



Research on Application of Humidity Instrument in Nuclear Power Plant Ventilation System

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Abstract. Humidity regulation and control of ventilation system in nuclear power plant plays an increasingly important role in the third generation nuclear power plant. Humidity meter is an important equipment to realize this function. In this paper, the measuring principle of humidity instrument and the application requirements of the third generation nuclear power humidity instrument are compared and analyzed in detail. Combined with the application of humidity instruments in nuclear power plants, two kinds of humidity instruments, capacitive and optical fiber, are proposed to meet the application requirements of the third generation of nuclear power plants.

Keywords: Nuclear power plant · Ventilation system · Humidity measurement · Humidity meter

1 Introduction

The ventilation system of nuclear power plant undertakes the functions of air supply and exhaust, temperature and humidity regulation of all plant buildings. With the development and requirements of the third generation nuclear power technology, the role of ventilation system in nuclear power plant is becoming more and more significant. Humidity regulation is an important part of ventilation system. The accuracy of humidity meter measurement directly affects the function of humidity regulation. In the third generation nuclear power plant, higher requirements are put forward for humidity control in the main control room and instrument control electronic equipment room, and related humidity instruments also need safety level instruments. The humidity instruments used in the previous CPR nuclear power project have been unable to meet the application requirements of the third generation nuclear power plant. It is necessary to carry out the research of humidity instrument and develop the high performance safety level humidity instrument which meets the requirements of the third generation nuclear power application.

2 Analysis of Humidity Measurement Scheme

Humidity, the amount of water vapor in the air, is used to indicate the degree of dryness and wetness of the air. There are three kinds of expression methods: absolute humidity, relative humidity and dew point [1]. In industry, ventilation systems usually measure relative humidity [4].

2.1 Common Methods of Humidity Measurement

According to GB/T 11605-2005 humidity measurement method, the commonly used humidity measurement methods include stretching method, wet bulb method, condensation dew point method, chloride dew point method, resistance capacitance method, electrolysis method and weight method [3]. Capacitance method and resistance capacitance method are widely used in industry.

2.2 A New Optical Fiber Humidity Measurement Method

In recent years, with the development of technology, optical fiber humidity sensor has gradually appeared. It has the advantages of high sensitivity, fast response speed, small size, light weight and strong anti-interference ability. Compared with the traditional electronic hygrometer, optical fiber humidity sensor has great advantages [5].

High Sensitivity, High Detection Limit. The optical fiber humidity sensor can measure humidity accurately to 2 to 3 decimal places. The general electronic hygrometer can only measure humidity to one decimal place [6].

Fast Response. When the humidity quickly reaches a certain stable value, the general electronic hygrometer needs a response time of several seconds to tens of seconds to display the current humidity accurately. The optical fiber humidity sensor can measure the current humidity in less than one second [7].

Small Size, Light Weight. Compared with the traditional chip electronic hygrometer, the volume and mass of optical fiber humidity sensor are much smaller. It can measure some precise structure environment. It has strong ability to resist environmental disturbance. The optical fiber humidity sensor can still work normally in the environment of electromagnetic interference, high temperature and rapid change of humidity [8].

After years of research, various types of fiber optic humidity sensors have emerged. At present, the common sensors can be roughly divided into optical fiber transmission type, optical fiber sensor type and fiber grating type [2].

3 Application Requirements of Humidity Instrument in Ventilation System of Nuclear Power Plant

In the CPR project, the ventilation system is relatively simple. The opening of fresh air valve and the operation of electric heater are mainly controlled by humidity monitoring,

so as to control the humidity of downstream air supply. It is only used for humidity control in some local areas, which is a non safety level function.

In the third generation nuclear power technology, there are two main ways for humidity instruments to participate in the humidity control and regulation of ventilation system. It is mainly used to ensure the temperature and humidity of the main control room area and the important electrical I & C equipment area of the safety building, and its functions are safety level functions.

By measuring the temperature and humidity in the ventilation duct, the corresponding enthalpy is calculated. The operation mode of the ventilation system is determined by comparing the enthalpy values in the supply, return and exhaust ducts. So as to adjust the opening of fresh air valve, return air valve and exhaust valve, and simultaneously adjust the electric heater and cold water valve to ensure that the air supply temperature and humidity are within a certain range.

Humidity measuring instruments and humidifiers are installed in important electronic equipment rooms. Adjust the humidifier according to the measured value of humidity meter to ensure that the room humidity is within the required range.

In the third generation nuclear power technology, humidity instruments participate in the realization of safety level functions, so there are higher requirements for humidity instruments themselves. The instrument needs to meet K3 identification, and the instrument also needs to meet certain radiation resistance requirements according to the different instrument layout areas. At the same time, higher requirements are put forward for the EMC characteristics of the instrument, which should meet at least 14 tests in IEC61000 standard test. At present, there are embedded software in humidity measuring instruments. As a safety level instrument, its software needs independent V & V verification. See Table 1 for the comparison of requirements for humidity instruments under different nuclear power technology routes.

Table 1. Comparison of requirements for humidity instruments under different nuclear power technology routes

Technology route	Safety classification	Equipment qualification	Seismic requirements	Radiation resistance requirements	EMC	Software V & V verification
CPR nuclear power project	Non safety class	No	No	No	IEC61000 (4 items in total)	No
Third generation nuclear power project	safety class	K3 identification (RCC-E standard)	Yes	Yes	IEC61000 (14 items in total)	Yes

4 Application Analysis of Humidity Instrument in Ventilation System of Nuclear Power Plant

At present, the humidity instruments used in nuclear power plants are mainly capacitive humidity measuring instruments or resistance capacitance humidity measuring instruments. The main manufacturers are E+E of Germany, Rotronic of Switzerland, Michell of England. At present, there is a certain gap between the performance of domestic humidity measuring instrument and foreign instrument, and it is not used in nuclear power plant. The main performance parameters of humidity instruments used in nuclear power plants are shown in Table 2 and Fig. 1.

Table 2. Performance parameters of humidity instruments used in nuclear power plants

Measuring range	0–100% RH
Accuracy	±2.3% RH (–15 °C–40 °C)
Response time	<15 s
Output signal	4–20 mA
Protection level	IP65
Shell material	Plastic or metal
Operating temperature range of electronic components	–40 °C–60 °C



Fig. 1. Appearance of humidity instrument used in nuclear power station

Compared with the requirements for humidity instruments in the third generation nuclear power project in Table 3, the humidity instruments currently used can meet the seismic requirements, K3 appraisal is in progress, and other application conditions are not met.

In order to develop a humidity meter meeting the requirements of the third generation nuclear power project, there are two ideas.

Table 3. Comparison of the technical requirements of the third generation nuclear power plant

	Safety classification	Equipment qualification	Seismic requirements	Radiation resistance requirements	EMC	Software V & V verification
Third generation nuclear power project	safety class	K3 identification (RCC-E standard)	Yes	Yes	IEC61000 (14 items in total)	Yes
The current situation of humidity meter	Non conformity	K3 identification in progress	conformity	Non conformity	Non conformity	Non conformity

One is to develop a new instrument based on capacitive measurement principle to meet the application conditions of the third generation nuclear power plant. The research and development of the new instrument can improve the relevant components and shell materials and redesign the overall structure to meet the specific requirements of seismic resistance, irradiation, qualification and electromagnetic compatibility. At the same time, the circuit and related software can be redesigned to meet the requirements of software V & V verification. Some domestic instrument manufacturers have the ability and experience to develop nuclear grade instruments, with mature technology and short development cycle.

The other is to develop new instruments based on optical fiber measurement principle. Optical fiber humidity meter with its unique huge advantages, has become a hot research and development of new humidity instruments, and will be widely used in various industries in the future. However, due to the development and application of new technology is not very mature, optical fiber humidity has not been widely used in industry. If we want to apply it to the ventilation system of nuclear power plant, we need to design and develop a new one for nuclear power application conditions, and the research and development is difficult (Table 4).

Table 4. Comparison of two kinds of humidity meter development schemes

	Advantage	Disadvantages	Implementation status
Capacitive type	Mature technology, The development cycle is short, It can meet the requirements of the third generation of nuclear power, It can also be used in the subsequent modification of humidity instruments in active nuclear power plants	Old technology, The performance of the instrument can not be further improved due to the limitation of the measurement method	At present, the domestic instrument manufacturers have the ability to develop nuclear grade instruments, and the implementation is strong
Fiber optic	High sensitivity, Fast response, Small size, Light weight, Strong ability to resist external environment interference	It is necessary to design new instrument structures for nuclear power applications. A large number of tests and qualification processes are required, and the development cycle is long	Domestic instrument manufacturers are required to invest in scientific research, which is difficult

5 Conclusion

The humidity instrument of ventilation system under the third generation nuclear power technology plays an increasingly important role. At present, the capacitive humidity measuring instrument widely used in nuclear power plants has been unable to meet the application requirements of the third generation nuclear power plant. In this paper, the measurement principle of humidity meter and the application requirements of three generations of nuclear power humidity instrument are compared and analyzed in detail. The development direction of two kinds of humidity instruments for ventilation system of nuclear power plant is proposed. Based on the principle of capacitive measurement, it is an effective way to research and develop a humidity meter which can meet the requirements of the third generation nuclear power plant on the basis of the existing humidity instruments. Based on the optical fiber measurement principle, the development of new humidity meter can further improve the performance of the instrument. The two methods can go hand in hand to provide good equipment support for the subsequent humidity measurement of ventilation system in nuclear power plant.

References

1. Zhang, J.-H.: Analysis of flue gas humidity monitoring method in thermal power plant. *Sci. Technol. Innov. Herald* **36**, 104–105 (2018)
2. Wu, Z.: *Relative Humidity Sensor Based on Fiber Grating*. Beijing University of Posts and Telecommunications, Beijing (2012)
3. Lin, Y.-G., Yu, Y.-H., Fu, Z.-H.: *Methods of Humidity Measurement (G B/T11605-2005)*. Standards Press of China, Beijing (2005)
4. Li, Z.-J.: Research of humidity measurement method. *Metrol. Meas. Tech.* **38**(6), 41–42 (2011)
5. Wang, B.: *High Sensitivity Fiber-Optic Humidity Sensor*. Harbin Institute of Technology, Shenzhen (2018)
6. Du, B., Yang, D., She, X.: MoS₂-based all-fiber humidity sensor for monitoring human breath with fast response and recovery. *Sens. Actuators B Chem.* **251**, 180–184 (2017)
7. Wang, W., Sun, T., Peng, J.: Humidity sensor based on fiber bragg grating coated with different pore-foaming agent doped polyimides. *IEEE Photonics Technol. Lett.* **29**(22), 1963–1966 (2017)
8. Wang, X.-F., Farrell, G., Lewis, E.: A humidity sensor based on a single mode-side polished multimode-single mode optical fibre structure coated with gelatin. *J. Lightwave Technol.* **35**(18), 4087–4094 (2017)