Measurement of Water Vapor in Sulphur Hexafluoride, SF_6

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Introduction
Sulphur hexafluoride, SF_6, is a non-toxic, inert, insulating and cooling gas of high dielectric strength and thermal stability. Due to its high dielectric strength, it is particularly suited for application in high power circuit breakers as well as in high-voltage cables, transformers, and switchgears. The excellent arc-quenching and insulating properties of SF_6 allow the construction of new circuit breakers and switching stations of higher voltage in smaller size with less noise.

Under the influence of an arc, a small portion of the gas dissociates into its atomic constituents, sulphur and fluorine. Since the reaction is completely reversible, the dissociated products recombine naturally into SF_6 provided that no secondary reactions occur with vaporized electrode metal, or other materials used in the construction of the component. Generally, solid or gaseous products formed as a result of these secondary reactions are themselves good dielectrics, and cause no degradation to the operational efficiency of the high-voltage equipment.

Water Vapor in SF_6
Since SF_6 itself is chemically inert, it can not and does not cause corrosion. However, in the presence of water vapor, H_2O, primary and secondary decomposition products hamper natural recombination of the SF6. These decomposition products form the highly corrosive electrolyte hydrogen fluoride (HF). Hydrogen fluoride vigorously attacks glass, porcelain, paper and other commonly used insulating materials. The amount of damage, and the rate of destruction, depends on the concentration of hydrogen fluoride formed, which is ultimately based on the amount of water vapor present. A higher concentration of water vapor allows for formation of a higher concentration of hydrogen fluoride.

Measurement of Water Vapor
To ensure that corrosive electrolytes remain at low concentration levels, it is important to make periodic measurements of the water vapor content of the gas used within the SF_6 filled equipment. Chilled mirror technology is commonly used as an accurate, reliable, and robust method for measurement of water vapor in SF_6. While the initial cost to obtain the chilled mirror equipment is somewhat higher than systems relying on other measurement methods such as aluminum oxide sensors, overall cost of ownership is generally lower. In addition to lower cost of ownership, there are other significant advantages to consider in the use of chilled mirror technology as well.

Measurement Principles
Water vapor changes the dielectric properties of a porous aluminum oxide sensor, thereby altering its capacitance. This resulting capacitance is detected by an electronic circuit which gives a reading of the water vapor content. Aluminum oxide sensors are neither absolute nor fundamental devices, and provide indication relative to their calibration state at the time of measurement. A shift in calibration results in a shift in measurement reading.

Conversely, a chilled mirror hygrometer provides an absolute and direct measurement of water vapor content that relies on fundamental measurement principles. The mirror of the device is cooled until condensation of water vapor is detected on the mirror surface. Using an opto-electrical feedback control system, the mirror temperature is brought into stabile equilibrium with the gas where there is no further net change in the amount of condensation onto, or evaporation from, the mirror surface. The temperature at this equilibrium point is termed the dew point temperature and is measured directly using an industrial-grade platinum resistance thermometer (PRT) embedded within the mirror surface. The accuracy of dew point temperature measurement is related directly to the accuracy of the thermometer used to measure the mirror (or dew point) temperature.

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Affects of Contamination
Contamination of any measurement device, regardless of type, could affect the accuracy and reliability of measurements. Contamination of aluminum oxide sensors generally causes permanent alteration to the dielectric material of the sensor, resulting in a shift in calibration. Periodic re-calibration can overcome the affects of contamination.

Cleaning the mirror of a chilled mirror hygrometer removes all contamination, immediately restoring the system to its factory new condition. Contamination has no permanent affect on the accuracy or reliability of a chilled mirror hygrometer. Accuracy and reliability of the dew point measurements depend only on the cleanliness of the mirror and on the stability of the PRT used to sense the mirror temperature.

Maintenance
The only maintenance required when using chilled mirror hygrometers is infrequent periodic cleaning of the mirror surface and optics using commonly obtained items; alcohol, water, and soft cotton tipped swabs. The mirror surface is easily accessible from the front of the instrument, and may be cleaned by operating personnel, regardless of technical level or ability. No specialized tools or knowledge is required, and mirror cleaning can generally be performed in less than one minute. Once cleaned, the instrument is again immediately ready for use.

Calibration
Periodic re-calibration is recommended for systems utilizing aluminum oxide sensors to ensure the accuracy and reliability of measurements.

Re-calibration of chilled mirror hygrometers is generally not required. Since the measurement of dew point is dependent only on the measurement of the mirror temperature, it is only important to ensure that the PRT used to measure the mirror temperature is indicating properly. A quick and simple ice-melt test, performed by the operating technician, can be used to ensure that the PRT calibration has not shifted from its initial factory calibration. The ice-melt test is performed using the following procedure:

a. Remove the cover to expose the mirror surface
b. Press and hold the front panel TEST switch, cooling the mirror well below 0°C
c. Breathe on the mirror, if necessary, to form a layer of ice
d. Release the TEST switch to allow the mirror to warm toward 0°C, momentarily using the switch as necessary to approach the final few degrees slowly
e. As the mirror passes slowly through 0.0°C, the ice should immediately melt into water, ensuring the accuracy of the mirror temperature (and dew point temperature) measurement

An ice-melt test is all that is required in order to establish the reliability of chilled mirror hygrometer measurements. Whether the systems is frequently used on a daily basis, or stored on a shelf for months at a time, accuracy and reliability of an unknown instrument may be established within minutes.

Cost of Ownership
Cost of ownership includes the cost of original purchase, and subsequent costs associated with instrument use. Subsequent costs often include such things as re-calibration, transportation to and from the calibration laboratory, and lost work due to downtime.

The initial purchase price of chilled mirror hygrometers is generally much higher than that of aluminum oxide sensors. Since the mirror is easily cleaned, removing all the affects of contamination, and the mirror temperature measurement may be easily verified with the ice-melt test, periodic re-calibration of chilled mirror hygrometers is not required. Periodic re-calibration of instruments is one of the single highest ownership costs. Eliminating this requirement ensures that the cost of chilled mirror ownership remains at or near the cost of initial procurement.

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