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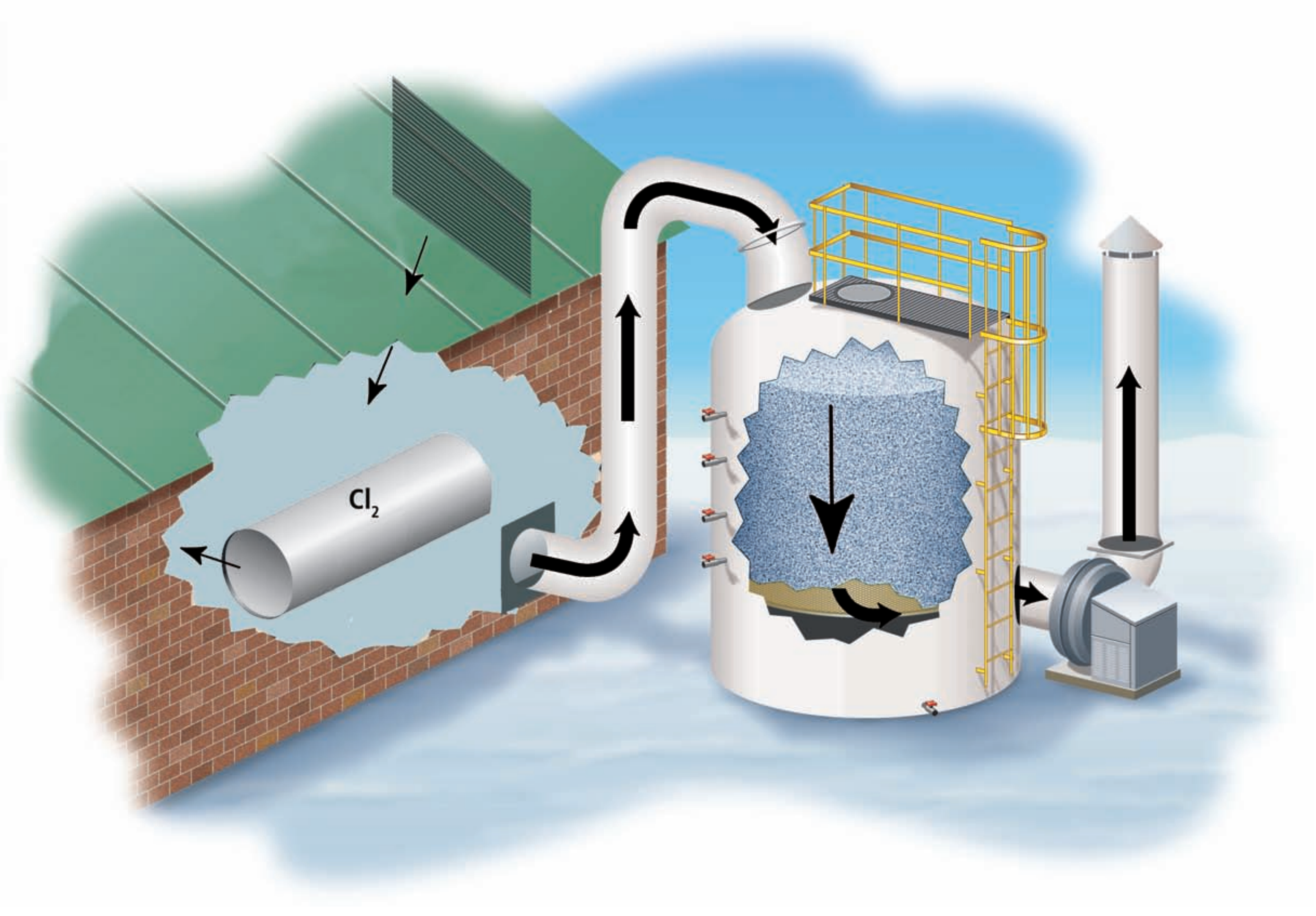
DRY EMERGENCY GAS SCRUBBERS AND COMPLIANCE WITH THE UNIFORM FIRE CODE



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DRY EMERGENCY GAS SCRUBBERS AND COMPLIANCE WITH THE UNIFORM FIRE CODE

For the past 15 years, dry chemical scrubbers have been considered low maintenance alternatives to wet scrubbers in controlling (for instance) a worst-case scenario chlorine (Cl2) leak from a 1-ton cylinder. As the U.S. Environmental Protection Agency (EPA) mandated Risk Management Plans (RMPs) in the late 1990s (Clean Air Act §112(r), June 1999), the use of dry Emergency Gas Scrubbers (EGS) has increased and remains steady.

The basic concept of a dry EGS is not complicated. At its essence, the dry scrubber is a packed-bed, chemical reactor. The basic components: a fiberglass vessel, dry media, and a blower give the appearance that any combination of these components would suffice. However due to the critical nature of the device and the regulations that govern the design of such scrubbers, a thorough investigation of the components and the system's operating parameters is demanded. Proper performance testing must focus on three criteria of the Uniform Fire Code and simulate the conditions in the field during a leak event.

DESIGN CRITERIA ESTABLISHED BY THE UNIFORM FIRE CODE

Uniform Fire Code Article 63 (NFPA 1, 2006) establishes the design criteria for all EGSs, both wet and dry. To ensure proper design, all validation testing must address three basic parameters simultaneously. These are:

1) **Design (Capacity):** Treatment systems shall be capable of processing the entire contents of the largest cylinder of gas stored.
2) **Performance (Efficiency):** Treatment systems shall be designed to reduce the maximum allowable discharge concentration of the gas to one-half the Immediately Dangerous to Life and Health (IDLH) condition at the point of discharge.
3) **Sizing (Airflow):** Treatment systems shall be sized to process the maximum worst-case release of gas based on the maximum flow rate of release from the largest cylinder utilized.

The industry-accepted values for these parameters have been established for some time and are as follows:

1) **Design (Capacity):** Generally, the largest container of gas stored is 1-ton of dry chlorine gas. This is considered a portable tank and is over-charged to 2,350 pounds of liquefied chlorine gas.
2) **Performance (Efficiency):** The IDLH level for chlorine is 10 parts per million (ppm), therefore the concentration at the point of discharge shall be no greater than 5 ppm.
3) **Sizing (Airflow):** The definition of a "portable tank" from 2006 UFC should be applied to a 1-ton chlorine cylinder. Typically, a portable tank with liquefied gas has a release period of 240 minutes as stated in Table 7.9.3.5 (NFPA 55-24, 2005). Using this data yields a release rate equal to 9.8 pounds per minute (2,350 lb / 240 minutes = 9.8 lbs/min). However, NFPA 55 Table 7.9.3.5 states that, "Sizing is based on peak flow from maximum valve orifice." Fusible plugs are commonly found on 1-ton chlorine cylinders. Therefore, the worst-case release rate should be derived, not calculated from Table 7.9.3.5.

The inner lead core of the fusible plug is designed to melt at 160oF and provide pressure relief. The vapor pressure of the chlorine will increase as its temperature approaches 160oF. At this point the fusible plug melts and liquefied chlorine is expelled from the tank at a rate of 42.5 gallons per minute. The density of liquid chlorine is 10.3 pounds per gallon. The result is 437 pounds of chlorine are released per minute. The released chlorine will vaporize while at ambient pressure and produce an increase in air volume as the chlorine expands from liquid to gas phase, thus generating a maximum flow rate of approximately 2,400 ft3/min (cfm) of airflow.

EFFECTS OF THE IDEAL GAS LAW

Reactions with chlorine are typically exothermic. During a release (leak) event, a large amount of chlorine is reacting with a dry, packed media bed in the EGS which produces a significant temperature rise within the media bed. Due to the high temperatures, the effects on media performance and on the fiberglass resin used in the construction of the EGS vessel have been examined and deemed to be within acceptable limits. Additionally, the effects on airflow and pressure drop are significant and must be considered to ensure proper blower design.

The Ideal Gas Law ($PV = nRT$) states that under constant or ambient pressure a gas being heated must expand, affecting its volume. Using the ideal gas law formula, the volume of a mole of ambient air is increased from 0.86 ft3 to 1.06 ft3, approximately 20%, when its temperature is increased by 100oF. Therefore, while the contaminated air is passing through the scrubber and being treated, it is being heated by the exothermic reaction and expanding. The temperature increase has a profound effect on the airflow being drawn into the scrubber. Additionally, large pressure drops are associated with packed media beds. For instance, a media bed consisting of 1/8" diameter pellets already has a high differential pressure, which is further amplified by the changing air volume in the reactor.

THE IMPORTANCE OF AIRFLOW

The purpose of the third criterion (sizing) of the Uniform Fire Code is to ensure the storage room is kept under negative pressure at all times by extracting air from the storage room at a greater rate than the gas flow being generated by the releasing gas. The maximum release rate from a full 1-ton cylinder is approximately 437 lb/min., which generates 2,400

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*P = the absolute pressure of the gas, V = the volume of the gas, n = the number of moles of gas, R = the universal gas constant, and T = the absolute temperature full 1-ton cylinder is approximately 437 lb/min., which generates 2,400 cfm. This calculation regarding the worst case scenario release has established an industry accepted criteria for wet scrubber airflow of 3,000 cfm.

Airflow is a critical parameter in the design of a dry scrubber system and needs to be an integral part of validation testing. Scrubbers designed with insufficient airflow will not keep the storage room under negative pressure and the released chlorine will leak out of any unsealed opening. To ensure a scrubber's blower is sized properly two parameters should be considered: 1) the pressure drop taken across a full media bed during the test while the media bed temperature is rising and the treated air is expanding and 2) sufficient airflow to ensure adequate dissipation of the heat created by the exothermic reaction before the expansion of air in the scrubber is greater than inflow of fresh air to the storage room.

CREATING A TEST METHOD THAT SIMULATES FIELD CONDITIONS

A proper “full bed-depth” test design will have many characteristics equivalent to those in a field application. Media bed depth, media size, time to complete release of gas, air velocity through the scrubber, and the method for moving air through the system are the same as field conditions. Variables that should be recorded throughout testing are differential pressure across the media bed, the fresh air intake, media bed temperature, and the exhaust efficiency.

Following are three examples with diagrams:

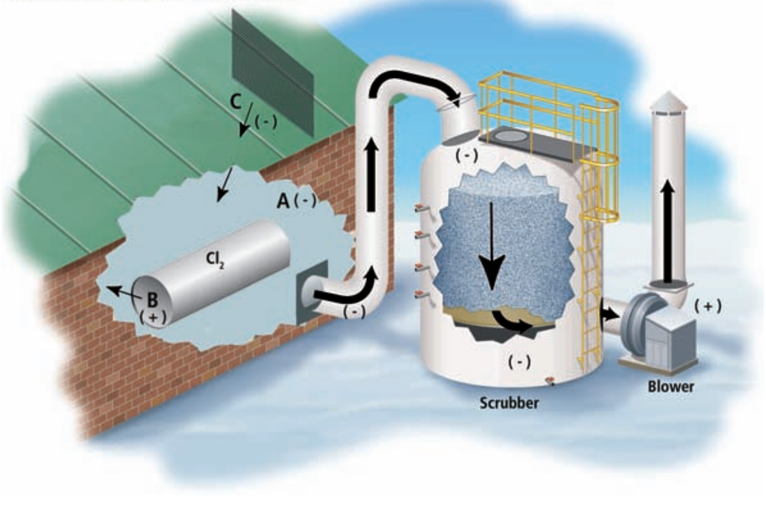
1) Typical EGS installation,
2) proper full bed-depth test assembly with blower, and
3) an example of an improper test method.

All three have the same basic elements:

(A) an area where chlorine is being introduced to (e.g., the chlorine storage room),
(B) the chlorine-laden air stream,
(C) fresh air being introduced into the system, and (D) the scrubber.

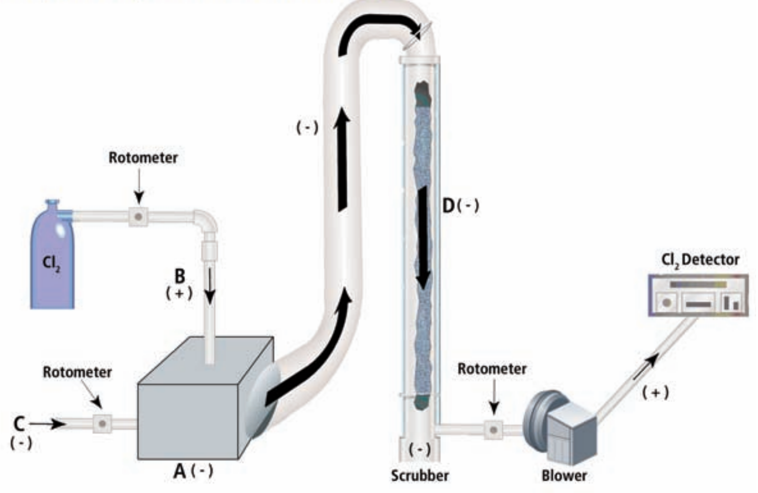
The aforementioned elements are present in all diagrams; however, the methods used to move the air and contaminants through the systems are quite different.

Actual Field Conditions



In the first two examples, the blower is placed downstream of the storage room (A) and the scrubber (D). Consequently, all components are under negative pressure. Fresh air (C) is being drawn into the room (A). Placing a blower downstream of the media bed and creating a negative pressure inside the test reactor is the only way to effectively compare the airflow being drawn into the storage room versus the airflow being discharged by the blower.

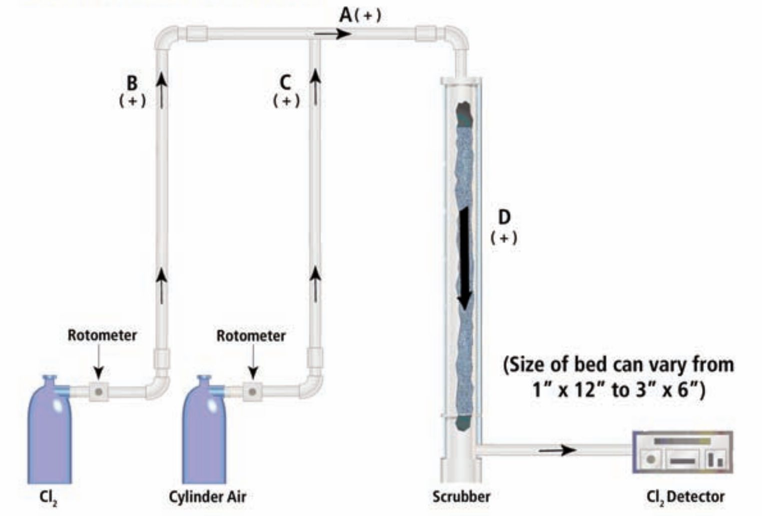
Proper Deep Bed Test with Blower



In the third (improper test method) example, airflow is being generated by two pressurized cylinders: (B) chlorine cylinder simulating the releasing gas and (C) pressurized cylinder air simulating the fresh air intake.

The result is that the storage room (A) and the scrubber (D) are under positive pressure and the fresh air (C) is being forced into the room (A). The effects of this test method will be present regardless of the test reactor size.

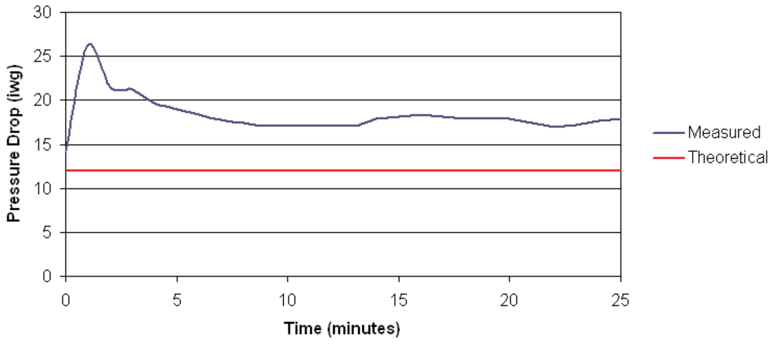
Improper Testing Method



PRESSURE DROP ACROSS MEDIA BED - THEORETICAL VS. MEASURED

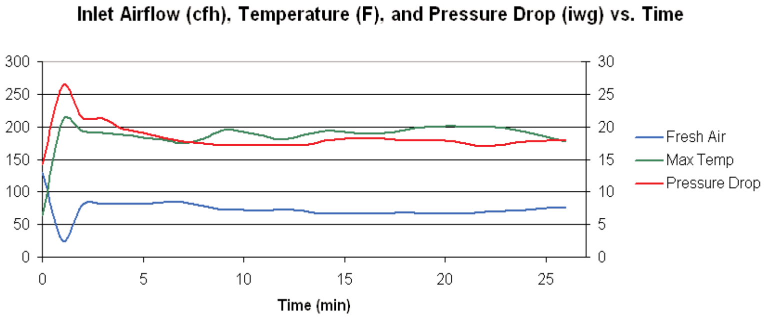
Pressure drop across the media bed is a key element in designing a proper blower or "chlorine mover." It is common for dry-scrubber EGS specifications to specify pellet size and pressure drop characteristics across a packed media bed. The pressure drop values through a 12-inch deep bed are 0.45 and 1.85 inches water gauge (iwg), respectively, for face velocities of 50 and 100 feet per minute (fpm). These pressure drops are used to confirm uniformity in pellet diameter (size), and not used to calculate the overall pressure drop across a full-scale media bed.

A typical dry scrubber design has a 6.5 ft media bed depth and an air velocity of 90 fpm through the media. Using the aforementioned pressure drop data, the theoretical pressure drop through 6.5 feet of media would be 12.0 iwg. However, measuring the pressure drop during actual testing yielded far different data. The average pressure drop across the full depth media bed was measured at >18.0 iwg. The maximum pressure drop was recorded at 26.25 iwg at the end of Period I.



INCREASED AIRFLOW REQUIRED FOR DRY EMERGENCY GAS SCRUBBERS

Evident in Purafil's testing is a correlation between media bed temperature, fresh air flow into the storage room, and pressure drop. As the media bed temperature rises, the air passing through the scrubber is heated and expands and a large increase in pressure drop across the media bed is noticed. At the same time, a dramatic decrease of fresh air coming into the system is evident. The volume of air drawn by the blower is fixed and as the discharge air from the scrubber increases, the air being drawn into scrubber must decrease.



Through experimental trials, Purafil has noticed a consistent decrease of approximately 40% in the fresh-air flow into the system. Purafil's FOC1 (fiberglass) EGS design calls for a 5,000 cfm flow rate, but with the expected 40% reduction, the air entering the scrubber will be approximated at closer to 3,000 cfm. The primary factors contributing to the decrease of fresh air coming into the scrubber are expansion of air traveling through the scrubber and the concurrent increase in pressure drop. Therefore, designing the scrubber with any airflow lower than 5,000 cfm could result in non-conformance to the Uniform Fire Code.

CONCLUSIONS FOR DESIGNING DRY EMERGENCY GAS SCRUBBERS

Without due diligence it would seem that the design of a dry emergency gas scrubber would be based upon using 3,000 cfm of total system air/gas flow, 4 iwg of pressure drop, and an 18-inch blower wheel with 20 hp motor. However, there are many variables to consider in designing a dry emergency gas scrubber including changes in temperature, differential pressure, specific gravity of the air moving through the scrubber, and air volume as it is being heated. Placing a blower downstream of the media bed and creating a negative pressure inside the test reactor is the only reliable way the true differential pressure can be measured during a test. The increase from estimated to measured pressure drop and the decrease in fresh air into the scrubber resulted in Purafil designing our blower with a 24-inch blower wheel with 40 hp motor in order to comply with the all criteria of the Uniform Fire Code.