

RX[®] Endothermic Gas Atmosphere Generator Advanced Diagnostics

Alex D. Kominek

Surface Combustion, Inc. Maumee, OH, USA
akominek@surfacecombustion.com, 419-891-1487

Abstract

In the continuing effort to improve the quality and consistency of gas produced from an RX[®] endothermic gas atmosphere generator, several enhancements have been developed and implemented to diagnose abnormal operating conditions.

Typically the variables monitored, controlled, and alarmed on gas generators were limited to the temperature of the heating chamber and the dew point of the gas being generated. As instrumentation has evolved, additional monitoring has been implemented, reducing the instances of sending “bad” endothermic gas into a process critical furnace. The new diagnostic tools allow predictive maintenance to be applied to endothermic gas generators.

Introduction

A Brief and Incomplete History of the Development of Endothermic Gas Generator Controls

When the first endothermic gas generators were built, a mixture of air and natural gas was passed through a heated retort containing a nickel impregnated catalyst bed to produce an approximate 20% CO, 40% N₂, and 40% H₂ exit gas.

Over the years, different methods of measuring and controlling the air-fuel mixture introduced into the heated retort were developed and used. Ratio regulators, mixture pumps, mass flow transmitters, and injector systems are among them.

At the same time, methods were advancing to measure the endothermic gas being generated. From the original dew cup, to three gas analyzers and continuous dew point analyzers, these methods have steadily improved.

Automatic control systems eventually linked the measurement of the produced gas with the mixing of the air-fuel ratio of the pre-mix to keep the endothermic gas

being sent to furnaces in check with closed loop feedback.

Another development involved separating multiple retort generators from a single heating chamber. The modular style generators incorporated simple, low maintenance combustion systems and features including on-line burnouts and more easily removable retorts.

Despite this improved control of endothermic gas, problems still arose with the generator operation. Over time, catalyst would wear out or fuse together. Water coolers would begin to leak or mineral deposits would develop, making the cooling less efficient. Air cooler filters would plug up, reducing the available cooling capacity.

Preventative maintenance schedules have been developed to reduce some of these problems. Regular catalyst burn-outs, periodic catalyst changes, regular water system maintenance cleanings or weekly air filter changes all reduce the likelihood of major upsets in endothermic gas quality. Advancing the preventative maintenance schedule to the predictive maintenance realm was the next step.

The four enhancement diagnostic tools described in this article have been implemented in multi-tube generators to take this step.

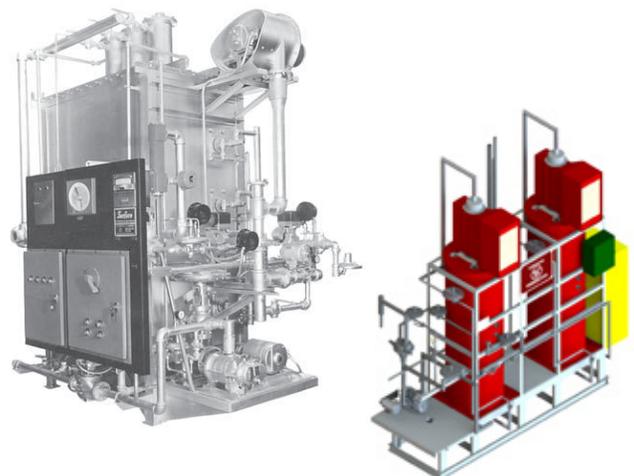


Figure 1: RX[®] Endothermic Gas Generator from 1939.

Implementation

Tool #1 - Control of Dew Point

A number of endothermic generators utilize one mixing device, one dew point measuring system, and one control loop to control the gas generated in two or more individual retorts. While the condition inside each of the retorts may vary, the single systems are not capable of distinguishing problems in the different retorts. Individual measuring and control systems would be a great solution for better operation, but this can also be costly.

By simply measuring the dew point coming out of each retort, the condition of the catalyst can be monitored and if measurements begin to drift, attention can be given to the errant tube.

Implementation of this feature may be performed with a second dew point measuring device or a sequencing program alternately measuring the blended gas and the individual retort dew point. Comparing the blended readings with the individual readings will allow the suspect retort to be pinpointed as the dewpoint value drifts from that of the main header gas.

By using a second dew point reading device, an added benefit is gained as the second device can be used as a control device if one loses power or fails.



Figure 2: An example of a RX-2T model modular generator capable of being equipped with advanced diagnostics.

Tool #2 - Control of Equal Flow

The second tool implemented compares the total flow between each retort tube by measuring the air-fuel pre-mix entering each retort.

A multi-tube generator, especially a generator with a built-in spare tube, may have different catalyst conditions in each retort. Rotating the “running” tubes with the “spare” tube should lengthen the catalyst and retort life, but keeping track of the running hours does not prevent or predict catalyst failure.

A single tube may have worn catalyst, beginning to fuse and block the flow of gas through the retort. The dew point being monitored from a main connected header can be producing good endothermic gas, but the worn, soon to be plugged retort can soon lead to bad gas or a failed retort.

By measuring the flows through each retort and comparing these flows to each of the other tubes on-line, a simple calculation and comparison can be made to assure relatively even flow is present in each retort. If the flow differs more than a configurable differential, it can signal that attention is required.

Tool #3 - On-Line Tube Monitoring

Typical generators may have a maximum flow rating between 2000-4500 CFH per retort. Larger multi-tube generators can produce up to 12,000 CFH or more of gas if multiple tubes are operating at once. As furnaces are gassed-up, the endothermic gas requirements may move beyond the current number of tubes on-line. Conversely, if furnaces are being shut down, the amount of gas required may dip below the recommended turndown design of the generator.

Most manufacturers of endothermic gas generators have designed mixing systems with 5:1 or 6:1 turndown capacity built in. In other words, the proper air fuel ratio can be maintained if the total endothermic gas flow is held within this range. Others systems have advertised infinite turndown, but the limits would seemingly not be endless.

By measuring the total amount of gas being generated and comparing this to the number of tubes producing gas, a quick check can be made to determine if a tube should be added or perhaps shut off.

For instance, if two tubes, each rated for 3000 CFH of endothermic gas are on-line, and the total flow being produced was measured at 6500 CFH, the system would alarm to add another tube on-line. The tubes may be producing good gas with good dew point and there may never be a process alarm or problem. However, overextending the endothermic gas output may lead to catalyst breakdown or overheating of the heat exchanger attached to the outlet.

On the other hand, the same two tubes may be producing 1500 CFH total. Although this is well within the turndown control allowed by the manufacturer's recommendations, the gas could easily be made by operating one tube on-line.

This feature can easily be implemented with a mass flow measuring device or a flowmeter with feedback signal and a PLC with simple logic.

For heat treat departments running continuous styles of furnace equipment requiring a set, uninterrupted flow of endothermic gas, the third tool would not be beneficial. However, for heat treat operations with batch furnace equipment coming on-line or shutting off frequently, knowing how much gas is required vs. being generated is another variable worth monitoring.

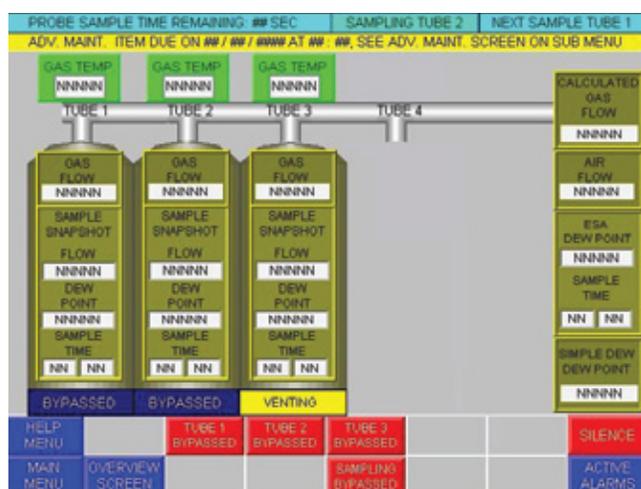


Figure 3: A digital display from an HMI with exit gas temperatures, individual and combined dew point readings, and individual and combined flow rates

Tool #4 - Keeping an Eye on the Outlet Temperature

The first three diagnostic tools would normally be applied to multi-tube generators only, while the final tool can be applied to any generator. Monitoring the heat exchanger outlet temperature is an easy tool to add and can save money and maintenance headaches over the lifetime of a generator.

Different sources recommend different targets required to quickly cool endothermic gas once it leaves the retort. A range of 150-315°C (300-600°F) is typically recommended by most sources.[1][2]

All sources agree the gas should be quickly cooled to prevent the carbon monoxide from breaking down into carbon dioxide and carbon. The leftover carbon “soot” can be developed between 500°C (900°F) and 700°C (1300°F), making it imperative for the cooling of the gas to occur quickly below that temperature range.[1] Minimizing the soot development will minimize the need clean out and vacuum endothermic gas piping throughout the building.

Cleaning air filters on a regular schedule is good preventative maintenance. Knowing when the dirty filters start affecting the cooling is an even better tool. Inserting thermocouples downstream of the outlet gas coolers allows a continuous reading and monitoring of the gas temperature. Deviation alarms can be set-up to notify operators to check the equipment for dirty filters, stopped fans, or other conditions causing elevated exit temperatures.

Trending the temperatures takes the tool one step further, providing a means of predicting the timetable for a hot exit gas.

In a study comparing the outlet temperature of a gas cooler with varying filter conditions, a temperature difference greater than 150°F was found between a clean air filter and a blocked air filter at flow rates nearing 2500 CFH. See figure 4 below.

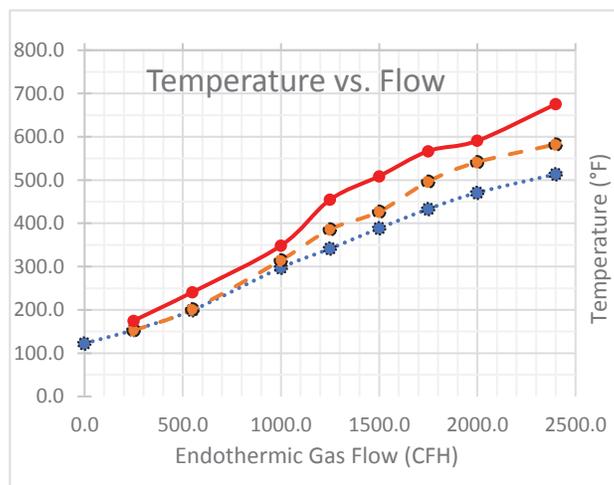


Figure 4: The results of an exit gas temperature vs. endothermic gas flow study with a clean (dotted line), partially blocked (dashed line), and blocked (solid line) inlet filter.

Conclusions

Although endothermic gas generators are supplying furnaces which ultimately control the final process guidelines of heat treating parts, a steady flow of good endothermic gas provides a solid base to start.

Controlling the carbon level of a generator with temperature control of the retort and dew point measurement of downstream gas has been steadily improving for decades and provide for a ground base for sending good gas to a furnace.

Maintaining equipment and predicting modes of failure is the next step. Implementing additional monitoring devices such as dew point measurements on the outlet of reaction tubes, flow monitors on the inlet of retorts, and temperature monitoring of cooled gas are relatively new methods of predicting modes of failure and assuring errant conditions are minimized.

Each of the tools described can be trended and tracked through a PLC and remotely viewed with the proper software implementation, providing a management level view of the conditions of the endothermic gas generator.

The next step in the evolution of the endothermic gas generator could include self-correcting, automatic features – automatic burn-out functions detecting when a burnout is required, placing tubes on-line or taking them off-line based on the flow requirements downstream, or self-cleaning air filters. Each item provides longer running equipment, with less operator time required, and more consistent carrier gas produced for heat treating processes.

Acknowledgments

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- [2] Poor, R. *et al.*, "Furnace Atmospheres for Heat Treating" ASM Handbook Vol. 4B pp. 108-134.

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Surface Combustion, Inc.
800-537-8980



700 Indian Wood Circle
Maumee, OH 43537



Voice: 419-891-7150



Fax: 419-891-7151



www.surfacecombustion.com



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