Chlorine Stack Emissions for the Sentry 2000

US Patent # 5, 393, 314

Introduction

The Sentry 2000 is a patented horizontal crossflow packed bed scrubber system with major applications in chlorine and sulfur dioxide emissions control. These systems have been installed for the emergency scrubbing of chlorine and sulfur dioxide container rooms should leakage of the containers or piping systems occur.

The major design criterion applied to scrubber systems is the stack discharge concentration during emergency operation. This concentration is specified by the Uniform Fire Code (UFC) not to exceed one half of the immediately dangerous to life and health (IDLH) level of a toxic gas. From the late 1980's to 1995 the IDLH level, expressed in parts per million (PPM), had been set at 30 PPM for chlorine. During 1995, however, the chlorine IDLH level was changed to 10 PPM.

In 1993, Powell Fabrication & Manufacturing, Inc. in conjunction with Mr. Ralph Strigle, a world-recognized expert in packed tower scrubber systems, designed the Sentry 2000 to neutralize chlorine and sulfur dioxide. Based on mass transfer efficiency calculations, the Sentry 2000 system utilized packed bed technology developed over more than 50 years. Mass transfer efficiency calculations for packed beds have proven to be accurate when compared to actual systems. Additionally, results for packed beds, unlike spray chambers or venturi scrubbers, can be scaled upwards or downwards reliably. Enclosed is a technical paper by Mr. Strigle presenting the calculations used to predict and corroborate the performance of the Sentry 2000. System performance is verified using two independent methods consisting of mass transfer driving forces with inlet and outlet concentrations.

The Sentry 2000 was designed to operate at an inlet flow rate of 3,000 ACFM for contaminant release rates in excess of 78 lbs/min. This leakage rate is specified by the UFC and represents an overfilled one ton chlorine or sulfur dioxide cylinder emptying in 30 minutes. The design was originally based on the 1993 IDLH of 30 PPM for chlorine and 100 PPM for sulfur dioxide but is easily adaptable to reduced IDLH levels.

Sentry 2000 Design Evaluation

Full scale testing was carried out to verify the design and demonstrate the performance of this scrubber system for emergency operation. The Sentry 2000 was successfully tested in 1993, achieving chlorine discharge levels of less than 5 PPM for a 3,000 ACFM inlet gas flow. Tests were conducted with full one ton releases of chlorine at leakage rates in excess of 78 lbs/min throughout the entire release periods. For these tests, a caustic flow rate of 400 gallons per minute (GPM) was selected for chlorine neutralization based on Mr. Strigle's calculations using the 1993 UFC 15 PPM outlet stack limit.

Due to the importance of accurate test procedures, Entropy, Inc., the largest gas testing company in the industry, was contracted to conduct the performance evaluation of the Sentry 2000. Dr. John Richards of Entropy, a nationally recognized chemical engineer specializing in air pollution control equipment, was on-site and in charge of all data collection using EPA referenced test methods (EPA Method 26). These referenced test methods are the only means of chlorine emissions testing recognized by the EPA.

In addition to the EPA reference test methods, Drager test tubes and a continuous electronic monitor were utilized during testing of the Sentry 2000. The EPA test methods provided average stack discharge concentrations and these data were used for performance review. Drager test tubes provided an immediate check of the system performance. The continuous monitor provided an indication of the outlet concentration trends but was not used to provide quantitative chlorine levels. As detailed in the letter located in the appendix by Dr. John Richards of Air Control Techniques, P.C., currently there is not EPA approved performance specification test for chlorine electrochemical sensors nor is there any work in progress to develop one. In addition, the letter located in the appendix by Mr. Phillip Juneau of Emission Monitoring, Inc., states that continuous chlorine sensors can suffer from calibration drift, non-linearity and temperature effects that produce erroneous results. According to Mr. Juneau, EPA validation tests have not been conducted successfully for continuous electrochemical chlorine sensors and thus the EPA does not recognize them as acceptable chlorine measurement systems.

The continuous chlorine monitor, while not suitable for absolute chlorine concentration measurements, does provide a relative indication of changes in concentration. This indication of concentration change allows for the stimulation of peak chlorine levels relative to the average chlorine concentrations provided by the EPA Method 26 results. Addition of the difference between peak and average continuous monitor reading the EPA Method 26 provides an estimate of peak concentrations during the chlorine release period.

Test Results

Tests of the scrubber system were conducted on August 11 and 12, 1993. Two chlorine releases were conducted with release rates above the 78 lbs/min specification. The tests were observed by Airflow Sciences Corporation (ASC), an independent engineering firm specializing in numerical fluid flow simulation, and the results were documented in ASC report number R-93-020.

The first test of the scrubber system was a 2,000 lb chlorine release with an initial leakage rate of 120 lbs/min This leakage rate resulted in an inlet chlorine concentration of 193,400 PPM as opposed to the 130,000 PPM expected for a 78 lbs/min release, an increase of 150% over the chlorine flow rate in the UFC specification. The gas flow rate of the unit was measured at 3,094 ACFM with a caustic flow of approximately 400 GPM. The average chlorine flow rate for the test was 88.4 lbs/min and did not drop below 80 lbs/min throughout the release period.

Drager measurements taken at the beginning of the test peaked at a chlorine concentration of 3 PPM with an average of approximately 2.5 PPM. The EPA reference method test indicated an average chlorine concentration of 3.63 PPM in the outlet stack during the chlorine release period. The continuous monitor showed a peak value approximately 0.5 PPM higher than its average reading during the release period. Adding this 0.5 PPM to the EPA Method 26 average of 3.63 PPM gives an estimated peak of 4.1 PPM. This peak value is well below both the 1993 UFC limit of 15 PPM and the 1995 maximum of 5 PPM even though initial chlorine concentrations exceeded design specifications by 150%.

A second chlorine neutralization test was conducted at an initial release rate of 140 lbs/min This resulted in an initial chlorine concentration of 231,500 PPM, a 180% increase over the design specifications. The gas flow rate of the unit was measure at 3,024 ACFM with a caustic recirculation rate of approximately 400 GPM. The average chlorine flow rate for this test was 90.8 lbs/min and did not drop below 84 lbs/min during the release period.

Drager measurements during the release period indicated an average chlorine concentration of about 3.5 PPM with a peak of 5 PPM. The EPA reference method test indicated an average chlorine concentration of 5.08 PPM in the outlet stack during the release. The continuous monitor indicated a peak value 2 PPM higher than the release period average. This value when added to the EPA reference method average of 5.08 PPM gives an estimated peak concentration of 7.1 PPM. The peak value is well below the 1993 UFC maximum and is only slightly above the 1995 limit of 5 PPM, despite initial chlorine concentrations 180% higher than design specifications.

As mentioned previously, the caustic recirculation rate had been selected based on a goal outlet chlorine concentration of 15 PPM. As indicated by Mr. Strigle’s calculations, the only change to the system required for designing below the 5 PPM limit would be an increase in the caustic flow rate to 520 GPM instead of the 400 GPM used during testing. Based on the EPA test method results the Sentry 2000 system did not exceed the 1995 UFC limit of 5 PPM on the first chlorine test with initial inlet concentrations 150% above design specifications. In addition, the scrubber system would not have exceeded 5 PPM during the second test (where the initial flow rate of chlorine was 180% over design specifications) if the caustic recirculation rate had been increased to 520 GPM.

Summary

The Sentry 2000 was designed to neutralized chlorine and sulfur dioxide and has been thoroughly evaluated in a rigorous test program. Prior to this testing in 1993, no manufacturer had tested at an air flow rate of 3,000 ACFM and contaminant leakage rates exceeding 78 lbs/min for the entire release period. Test results correlated very well with Mr. Strigle’s predicted mass transfer efficiencies giving further proof of the validity of the calculations. This close agreement between predicted and actual results also provides additional confidence in the ability to use the equations for packed beds to accurately scale results of different flow rate. The test results and mass transfer efficiency calculations indicated that the Sentry 2000 will meet or exceed performance levels specified by the Uniform Fire Code.

It has been reported that another manufacturer has conducted testing of a chlorine scrubber system. The claims of this manufacturer, however, are not comparable to the Sentry 2000 test results for several reasons. The manufacturer’s test was conducted at 1,180 ACFM with only 550 lbs of chlorine released at a leakage rate that dropped below 78 lbs/min during the release period. In addition, this manufacturer’s test results were obtained using a continuous chlorine monitor as opposed to following EPA Test Method 26.

Gas flow rate has an important effect on outlet concentrations. For example, if the packed bed design of the Sentry 2000 had been tested at 1,500 ACFM instead of 3,000 ACFM the calculated chlorine concentration at the outlet would have dropped to 0.55 PPM for a 400 GPM caustic flow rate. With a 500 GPM caustic recirculation rate at 1,500 ACFM, the outlet chlorine concentration would have been 0.26 PPM. These calculations indicate that testing at a lower airflow rate can lead to significantly lower outlet chlorine concentrations. While results for the Sentry 2000 can be scaled up or down using the mass transfer calculations for packed beds, results from other manufacturer's test cannot be scaled because their system contains a spray chamber.

Allowing the chlorine leakage rate to fall below 78 lbs/min in addition to a lower release weight (550 lbs versus 2,000 lbs) put considerably less strain on a scrubber system. The manufacturer who conducted this test initially had a release rate above 78 lbs/min but allowed it to drop below this rate after a few minutes. This reduced leakage rate combined with the lower release weight will obviously result in lower concentrations at the outlet, but compliance with the UFC standards cannot be inferred from these results.

Finally, the use of a continuous chlorine monitor can provide a relative reading with respect to high and low concentrations, but cannot measure quantitative chlorine levels accurately. The only approved means of chlorine measurements is through the implementation of EPA Method 26 as was utilized in the testing of the Sentry 2000.

Tests have shown that the patented Sentry 2000 design provides discharge chlorine concentrations of less than 5 PPM for a gas flow rate of 3,000 ACFM, even when chlorine leakage rates exceed design specifications by 150%. Increasing the caustic recycle rate of the scrubber, based on calculations for inlet and outlet concentrations, will allow guaranteed system performance at even higher chlorine inlet levels. Therefore, the Sentry 2000 can meet current chlorine outlet concentrations required in any specification.

Please refer to the enclosed technical paper with accompanying calculation for details on the Sentry 2000 performance.

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