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Introductions for a Multi-function Portable SF_6 Leaking Alarm Testing Device Based on a Two-level Configure Gas Technology

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Abstract: In this study, we make a study of a new two-level configure gas technology. This technology can expend the configure gas device's dilution ratio and combined with inner set baffled spiral cast to achieve a full-sacle configure gas of SF_6 and air. Further to make the SF_6 leaking alarm testing device to be not only a multi-function portable device but also have the advantages like compact structure, light weight, large dilution ratio, high accuracy, degree of automation and so on. And this device can solve the situation of SF_6 leaking alarm device can't calibrate conveniently in indoor workplace, such as electric power system GIS obviously.

Keywords: Leaking alarm, SF_6, test

INTRODUCTION

The sulfur hexafluoride is widely used in power system because of its good performance in insulation and arc extinction. With the developing of electric power technology and wide application of GIS electrical equipments, electrical room with SF_6 equipments, but a part of SF_6 will be separated with the effects of high-voltage arc or high temperature, the products are always highly toxic. And when the switches or the devices indoor for SF_6 are leaking, it will pose serious life-threatening risk to the workers who are indoor. So it needs SF_6 leaking alarm testing device to test the levels of SF_6 and O_2. And there are a great variety of the SF_6 gas leaking alarms with different detection principle, but most of their sensitivity, accuracy or stability can not be effectively guaranteed at present. A random sample of SF_6 leaking alarm testing devices which are installed in two cities' power network system, we find that about 70% can't work normally or relatively great detection error. So they can't test the levels of SF_6 and O_2 effectively, hidden trouble in safety.

For the moment, the reports about SF_6 leaking alarm testing device are less both at home and abroad. And the internal power network system majority uses traditional configure gas technology to check the SF_6 leaking alarm testing device. At present the SF_6 gas leaking alarms have problems in testing: first, most of companies don't take any testing action for the device, don't familiar with its performs of real time monitoring. Second, at the scene there are a great variety devices with different detection principle, include of electrochemical technology, electric breakdown technology, infrared spectroscopy absorb technology and so on, it bring problems for devices testing because of the lack of SF_6 leaking alarm device testing technology's versatility. Third, part of companies use the standard gases to test devices, the rate is slowly. And the varying concentrations standard gases cylinders needed for scene testing also bring problems for testing and operating.

This study is mainly to solve the testing problems above-mentioned. Via studying on a two-level configure gas technology, expending the configure gas device's dilution ratio to achieve a full-sacle configure gas of SF_6 and air. Further to get an alarm testing device for SF_6 leaking with compact structure, light weight, large dilution ratio, high accuracy and degree of automation by using liquid SF_6 and air pump as gas source.

TWO-LEVEL DYNAMIC CONFIGURE GAS TECHNOLOGY

It needs compounding multi-component and various concentrations mixture gases to test the alarm testing device for SF_6 leaking. So we need selecting the suitable configure gas methods to ensure the inspections work can be carried out better. At present, the common methods to configure gas standard material include both static and dynamic at home and abroad.

The static methods include gravimetric method, differential pressure gas preparation method, gas bag method and so on. The basic principle of gravimetric method is weight hybrid, mixing different weight and various gases. Differential pressure gas preparation method relies on the ideal Dalton law, filling with the species gases and dilute gas into a assumed constant and sealed steel cylinder. Gas bag method is pressing the quantitative tube's raw material into gas bag, diluting to a certain volume, kneading the gas bag by

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Table 1: Several air flow devices' parameters contrast table

	US ALICAT	Japan KOFLOC	US AALBORG
Type	MC series	8500 series	GFC17S series
Effective control range	0.5%-100% FS	2%-100% FS	1%-100% FS
Control precision	±(0.8% reading data+0.2%FS)	±1.5%FS	±1.0%FS
Repeatability	±0.2%	±0.5%	±0.2%
Responding time	0.1-0.3S	1-2S	1-2S
Working temperature range	-10°C to +50°C	0°C to +50°C	5°C to 50°C
Inner set gas species	20 common gases and 10 mixed gases, automatically switch	Single calibration gas	Single calibration gas

hand to mix well-distributed. These methods are tedious operation, rigorous technology steps. It's hard to get a certain accurate concentration. And the short stable time led the limitation of using (Du and Deng, 2008).

The dynamic method is making a known concentration raw gas with diluted gas into the mixer to mix at a constant ratio incessantly. So we can compound and supply a certain concentration standard gas incessantly. The dynamic method is suitable for our device because of it can both long time supply massive standard gas and compound various concentration mixed gas (Zhou and Yi, 2008).

At the pressure of one standard atmosphere, SF_6's relative density is 6. 16 g/cm^3 in the gaseous and 1400 g/cm^3 in the liquid. Therefore, when we use 2 L the liquid SF_6 is roughly equivalent to 454 L in the gaseous. This ensure that you can have a long-term compounding gas with 2 L liquid SF_6 without aerating frequently or a 10 L's steel cylinder, so we get a portable device and the device needs a full-sacle configure gas of SF_6 and air. Thus it needs two-level dynamic configure gas system, achieve twice dilutions for raw gas, to ensure control precision.

Considering SF_6 leaking alarm devices have a larger structural differences and various installing positions, this study select the dynamic method combined with gas bag method, compounding standard gas by dynamic configure gas system. And test the gas in the sealed soft bag which is install onto the alarm device.

The dynamic method uses the high precision quality flow controller to control the species gases' flow. Some common air quality flow controllers' parameters are compared in Table 1.

From Table 1 we can get that US ALICAT's MC flow controller has a higher control precision and more suitable for configurating the trace level mixed gas conditions. Meanwhile the 20 common gases and 10 mixed gases, automatically switch bring great convenience to compounding multi-component mixture gases for portable SF_6 leaking alarm testing device.

Due to air quality flow controllers' calibration gases are pure concentration gases when they are in factories, so they will have indicator value errors while the first time to dilute the raw gases be the multi-component gases via the devices, needed correcting. Under the standard status, test the different gases' flow need a linear parameter transformation and it's general decided by the absolute viscosity of gas. This parameter can be calculated as follows:

$$Q_{og} = Q_1 \times (\eta_1/\eta_{og})$$

In formula:

Q_1 = The flow that flow controller display
η_1 = Calibrating gas' viscosity under the standard status
Q_{og} = The actual flow of multi-component gases'
η_{og} = The multi-component gas' viscosity under the standard status (Alicat Company, 2005)

If consider the influence of pressure and temperature, the multi-component gas' formula is:

$$Q_{og} = Q_1 \times (\eta_1/\eta_{og}) \times (298.\ 15/273+t) \times (p/101.\ 325)$$

In formula:

t = The actual temperature
p = The actual pressure

We can get that pressure and temperature have very small influence on the compounded concentration of standard gases, so we can neglect them. And we have prove it through experiments under many times, different conditions.

The viscosity calculation formula of multi-component gases under the standard status is:

$$\eta = \eta_1 \times (\omega_1/\omega_T) + \eta_2 \times (\omega_2/\omega_T) + \ldots + \eta_n \times (\omega_n/\omega_T)$$

In formula: $\omega_1 \ldots \omega_n$ is the corresponding gas' flow; ω_T is flow of mixture gases; $\eta_1 \ldots \eta_n$ is the corresponding gas' viscosity.

MULTI-FUNCTION PROTABLE SF_6 LEAKING ALARM TESTING DEVICE'S WORKING PRINCIPLE

This device include gas source, two-level configure gas system, gas mixed system and so on. It can be automatically switch according to the dilution ratio. So when the dilution ratio is lower it takes the first order gas distribution mode to achieve a fast configuring and when the ratio is greater than 100:1 it takes the second order gas distribution mode to achieve the low concentration's automatically configuring. Moreover, it

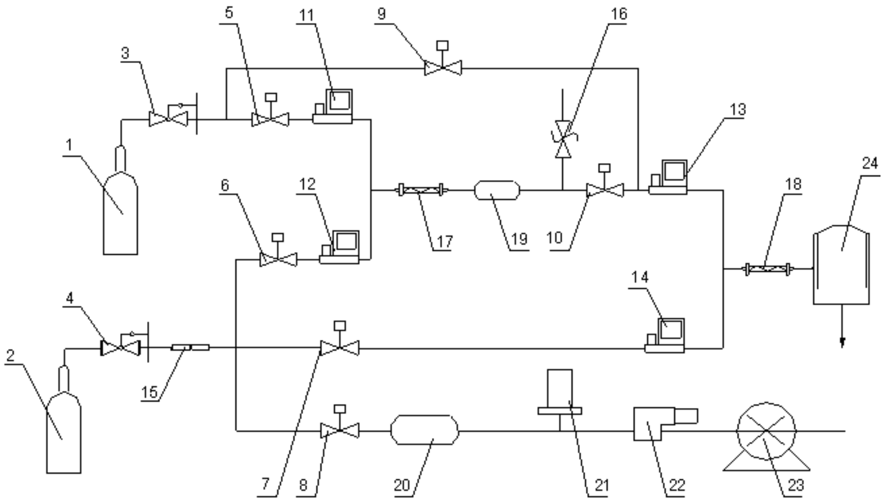

Fig. 1: Multi-function portable alarm testing device for SF_6 leaking working principle's figure; 1: Raw gas steel cylinder; 2: Dilution gas steel cylinder; 3: The first pressure reducing valve; 4: The second pressure reducing valve; 5: The first electromagnetic valve; 6: The second electromagnetic valve; 7: The third electromagnetic valve; 8: The 4th electromagnetic valve; 9: The 5th electromagnetic valve; 10: The 6th electromagnetic valve; 11: The first quality flow controller; 12: The second quality flow controller; 13: The third quality flow controller; 14: The 4th quality flow controller; 15: Check valve; 16: Relief valve; 17: The first mixer; 18: The second mixer 19: The first buffer tank; 20: The second buffer tank; 21: Pressure transmitter; 22: Air cleaner; 23: Microminiature air pump; 24: Check cavity

can test the concentration of O_2 because of the alarm device's O_2 content is usually 18%. Therefore, take the standard SF_6 as dilute gas, air as raw gas (air has about 21% O_2 under the standard status) to configurate the 15-21% standard O_2 gas can completely meet the O_2's concentration testing requirements, instead of carrying steel cylinder. It's working principle as Fig. 1.
It's working principle are:

- **The gas configuration of the first order cylinder:** Switch on the raw gas steel cylinder and regulated to a suitable gas pressure by the first pressure reducing valve; switch on the dilution gas steel cylinder and regulated to a suitable gas pressure by the second pressure reducing valve; switch on the 5th and the third electromagnetic valve, the third and the 4th quality flow controller, the diluted raw gas and the dilution gas into check cavity after mixing in the second mixer, completing the gas configuration of the first order cylinder.
- **The gas configuration of the second order cylinder:** Switch on the raw gas steel cylinder and regulated to a suitable gas pressure by the first pressure reducing valve; switch on the dilution gas steel cylinder and regulated to a suitable gas pressure by the second pressure reducing valve; switch on the first and the second electromagnetic valve, the first and the second quality flow controller, the diluted raw gas and the dilution gas into the first buffer tank after mixing in the first mixer, completing the primary gas distribution.

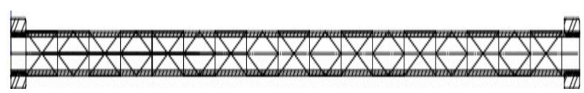

Fig. 2: The inner set baffle spiral cast mixer's internal structure images

The relief valve switch on automatically when the primary distribution get the pressure of mixed gas are above the relief's setting pressure, then excreting the redundant mixed gas to keep the pressure, or carry the second order distribute. Switch on the third electromagnetic valve and the 4th quality flow controller at same time, the mixed gas in the first buffer tank and the diluted gas enter into the check cavity through the second mixer. Then, complete the gas configuration of the second order cylinder.

This device can also take the air pump mode: switch off the second pressure reducing valve and use check valve to shut the pathway of diluted gas steel cylinder. Switch on micro miniature air pump and the 4th electromagnetic valve, the air go through the second buffer tank at a constant pressure under the pressure transmitter's control; to be instead of steel cylinder, reduce the real time labor intensity.

The gas mixer is the core of the gas mixing uniform or not and the key of the dynamic system can mix various gases unform quickly. Its mixed performance determines the accuracy and stabilization of compounding gases. The first mixer and the second mixer in Fig. 2 use the inner set baffle cast mixer with 17 inner set baffle spiral cast, in fluid's process,

Table 2: The performance test results for 3 kinds of mixers

Structural pattern	Inner set baffled spiral cast	Spiral cast	Through type
SO_2/SF_6 concentration is 20 μL/L	19.8	19.5	19.2
SO_2/SF_6 concentration is 2 μL/L	1.8	1.6	1.4
H_2S/SF_6 concentration is 20 μL/L	20.2	19.6	19.5
H_2S/SF_6 concentration is 2 μL/L	1.8	1.7	1.5
CO/SF_6 concentration is 100 μL/L	100.5	100.8	101.1
CO/SF_6 concentration is 10 μL/L	9.6	9.4	9.1

Table 3: The determination results of SF_6 gas leaking alarm calibration device's accuracy

SF_6's concentration (%)	The setting flow L (mL/min)	SF_6's setting concentration (μL/L)	SF_6's actual concentration (μL/L)	The errors of gas distribution (%)
50.0	2000.0	100.0	98.5	1.500
50.0	2000.0	200.0	197.0	1.500
50.0	2000.0	300.0	297.0	1.000
50.0	2000.0	400.0	395.5	1.125
50.0	2000.0	500.0	503.5	-0.700
50.0	2000.0	600.0	602.0	-0.333
50.0	2000.0	700.0	697.0	0.429
50.0	2000.0	800.0	797.0	0.375
50.0	2000.0	900.0	903.0	-0.333
50.0	2000.0	1000.0	1008.0	-0.800
50.0	2000.0	1100.0	1095.0	0.455
50.0	2000.0	1200.0	1193.0	0.583
50.0	2000.0	1300.0	1292.0	0.615
50.0	2000.0	1400.0	1392.0	0.571
50.0	2000.0	1500.0	1512.0	-0.800
50.0	2000.0	1600.0	1590.0	0.625
50.0	2000.0	1700.0	1706.0	-0.353
50.0	2000.0	1800.0	1790.0	0.556
50.0	2000.0	1900.0	1890.0	0.526
50.0	2000.0	2000.0	2004.0	-0.200
50.0	2000.0	2500.0	2488.0	0.480
50.0	2000.0	3000.0	2994.0	0.200
50.0	1500.0	4000.0	3985.0	0.375
50.0	1500.0	5000.0	4970.0	0.600
50.0	1000.0	6000.0	6005.0	-0.083
50.0	1000.0	7000.0	6976.0	0.343
50.0	1000.0	8000.0	7930.0	0.875
50.0	1000.0	9000.0	9014.0	-0.156
50.0	1000.0	10000.0	9941.5	0.585

segmentated times increase in power series, formed 2^{17} times cutting, shear, rotation and mixed again, to get a good dispersion and a fully mix.

The performance test for the mixers of inner set baffled spiral cast, spiral cast and through type and the results are showed in Table 2.

In Table 2, we can get that use the spiral cast mixer and spiral cast mixer can urge each gas molecular inter-collision's affects. For the air uniform of both large concentration and small concentration, to achieve a stable mixing, the performance of mixing gas: inner set baffled spiral cast>spiral cast mixer>through type mixer.

PERFORMANCE TEST

The sample gas of SF_6's concentration is 50%, the diluted gas is clean air and configurating the concentration of SF_6 standard gas from 100 μL/L to 10000 μL/L, the flow of SF_6 standard gas is 2000 mL/min. Use the SF_6 chromatograph to test the actual concentration, observe the relative errors between the setting concentration and the actual concentration, the determination results are showed in Table 3.

From the determination results, we can get that the flow control precision is less than 0. 9%; the uncertainty of gas distribution is less than 1. 5%. This suggests that the dynamic system is large dilution ratio, good stability and high accuracy.

CONCLUSION

At present, the reports about the SF_6 gas leaking alarms testing technology are comparative little and have not found a multi-function portable alarm testing device for SF_6 leaking with two-level configure gas technology. This device has these advantages compared with other test system:

- This device can use SF_6 and air pump as the gas source, get the requisite various concentration's SF_6 standard gas through the two-level configure gas technology to avoid bringing massive SF_6 standard gas and diluted gas steel cylinder.
- This device can take both air pump model and air bottle model as the air source. The clean air is provided by air pump in air pump model and provided by exteriorization air bottle in air bottle model.
- This device uses the dynamic two-level configure gas method, can be used when the amount of standard gas is larger, the dilution ratio is higher, the configure gas's time is longer or have a big difference in molecular weight.
- This device use a special mixer with 17 inner set separators, can configure gas with high precision, low concentration effectively.

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