, the uncertainty evaluation are not performed in some factories, which may cause the tests remain unreliable.

2. Measure precision analysis

2.1. Test requirements

Residential central air-conditionings properties should be tested according to *The methods of performance test for positive displacement & centrifugal water-chilling units and heat pump* (GB/T10870) [6]. All apparatuses and equipment should be within their effective checking period, with all indicators of apparatuses meeting relative specifications.

While the power of air-conditioning could be calculated, in this test the power value is acquired by measurement.

The uncertainties evaluation process was conducted on XFHLR13.6 Unit (Xinfei 13.6kW air cooled heat pump residential central air-conditioning) as shown in Fig.1. Fig.2 shows the property test system.

Figure 1. XFHLR13.6L Unit

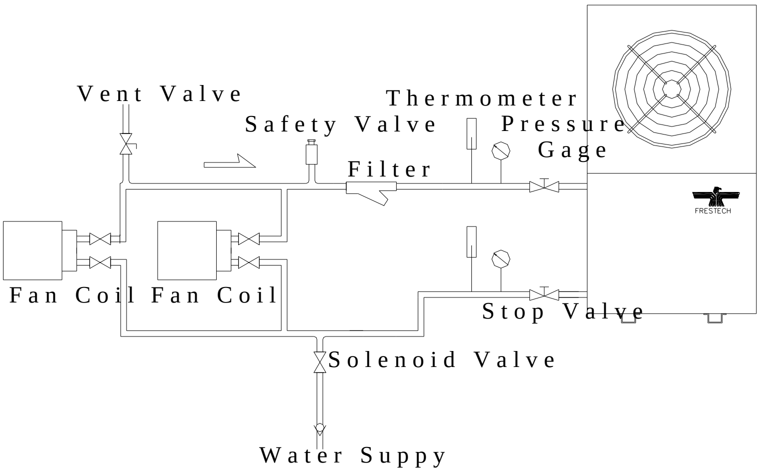

Figure 2. Properties Test System

2.2. Test errors and precision

As the level of precision relates to error, error could be used as a measurement of the level of precision. The smaller the error, the higher the precision level is.

While error is a determined value, the truth value is an ideal concept. The truth value refers to the measure value when certain value can be determined and all limits are eliminated. When processing data, the truth value should be replaced by conventional truth value.

Uncertainties refer to the range of measure error obtained in the evaluation of the magnitude range of the measured truth value. To be specific, uncertainties show the comprehensive distribute range of the random error and uncertain system error. It could be interpreted as the value of error under certain confidence probability. As they are important indicators of measurement quality, uncertainties should be given when physical value measurement data is provided, so that users could evaluate the reliability. Uncertainty should be evaluated at appropriate level of precision. Higher precision level may lead to suspicion of the test result validity. Otherwise, it may lead to wrong conclusion and may potentially affect the quality assurance of products.

2.3. Measure precision analysis

Regarding the actual measures, high level of exactitude does not necessarily mean high degree of veracity. Likewise, high degree of veracity does not necessarily mean high level exactitude as well. However, high level of accuracy means high level of exactitude and high degree of veracity.

The quantitative characteristics of the accuracy can be expressed by uncertainty in measurement.

The sources of uncertainty measurement include imperfection of measured amount, non-ideal measure method and sampling, artificial deviation in apparatus indicator reading, uncertainty of measure standard and the localization of measure instrument.

3. Evaluation of uncertainty in measurement[7]

Guide to the Expression of Uncertainty in Measurement [8] was issued in 1993 by ISO and other six international organizations. *Evaluation and Expression of Uncertainty in* Measurement (JJF1059-1999) and *General requirements for the competence of testing and calibration laboratories* (GB/T15481-2000) were issued in China 6 years later, which request that testing laboratories should have the capabilities of evaluating uncertainties in measurement.

Standard uncertainty refers to the uncertainty in measurement shown as standard deviation. Related uncertainty refers to the ratio of uncertainty in measurement to true value.

In accordance with JJF1059-1999, the evaluation process of uncertainty in measurement is shown in Fig.3.

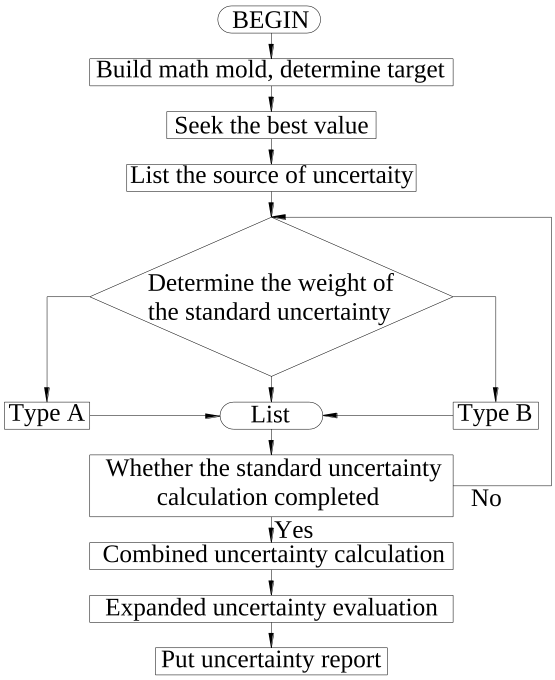

Figure 3. The evaluation process of the uncertainty in measurement

3.1. Estimation of uncertainty in measurement

Uncertainty is caused by error. Due to the complexity of error, it is difficult to calculate the uncertainty accurately. The estimation method is often used as follows.

$$U = \sqrt{U_A^2 + U_B^2} \tag{1}$$

U_A -Type A standard uncertainty, acquired by statistical method.

U_B -Type B standard uncertainty, acquired by non-statistical method.

Type A component estimate:

When an independent variable x_i is the result of the arithmetic mean $\overline{x_i}$ in n times repeat measurements, the standard uncertainty is the standard deviation of $\overline{x_i}$.

$$U_A = \sqrt{\frac{\sum_{i}^{n}\left(x_i - \bar{x}\right)^2}{n(n-1)}} \tag{2}$$

Type B component estimate:

Type B standard uncertainty can be evaluated using different information sources under relative conversion relationship. In this test, x_i is obtained from the instruction book or operation manuals of the instruments. The expanded uncertainty U and its coverage factor d are known, then:

$$U_B = \frac{U}{d} \tag{3}$$

If the measured estimate value obeys uniform distribution, then:

$$d = \sqrt{3} \tag{4}$$

If the measured estimate value obeys inverse sine distribution, then:

$$d = \sqrt{2} \tag{5}$$

3.2. Uncertainty in measurement evaluation

The ranges and accurate degree of the main measurement instrument are shown in Table 1.

Table 1. Range and accuracy degree of the instrument

No.	Instrument	Type	Serial number	Range	Accuracy degree
1	Poly temperature tester	TC-2	180231	-50~250 ℃	0.05 ℃
2	Turbine flowmeter	LWGY-25	04-084877 04-089212	1~10 m^3/h	±0.5%
3	Electricity tester	AN7931A	047903072 047903073	Voltage: AC10.0V~600.0V Current: 0.030~40.00A Power: 0.001~72kW	0.25% × (Indication +Range)

3.2.1. The power measurement uncertainty

Type A uncertainty:

Power varies with the environment temperature in varying duty tests. The independent variable cannot be evaluated with statistic analytical method. Thus the type A uncertainty is non-existent, that is:

$$U_A = 0 \tag{6}$$

Type B uncertainty:

According to Table 1, then:

$$\Delta_I = 0.25\% \times \text{Indication} + 0.25\% \times \text{Range} = 0.25\% \times 6.28 + 0.25\% \times 72 = 0.196\text{kW} \quad (7)$$

(The maximum power value is 6.28 kW)

If power measurement obey uniform distributing, then:

$$U_B \le \frac{\Delta_{仪}}{\sqrt{3}} = \frac{0.196}{\sqrt{3}} = 0.113 \text{ kW} \quad (8)$$

The combined uncertainty is:

$$U = \sqrt{U_A^2 + U_B^2} = U_B = 0.113\text{kW} \quad (9)$$

3.2.2. The temperature measurement uncertainty

Type A uncertainty:

Same as the power measurement:

$$U_A = 0 \quad (10)$$

According to Table 1:

$$\Delta_I = 0.05 \text{ ℃} \quad (11)$$

Type B uncertainty:

If temperature measurement obeys uniform distribution, then:

$$U_B \le \frac{\Delta_I}{\sqrt{3}} = \frac{0.05}{\sqrt{3}} = 0.029\text{℃} \quad (12)$$

The combined uncertainty is:

$$U = U_B = 0.029\text{℃} \quad (13)$$

3.2.3. The flux measurement uncertainty

Same as the power measurement:

$$U_A = 0 \quad (14)$$

Type B uncertainty:

According to Table 1:

$$\Delta_I = 10 \times 0.5\% = 0.05\text{m}^3/\text{h} \quad (15)$$

$$U_B \le \frac{\Delta_I}{\sqrt{3}} = \frac{0.05}{\sqrt{3}} = 0.029\text{m}^3/\text{h} \quad (16)$$

The combined uncertainty is:

$$U = U_B = 0.029\text{m}^3/\text{h} \quad (17)$$

3.3. Related uncertainty in measurement valuation

The standard condition test result is shown in Table 2.

Table 2. Test parameters

No.	Content	Refrigeration	Heating
1	Water flux	0.626	0.688
2	Δt, ℃	5	5
3		13.10	15.37
4	Input power, kW	4.87	4.92
5	COP	2.69	3.12
6	Freon high pressure	1.82	1.80
7	Freon low pressure	0.41	0.32
8	Compress ratio	4.44	5.63
9	Power factor	83.6%	86.3%

When the above values are taken as true values, the related uncertainties in measure of each parameter are as follows:

$$\text{Power: } U = 0.113/4.87 = 2.32\% \tag{18}$$

$$\text{Temperature: } U = 0.029/7 = 0.41\% \tag{19}$$

$$\text{Flux: } U = 0.029/2.25 = 1.29\% \tag{20}$$

4. Conclusion

Based on the calculation of uncertainties in measurement, a conclusion could be reached: for the residential central air-conditioning property tests, all the related uncertainties in measurement of the measurement parameters are less than 2.5%. So the test results are true and reliable.

5. Acknowledgments

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6. References

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