

# Novel, Sustainable, and Safe Alternative Fire Protection Solution for Protecting Gas Turbines

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## Introduction

Fire suppression systems protecting gas turbines play a critical role in ensuring business continuity for power generation facilities. Although fires in gas turbines are uncommon, they do occur, creating losses to capital equipment and business interruption, which can lead to significant financial loss for the utility. Fire protection systems in power plants have historically been CO<sub>2</sub> and Halon 1301 as suppression agents for gas turbine protection. Since the Montreal Protocol was adopted in 1987 and halon production was eliminated, CO<sub>2</sub> became widely adopted for gaseous fire suppression in turbines. Although an effective fire suppression agent, CO<sub>2</sub> is a lethal at design concentrations, having caused multiple deaths and injuries annually.<sup>1</sup>

To increase life safety without compromising fire suppression performance, a CO<sub>2</sub> extended discharge replacement system was developed using 3M™ Novec™ 1230 Fire Protection Fluid at the request of a western USA utility. A modular extended discharge system design was developed that could be readily modified for varying room leakage rates. A full-scale discharge test of the system on a natural gas turbine was used to verify the performance-based system design using agent concentration analysis.

## Instrumentation

A National Instruments cDAQ 9174 CompactDAQ was used to collect pressure, temperature and concentration measurements. An NI-9213 module was used to collect temperature readings from Type K thermocouples. An NI-9219 module was used to collect pressure and concentration measurements. Two types of pressure transducers were used: a 0-500 psig Omega PX102 0-100 mV flush diaphragm pressure transducer for monitoring the pre-orifice plate pressure and a 0-100 psia Omega PX429-100AV pressure transducer for monitoring the nozzle pressure. Only the nozzle pressure was able to be recorded during the full-scale test.

Agent concentration was determined using a modified Tripoint Perco Model 113 Dual Gas Analyzer. The instrument was wired to output a voltage signal that was recorded by the data acquisition system at a rate of 0.20 Hz. The meter was calibrated before use using an Airgas calibration standard with a concentration of 5.99 mol%.

Room hold time was determined using a Retrotec blower system utilizing a model 1000 fan and DM32 pressure gauge. Testing was conducted in compliance with NFPA 2001 (2015 Edition) Annex C: Enclosure Integrity Procedure.

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<sup>1</sup> Wickham, Robert, 8 August 2003, REVIEW OF THE USE OF CARBON DIOXIDE TOTAL FLOODING FIRE EXTINGUISHING SYSTEMS, Table 4, p 11. Peer Reviewed.

## Development Testing

An 892.5 ft<sup>3</sup> chamber of plywood construction was used to represent a scaled version of the turbine lubricant pump room. Penetrations were made throughout the structure to match the leakage rate of the turbine lubricant pump room. The leakage rate was verified by a door fan test per NFPA 2001, Annex C.

Prior to conducting the full-scale tests, several small-scale tests were conducted. Various nozzle designs were evaluated for agent aspiration and distribution. A custom nozzle was developed that exhibited superior aspiration and dispersion characteristics of Novec 1230 fluid than the other nozzles that were evaluated. It was important that the nozzle orifice area stay consistent throughout designs for system simplicity and not affect the flow rate for an individual system. Several orifice plates were evaluated, and flow rates based on orifice size were confirmed over multiple tests to ensure consistency in delivery of the agent.

Once the system components were optimized, two full scale tests were conducted in the enclosure using two orifice plates to demonstrate that the system can be designed to account for varying leakage rates. Two systems were used for these tests, a traditional NFPA 2001 clean agent system with a maximum 10 second discharge time to bring the room to the initial design concentration and a performance-based extended discharge system to maintain the design concentration for the required hold time. The room concentration for both tests can be seen in Figure 1. The nozzle pressures can be seen in Figure 2.

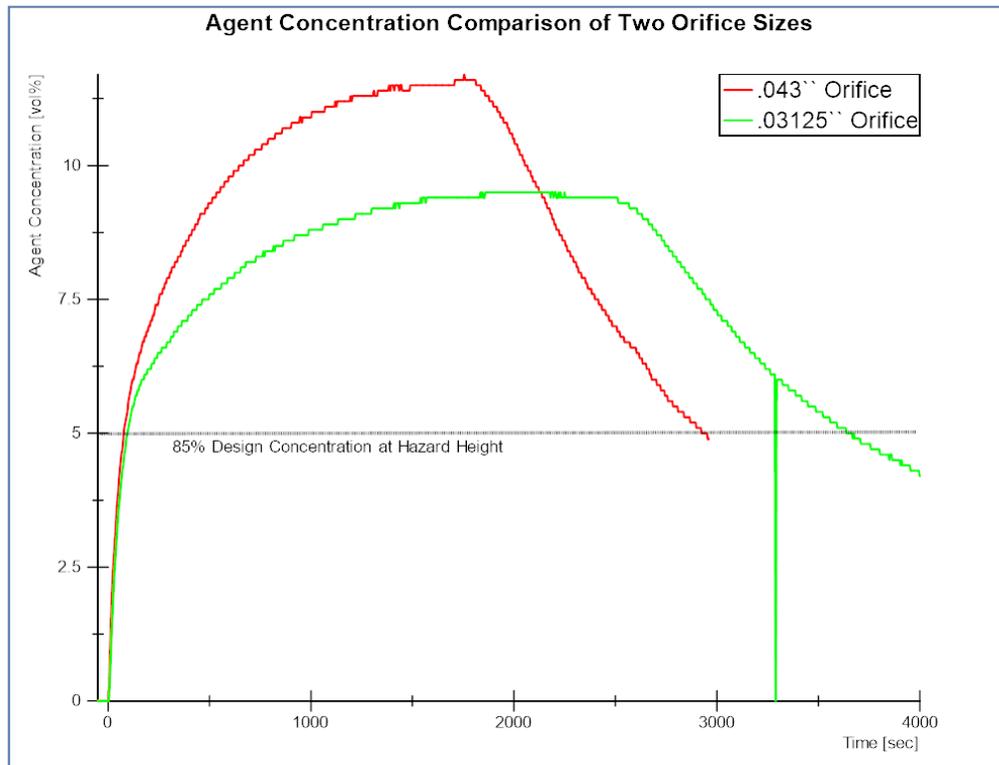


Figure 1: Agent Concentration Test for Two Orifice Plate Sizes

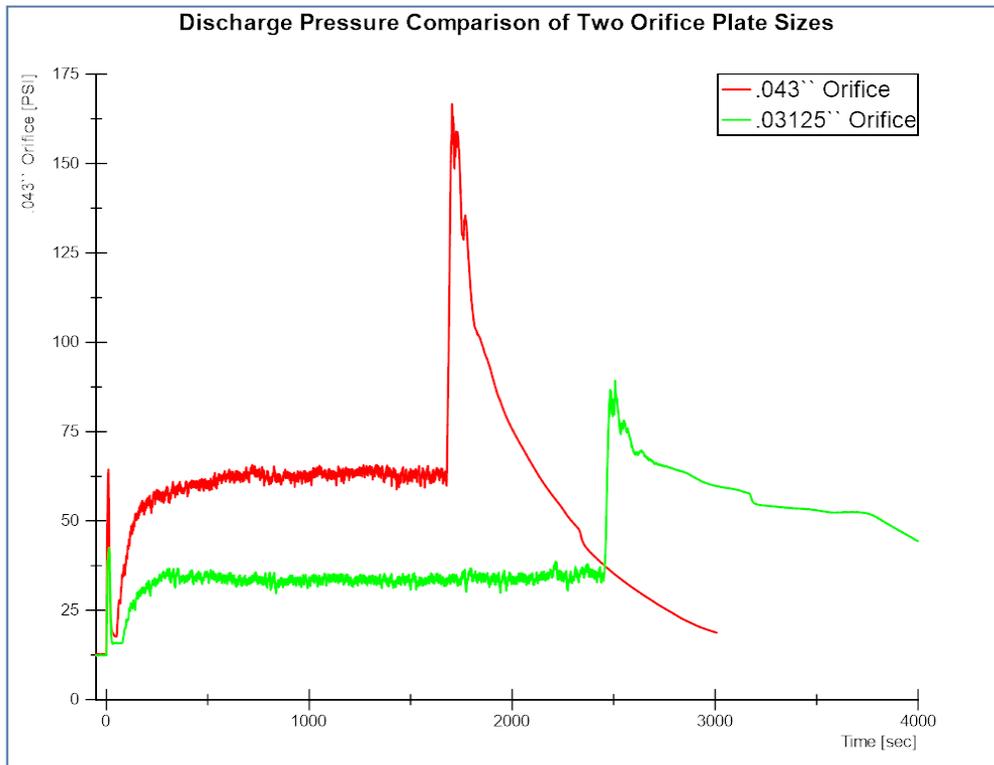


Figure 2: Nozzle Pressure for Two Orifice Plate Sizes

System data can be seen in Table 1. It was critical to maintain a constant pressure on the orifice plate to ensure a consistent nozzle pressure and flow rate. This was done by installing a high-pressure regulator between the agent cylinder and nitrogen booster tank that was set at a pre-determined pressure. The extended discharge time was determined by a pressure spike that signaled the agent cylinder had been depleted.

Orifice Diameter [in]	Initial Discharge Agent Weight[lbs]	Extended Discharge Agent Weight [lbs]	Nozzle to Orifice Area Ratio	Mean Nozzle Pressure [psig]	Discharge Time [sec]	Concentration Max [vol%]	Hold Time [sec]
0.03125	47	200	8.0001	33.9	2454	9.5	3680
0.043	47	200	4.2253	65.5	1678	11.7	2960

Table 1: Extended Discharge Test Data of Two Orifice Sizes

### Full Scale Concentration Test

#### Alarm and Notification

Tech Electronics of Colorado installed a Notifier NFS2-3030 control panel featuring an integrated voice evacuation system with the ability to select up to 3,000 different messages or up to 32 minutes of continuous play time. This was done with the intent that anyone working around the generator would understand the sequence of the suppression system without having to be trained on tones and pulse

rates of the horn signals. It also eliminated required training on an annual basis to maintain their understanding of the system tones. Any function in the system could be assigned a custom message that would provide direction and clarification to individuals working in and around the generator. With a specific message associated with each function being played it was easier for operators onsite to make intelligent decisions to intervene or evacuate the space.

### System Design

A system protecting 3 separate areas was designed by ETG Fire. Zone 1 was the lubrication oil equipment room, zone 2 was the turbine housing and zone 3 was the turbine bearing compartment. Each zone had a dedicated control panel utilizing various types of detection customized for the requirements of each individual zone. A traditional 10 second clean agent system designed per NFPA 2001<sup>2</sup> and a performance-based design extended discharge system protected each individual zone. The extended discharge systems were designed to provide approximately 60 minutes of protection per the request of the utility.

### Full Scale Verification Test

A full-scale discharge test was conducted at the utility’s facility for the turbine lubrication pump room. Agent concentration was taken at the highest height of protected content. The room concentration for the test can be seen in Chart 3.

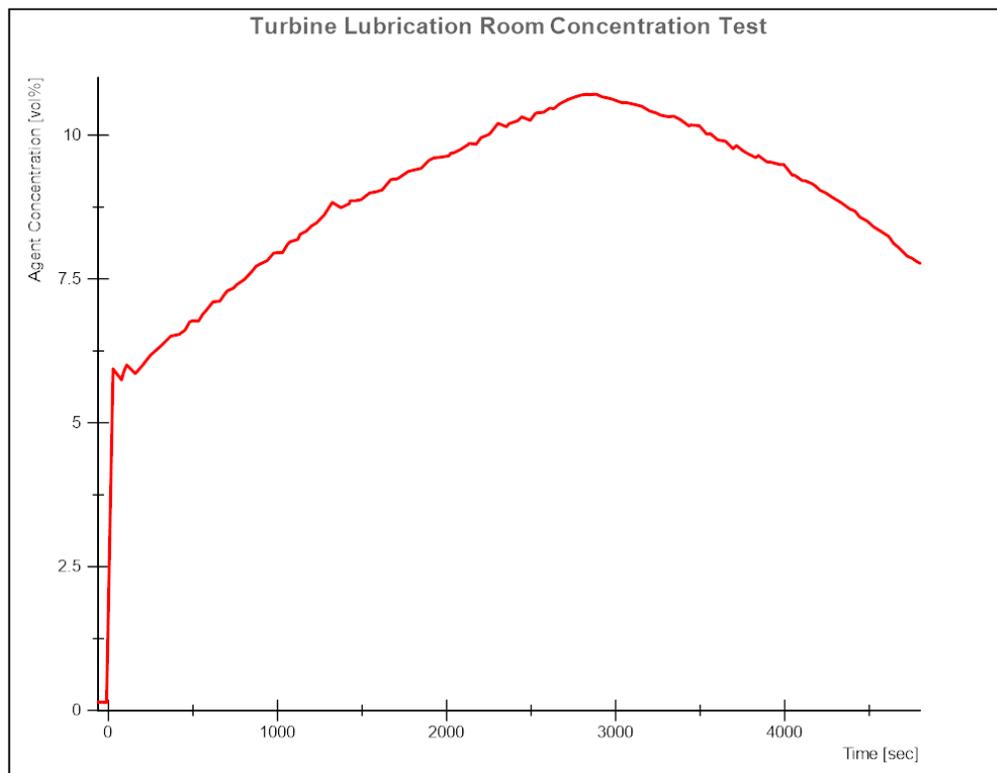


Figure 3: Full Scale Agent Concentration Test

<sup>2</sup> NFPA 2001 (2018 Ed.) 5.7.1.1.1

After ninety minutes the test was stopped by the utility prior to the room concentration reaching 85% of the design concentration at the height of the hazard<sup>3</sup>. The test exceeded the utilities required hold time and the lubricating pumps needed to be reactivated to ensure no damage to the turbine bearing. Test data can be seen in Chart 2. The estimated hold time was determined by extrapolating the concentration rate of depletion.

<b>Orifice Diameter [in]</b>	<b>Initial Discharge Agent Weight [lbs]</b>	<b>Extended Discharge Agent Weight [lbs]</b>	<b>Nozzle to Orifice Area Ratio</b>	<b>Discharge Time [sec]</b>	<b>Concentration Max [vol%]</b>	<b>Estimated Hold Time [sec]</b>
<b>0.03125</b>	100	180	8.0001	2885	10.7	6985

*Table 2: Full Scale Discharge Test Data*

### **Conclusion**

With the completion of the onsite installation and the testing of the equipment, the fire extinguishing system was put into service. The system has been in service for over a year and continues to provide a reliable extinguishing system that eliminated the need for the potentially lethal CO2 gas and provides protection during the entire 60 min turbine winddown. This performance-based design allows for flexibility in system design based simply on the leakage rate of a given enclosure.

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<sup>3</sup> NFPA 2001 (2018 Ed.) 5.6