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FAST DEGAS CARBON DIOXIDE EVAPORATOR

Kyle T. Howard
Lectrodryer, LLC
Mechanical Project Engineer
P.O. Box 2500
Richmond, Kentucky 40475
USA
(859) 624-2091
khoward@lectrodryer.com

Blanca A. Ramirez
Lectrodryer, LLC
Marketing
P.O. Box 2500
Richmond, Kentucky 40475
USA
(859) 624-2091
bramirez@lectrodryer.com

ABSTRACT

Two reasons exist for the rapid degassing of Hydrogen cooled generators. The first is an upset condition which could cause an unsafe condition or generator failure if the Hydrogen is not removed. The second is the time savings that can be recognized by reducing the time required to fully purge the generator and refill during an unplanned or planned outage.

A generator bearing fire is an example of the first condition where the ability to remove the Hydrogen and purge with Carbon Dioxide rapidly would result in a significant reduction in the risk of a catastrophic situation.

Current purge operations typically require many hours for the gas change from Hydrogen to Carbon Dioxide during maintenance outages. This new system reduces the time required for this step to less than 20 minutes. Times for refilling can also be reduced by similar amounts. This time can be extremely valuable during peak generation periods.

The Carbon Dioxide vaporizer systems that have been installed previously have been limited by the rate they can vaporize the Carbon Dioxide and feed the gas to the generator without freezing. The system described uses flow controls, a large heater and backup Carbon Dioxide storage to perform the necessary operations quickly. The system can be operated manually or fully automatic. Automatic operation is preferred for the safety concerns since any fire or other upset would likely occur in the area of the equipment and time would be of the essence.

The system described has been installed and tested in a number of operating plants and is performing satisfactorily.

OUTLINE

A. Description of purging process
B. Need for rapid degassing process
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C. Fast Degas Carbon Dioxide Evaporator Testing and Design
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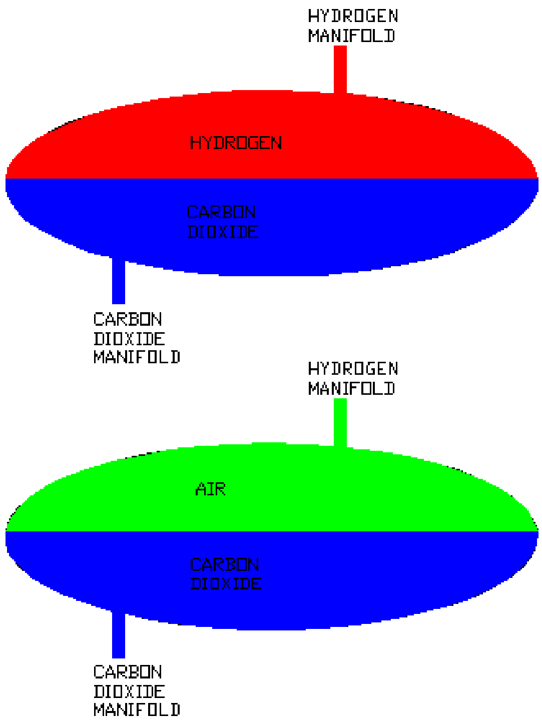
INTRODUCTION

Large electric generators use hydrogen as a cooling media within, due to its extreme capability to retain and remove heat. Hydrogen's high thermal conductivity, as well as its low density makes it advantageous to use as a heat exchanging media over air. [2] The caution with hydrogen is its flammable limit in air ranging from 4 percent to 75 percent of hydrogen in air by volume. [3] Maintenance operations or entry to the generator however require that the generator be purged first with an inert gas and then air. The inert gas step is necessary to prevent explosive mixtures of Hydrogen and air.

To accomplish the filling and purging process the generator is equipped with two gas manifolds. The top manifold is the Hydrogen manifold and the bottom manifold is the Carbon Dioxide manifold. During the first step of the purging process the heavier Carbon Dioxide will be supplied to the bottom of the generator through the Carbon Dioxide manifold and it "pushes" the lighter Hydrogen out through the Hydrogen manifold, which is in the top of the generator. [6] The process is continued until the Hydrogen is fully evacuated. The Carbon Dioxide is the forced out by bringing air into the generator through the upper manifold forcing the Carbon Dioxide out through the lower manifold to vent.



For the purging process, carbon dioxide is stored at the power plant in bottles at high pressure. Unfortunately the expansion of Carbon Dioxide is endothermic, and a portion of the liquid will flash into vapor, resulting in the rapid cooling (to as low as -70 F) of the piping and valves where the expansion occurs. [5] This cooling causes icing (dry ice) of the piping and typically the gas flow is reduced or even completely blocked by the ice. This limits the flow of Carbon Dioxide extending the Carbon Dioxide purge step to hours, with 2 to 6 hour purge times typical. This extended period of purge can be very costly in upset situations. The ability to bring the Hydrogen level down quickly during an upset condition like a bearing fire or during peak generating season provides a large benefit from both a safety and economic perspective.

This paper will discuss a very cost effective design that will provide a large volume of Carbon Dioxide in a very short amount of time.

A. DESCRIPTION OF THE PURGING PROCESS

Typical purging processes either have nothing at all or use water/ambient air to warm the high pressure Carbon Dioxide during expansion to the low pressure gaseous state.

Before the addition of the Fast Degas System, Southern Illinois Power Cooperative would open the Carbon Dioxide supply line for a short amount of time until the line froze. Then, they would run water on the pipe until the line “thawed” enough for Carbon Dioxide to be supplied again. They would repeat this process until enough Carbon Dioxide was supplied to the generator to displace the hydrogen or air. This was not time efficient, required operator involvement, and posed a safety risk during wintertime when the water used for thawing would freeze causing extremely slippery conditions.

Another design is the dual coil supply system. This design has two supply lines with two coils, allowing continuous operation. As one line is being “thawed”, the other is supplying Carbon Dioxide. The coils are typically finned heat exchangers, with ambient air blowing across each coil. During the winter cold ambient temperatures do not provide a very large temperature gradient between the pipe and ambient air causing delays is the purging process.

Both designs require operator involvement and have operational limitations. These limitations were the motivation for the development of the Fast Degas Carbon Dioxide Evaporator.

B. NEED FOR RAPID DEGASSING PROCESS

1. Safety/Risk Mitigation

There are two reasons for the rapid degassing of a hydrogen cooled generator. The first is the safety/risk mitigation factor and the second is the time savings that can be recognized by reducing the amount of time it takes to purge the generator in a planned or unplanned outage.

One of the most significant hazards is a bearing fire. “Inadequate fire-protection systems and lack of proper emergency protocols can lead to serious damage. In a 15 year period, FM Global found that fire protection deficiencies for lube-oil systems were a major factor in 17 large turbine building fires. The property damage alone totaled more than 400 million U.S. dollars. Lost generating capacity was in excess of 20 million MWh.” [1] In and around the power sector, there has been a growing concern for proper fire prevention and implementation of safety procedures.

The Fast Degas System becomes invaluable when you begin to analyze the ramifications of not being able to purge the generator automatically and in a timely fashion. Loss of containment during a fire while still pressurized with Hydrogen becomes a catastrophic event. The displacement of the hydrogen with Carbon Dioxide in the matter of minutes could eliminate a fire and/or explosion and limit injury to personnel, damage to the generator and the facility.

2. Time/Cost Savings

The second major reason for the Fast Degas System is the cost savings that can be recognized by reducing the purge time of the generator in a planned or unplanned outage. An unplanned outage during peak hours is very costly, so it is vital to bring the generator back online as soon as possible.

With this new design, outages can be shortened by many hours and without operator involvement. This frees the operator to focus their time on the required repairs and to return the generator to service.

C. FAST DEGAS CARBON DIOXIDE EVAPORATOR

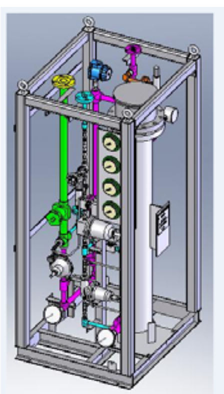
TESTING AND DESIGN

1. Description

The Carbon Dioxide Evaporator utilizes state of the art controls with a 50 KW heater to provide an exit temperature of 75 ˚F at a high flow rate.

2. Test Results

Performance of this product has been proven through many in house tests and successful installations around the world. The rest of this section will discuss the results of the latest test.



10 Carbon Dioxide bottles were hooked up to a common manifold that led to the inlet of the Carbon Dioxide evaporator skid, while the outlet was piped to atmosphere. Each bottle was equipped with a siphon tube, in order to provide liquid Carbon Dioxide (which is required) from the bottom of the bottle. Each bottle was labeled and weighed before and after to accurately measure the amount of Carbon Dioxide used.

Bottle weight before	= 1691 LBS.
Bottle weight after	= 1235 LBS.
Carbon Dioxide Used	= 456 LBS.

The manifold pressure began to drop fairly quickly around 15 minutes and the total test time was 18 minutes. As designed, the Fast Degas System held an outlet temperature of 75 ˚F ± 10˚ for the entire time period. This system does not require any warm up time assuring immediate full flow during an upset condition or during the need to perform an urgent repair.

With the amount of Carbon Dioxide versus the time, the flow rate was calculated:

$$\frac{456 lbs}{18\min} * \frac{60\min}{1 hr} = 1520\frac{lbs}{Hr} \quad \text{(Eq.1)}$$

$$1520 lbs * \left(.076\frac{lbs}{ft^3} * \frac{44}{29}\right)^{-1} \div 60\min = 220 SCFM \quad \text{(Eq.2)}$$

As calculated above, the Fast Degas System provided **220 SCFM (370 NCMH)** to vent.

The flow was also measured by a velometer reading (Alnor Instrument Company) at the vent header exit during test. The results agreed with the calculated flow rate.

At 220 SCFM, **1.5** volumes of Carbon Dioxide would be provided to a typical 2900 ft^3 generator in under 20 minutes!

In order for the system to produce maximum flows it is recommended that the power plant have 2” piping in the Carbon Dioxide manifold and vent header. [4] This will eliminate any significant pressure drop throughout the system that would limit volumetric flow.

The system is designed for liquid Carbon Dioxide feed. Bottles must have a siphon tube that reaches the bottom. These bottles are identical to normal Carbon Dioxide bottles except for the internal tube and they are commonly supplied by any Carbon Dioxide supplier. In the event that there is a need for the generator to be degassed rapidly it is recommended to have bulk storage available, or a minimum of 20 bottles.

3. Features

The Fast Degas System has been designed for fully automatic, semi-automatic, or manual operation. A typical installation location would be at the Carbon Dioxide bottle rack of each generator unit. If bulk Carbon Dioxide storage or additional cylinders are available, this system can be used for generators.

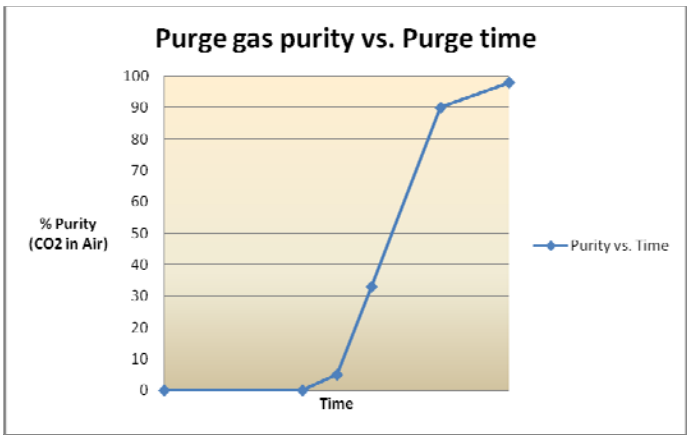
In the event that the main power supply to the skid were to fail and an alternate source of power (i.e. diesel) is supplied, the Fast Degas System can be supplied with a redundant power supply by using an automatic or manual transfer switch. The automatic power supply comes with an integral microprocessor and LED lights indicating what power supply is being used.

D. FIELD EXPERIENCE AND RESULTS

The current system has been installed and is operational in South Africa and in the US at Southern Illinois Power Cooperative. This section will detail the performance at SIPC.

At the end of the 2008 fall outage the plant was ready to bring the generator back on line. The new Fast Degas Carbon Dioxide Evaporator was used to purge the air from the generator prior to the hydrogen supply. During the purging process SIPC maintains a positive pressure of 12 psig inside the generator for the float traps. To maintain that pressure we found that it took between 16 and 17 bottles to purge the generator completely of air. This was calculated to be 3.4 generator volumes. During the purging process, the purity was calculated continuously by a Lectrodryer purity instrument, which uses the gas density to calculate the gas mixture. SIPC also used a General Electric thermal conductivity gas analyzer (CAT #421D183G) to double check the results. The results were consistent.

The chart below shows the purity response time during the purging process and indicates very marginal mixing of the two gases. There was 100% hydrogen until over half the process was complete. At that point the purity level rose quickly to 100% Carbon Dioxide.



E. SUMMARY OF BENEFITS

- Instantly ready for operation
- Redundant power supply option
- Provides 220 SCFM (370NCMH)
- Fully automatic, semi-automatic, or manual
- Purge Hydrogen from a generator with Carbon Dioxide in under 20 minutes
- Substantial risk mitigation
- Time and money savings
- Easy installation and operation
- No operator involvement

ACKNOWLEDGMENTS

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[4] Vogt F-12 Catalog, Page 183

[5] Copland Refrigeration Manual, Part 1 Fundamentals of Refrigeration. Copyright 1996. Page 3-6

[6] Thermodynamics, Fourth Edition, Pages 18-19, 828