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Promoted Ignition Testing of Metallic Filters in High-Pressure Oxygen

ABSTRACT: Currently, no test standard exists for evaluating the ignition tolerance and fault tolerance of metallic filters in high-pressure oxygen. Filters are a critical component in oxygen systems to ensure system cleanliness and mitigate ignitions by particle impact and contamination. However, filters are at risk to these same ignition mechanisms and fires have occurred in service. A new test method was developed using ASTM Standard G175 Phase 2 as a basis. The test subjects a pre-contaminated filter to a forced ignition event using an ignition pill while the filter is maintained at elevated pressure. Prior to testing, contaminant was applied to the filter element and was also placed at the filter inlet. This additional contaminant was based on contaminant that could potentially accumulate in a filter over time. This contaminant consisted of aluminum powder, iron particles, and perfluorinated lubricant. An ignition pill, consistent with ASTM Standard G175 Phase 2, was located on the upstream side of the filter. A back pressure was applied downstream of the ignition pill to ensure that the filter was pressurized during the ignition and burning of the pill. Testing was performed on brass and stainless steel filters of the same design using an oxygen shock to ignite the ignition pill at a test pressure greater than the back pressure applied to the filter. The brass filters safely contained the ignition event without breaching through the filter element or body. For the stainless steel filters, the ignition event kindled the filter element and burned through the filter body. This testing showed that the ignition fault tolerance of the brass filters was far superior to that of the stainless steel filters, which was consistent with the relative flammability of these metallic materials, and therefore verified the test methodology.

Introduction

Within medical and industrial oxygen systems, it is crucial to ensure that all components are compatible with oxygen. With careful selection of components and materials, the risk of ignition within an oxygen system can be minimized. When selecting a component for oxygen service, there are various ignition mechanisms that should be considered. The ignition mechanisms include energy release from a second material (promoted ignition), particle impact, flow friction, resonance, electrical energy, and adiabatic compression [1]. In the case of filters within oxygen systems, promoted ignition is a serious concern. Since the primary function of filters is to collect particulate and contaminates from a system, they are inherently susceptible to contaminant promoted ignition. Currently, there is no test standard for performing promoted ignition testing on filters. ASTM G175 Phase 2 is a promoted ignition test for medical regulators. The objective of this test is to determine the fault tolerance of oxygen regulators when subjected to a promoted ignition event. A new test method for filters was established using ASTM G175 Phase 2 as a guideline. The ASTM G175 Phase 2 procedure was modified to better simulate the actual service conditions of filters in service. The following paper presents the test design and procedure as well as the results from testing on various filters.

Background

There is neither a test standard for performing promoted ignition testing on filters nor is there any known previous data for this kind of testing. There have been ignitions in the field involving filters in industrial gas pipelines [2], oxygen boosters, and breathing gas systems (Fig. 1), in which the ignition event propa-

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FIG. 1—*Condition of a breathing gas booster filter after an ignition in the field.*

gated though the body of the filter and resulted in a catastrophic fire. These ignition events can and have resulted in damage to components and systems. The objective of this testing was to develop a method to evaluate the fault tolerance of filters to promoted ignition.

Test Set-up

The test system design was consistent with the adiabatic compression test system depicted in ISO 15001 Annex E [3] and previously reported in ASTM STP 1319 [4]. It consisted of an accumulator to supply heated (~60°C), high-pressure oxygen to a rapid opening valve (impact valve). Prior to testing, calibration cycles were performed on the test system to ensure that the required pressure rise time of 15–20 ms was achieved at the end of a capped, 750-mm-long, 14-mm inside-diameter tube. A test article was affixed to the test system at an interface located a distance of 750 mm from the impact valve. A vent valve, to relieve pressure in the test system, was located between the impact valve and the test article. A high frequency response pressure transducer was provided to ensure that the required test article pressurization rate was achieved for each calibration cycle. Pressurization rates were monitored and recorded during each pressure shock. The test was performed under computer control and data was recorded digitally.

The filter test articles required preparation before testing. A standard ASTM G175 ignition pill was installed immediately upstream of the filter inlet. Additional contaminant was applied to the filter element and placed at the filter inlet. This additional contaminant was based on contaminant potentially present in a filter after a typical service life. A portion of the filter element for each test article was contaminated with perfluorinated lubricant, aluminum, and iron. A thin layer of lubricant was placed on the filter element and then approximately one-half of the total aluminum and iron particles were spread onto the filter element. Prior to the testing, the other one-half of the aluminum and iron contaminant was poured into the filter inlet. A blank nylon disk (approximately 82 mg) was placed just downstream of the ignition pill. This blank nylon disk was used to isolate the standard ignition pill from the back pressure that was applied within the filter before the impact event. The back pressure of approximately 13.8 MPa (2,000 psi) was applied to the filters to ensure that the filters were pressurized during the time frame at which the fire from the ignition pill entered the filters. A 1-mm (0.040-in.) orifice was placed just downstream of the filter outlet. This orifice was used to simulate the flow rate of a typical flow controlling component that would be installed downstream of these filters in service. The filters were impacted with oxygen at the desired test pressure. The oxygen pressure surge was applied to the filter inlet, thus igniting the ignition pill.

Test Results

Table 1 provides further details regarding the test pressure, additional contaminant, and other specifics for each filter tested. Twelve (12) filters were subjected to positive ignition testing according to the requirements of a modified ASTM G175 Phase 2 test procedure. Testing was performed on the following test articles: five (5) brass inline filters, five (5) brass tee type filters, one (1) stainless steel inline filter and one stainless steel tee type filter. The filters were exposed to the ignition and combustion of a standardized ignition pill, a typical 82-mg nylon ignition pill blank and the additional contaminant applied to and added to the filter.

Stainless Steel Filters

For the stainless steel inline and tee type filters, sustained promoted ignition of the stainless steel filters bodies occurred causing a highly energetic fire release. Pre- and post-test photographs of the stainless steel inline and tee type filters are shown in Figs. 2–7. Based on the results observed during this testing, all of the stainless steel filters (inline and tee type) were judged to have failed the requirements of the promoted ignition filter test because the filter body failed to contain the ignition event.

Brass Filters

For the brass inline and tee type filters, sustained promoted ignition of the filter bodies and internal components did not occur. Some heat deterioration and melting on each test article was observed. These changes were due to the energy delivered by the pill and the additional contaminant that was consumed. No external flame or breach of the pressurized filter was observed during the testing. The filter element was not breached and therefore prevented slag and particulate associated with the ignition event, from migrating downstream of the filter. Post-test photographs of the brass inline and tee type filters are shown in Figs. 8–14. Based on the results observed during this testing, all of the brass filters (inline and tee type) were judged to have successfully passed the requirements of the promoted ignition filter test. It is noteworthy that these brass filters also endured the ignition event without breaching the filter element, which is above and beyond the requirement of this testing.

TABLE 1—*Filter promoted ignition test data.*

Test Article	Qty. Tested	Contaminate Added to the Filter Element and Inlet	Test Pressure	Result
Brass inline filter	5	100 mg aluminum powder, 250 mg iron particles inserted at the filter inlet. A thin layer of lubricant was smeared on the filter element.	34.5 MPa (5,000 psi)	Ignition pill and contaminant ignited but did not kindle the filter element and did not propagate through the filter body.
Brass tee filter	5	1 g aluminum powder, 2.5 g iron particles inserted at the filter inlet. A thin layer of lubricant was smeared on the filter element.	34.5 MPa (5,000 psi)	Ignition pill and contaminant ignited but did not kindle the filter element and did not propagate through the filter body.
Stainless steel inline filter	1	100 mg aluminum powder, 250 mg iron particles inserted at the filter inlet. A thin layer of lubricant was smeared on the filter element.	34.5 MPa (5,000 psi)	Ignition pill and contaminant ignited and propagated through the filter body.
Stainless steel tee filter	1	1 g aluminum powder, 2.5 g iron particles inserted at the filter inlet. A thin layer of lubricant was smeared on the filter element.	20.7 MPa (3,000 psi)	Ignition pill and contaminant ignited and propagated through the filter body.

Note: (1) All tests were performed with a back pressure of 13.8 MPa (2,000 psi) on the filter. (2) A standard ASTM G175 ignition pill and an 82-mg nylon blank were placed just upstream of the filters, pretest. (3) There was a 1-mm (0.04 in.) orifice downstream of the test article.

FIG. 2—*Pre-test photo of a stainless steel tee type filter.*

FIG. 3—*Post-test condition of the stainless steel tee type filter (View 1).*

FIG. 4—*Post-test condition of the stainless steel tee type filter (View 2).*

FIG. 5—*Pre-test photo of a stainless steel inline filter.*

FIG. 6—*Post-test condition of a stainless steel inline filter (View 1).*

FIG. 7—*Post-test condition of a stainless steel inline filter (View 2).*

FIG. 8—*Pre-test photo of a brass tee type filter.*

FIG. 9—*Post-test condition of a brass tee type filter.*

FIG. 10—*Post-test condition of a brass tee type filter element (View 1).*

FIG. 11—*Post-test condition of a brass tee type filter element (View 2).*

FIG. 12—*Pre-test photo of a brass inline filter.*

FIG. 13—*Post-test condition of a brass inline filter (View 1).*

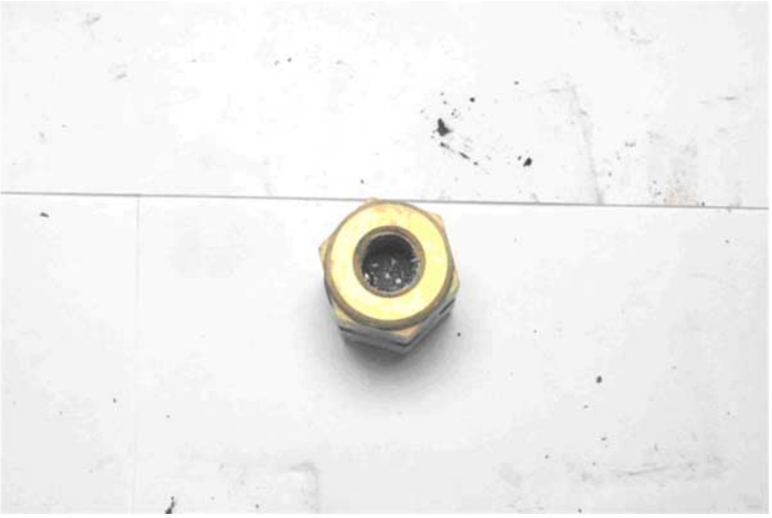

FIG. 14—*Post-test condition of a brass inline filter (View 2).*

Conclusion

Promoted ignition testing was performed on brass and stainless steel filters. The contaminant applied to the filters prior to testing was based on the amount and type of contaminant that could typically be found within filters that are out in the field. The promoted ignition test results indicated that the brass filters were able to contain the ignition event without breaching the filter element or body. The stainless steel filters were not able to contain the ignition event during the promoted ignition testing. The ignition event propagated the stainless steel filter element as well as the stainless steel body, eventually burning through the filter body. As previously determined, these findings are consistent with the difference in flammability between these two alloys [5]. Therefore, a new test was developed that was capable of evaluating the ignition tolerance of filters for high-pressure oxygen service.

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