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The Response of Aircraft Oxygen Generators Exposed to Elevated Temperatures

David Blake

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The purpose of this testing was to determine the temperatures that would cause self-activation of sodium chlorate oxygen generators. The data will be used to establish the degree of thermal protection that would be required to prevent the activation of chemical oxygen generators should they be exposed to heat from a cargo compartment fire involving other materials. The minimum temperature that caused the activation of one of the generators was 600°F. Due to uncertainties with other designs not tested and the physical properties of sodium chlorate, it is recommended that the generators not be exposed to temperatures above 400°F.

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EXECUTIVE SUMMARY

The purpose of this testing was to determine the temperatures that would cause self-activation of sodium chlorate oxygen generators. The data will be used to establish the degree of thermal protection that would be required to prevent the activation of chemical oxygen generators should they be exposed to heat from a cargo compartment fire involving other materials. Twenty-three tests were conducted inside a furnace with the generators subjected to various temperatures and exposure times. The minimum temperature that caused the activation of one of the generators was 600°F. A literature search revealed a range of temperatures between 482° and 572°F in which sodium chlorate will start to decompose and liberate oxygen. This project used readily available generators from two different manufacturers. There are other generator manufacturers, but their products were not tested. Due to uncertainties with other designs not tested and the physical properties of sodium chlorate, it is recommended that the generators not be exposed to temperatures above 400°F.

INTRODUCTION

The carrying of oxygen generators on passenger aircraft was banned following an in-flight cargo fire and subsequent crash of a ValuJet DC-9 near Miami, Florida, on May 11, 1996. The probable cause of the accident was determined to be the inadvertent activation of one or more oxygen generators in the forward cargo compartment that resulted in an uncontrollable fire [1]. The oxygen generators had been removed from other aircraft after exceeding the permitted service life and were being shipped back to the airline headquarters. The generators were improperly packaged and not declared as hazardous materials.

BACKGROUND.

Sodium chlorate oxygen generators are installed on many aircraft models to provide the oxygen source for emergency passenger breathing air. This air is required in the event of a fuselage depressurization while at altitude. The oxygen generators consist mainly of a sodium chlorate and iron powder mixture. Small quantities of other chemicals such as barium peroxide are also added to eliminate chlorine and control the reaction [2]. Most generators are equipped with a variety of mechanical spring-loaded mechanisms that strike a primer cap in one end of the generator. This produces sufficient heat to initiate the chemical reaction that liberates oxygen. A lanyard is typically attached between the passenger oxygen masks and the spring-loaded mechanism. When the passenger oxygen mask doors open, pulling the masks down will activate the generators. Some generators initiate the reaction electrically. The internal reaction temperature can be up to 1100°F. Insulation is installed around the sodium chlorate core to limit the temperature of the external steel case. Maximum surface temperatures measured with thermocouples welded to the side of an activated generator were approximately 400°F [3].

A literature search of the properties of sodium chlorate revealed that pure sodium chlorate will melt at 478°F and start to decompose and liberate oxygen at approximately 572°F [4]. Other literature lists a temperature of 482°F as the starting point of decomposition for sodium chlorate and iron powder mixtures [2].

The generators used in this testing had been in storage at the Federal Aviation Administration William J. Hughes Technical Center for several years. They had originally been donated to the Technical Center for previous testing after their removal from aircraft for exceeding their permitted service life. One of the reasons for specifying a maximum service life is that the sodium chlorate candle inside the generators can develop cracks over time. Should that occur, the chemical reaction could stop when it got to the crack and the generator would not produce oxygen for the entire time for which it was designed. Several hundred of the generators in storage had very recently been activated in order to dispose of them. Only a very small percentage of them failed to activate when the lanyard was pulled or to produce oxygen for approximately 15 minutes.

TEST SERIES.

Twenty-three tests were conducted in an electric box furnace. The multiple outlet fittings that feed the individual passenger oxygen masks were removed from all generators prior to testing. The main outlet of the generator was then attached to a copper tube that was routed outside of the furnace. A small strip of paper was placed over the outlet of this copper tube and used as an indication of the flow of oxygen from a generator activation. Figure 1 shows the test configuration.

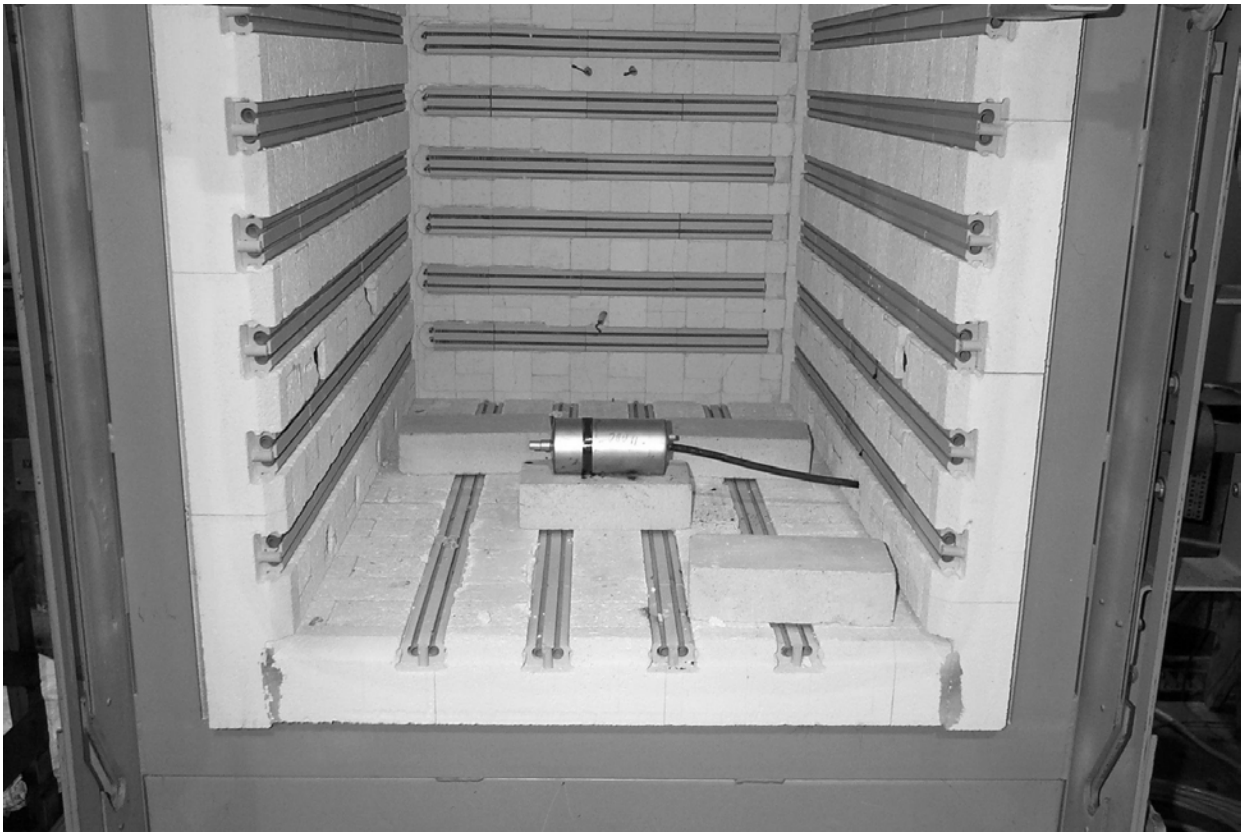

FIGURE 1. FURNACE AND OXYGEN GENERATOR

In 18 of the 23 tests, the furnace was preheated to the desired temperature and the generators were placed inside. In the remaining 5 tests the generators were placed in the furnace at ambient temperature, a set point of 800°F was selected and the furnace was then turned on. Following each test, the generators were allowed to cool to room temperature. After cooling, the lanyard was pulled on all the generators that did not activate in the furnace to determine if the generators were still capable of producing oxygen as designed. In all tests in which the generators activated, except for tests 15 and 18, the flow rate of oxygen was consistent with the flow rate that the generators are designed to produce in normal use. This is indicative of the reaction occurring as a result of the activation of the primer cap due to heat. The abnormal flow rates during tests 15 and 18 are indicative of the decomposition of the sodium chlorate/iron powder mixture at some other location within the generator. The outer case of the generator used in test 15 appeared normal, following the test. During test 18, oxygen was produced at a rate greater than could be discharged from the generator, and the outer case was significantly bulged outward due to internal pressure. Figure 2 shows the outwardly bulged generator from test 18 next to a normal generator. All of the generators that activated in the furnace were disassembled and the primer caps were examined. In all cases, the primer caps had activated. Table 1 summarizes the results of the testing.

FIGURE 2. OUTWARDLY BULGED GENERATOR (TOP) AND NORMAL GENERATOR (BOTTOM)

TABLE 1. SUMMARY OF TEST RESULTS

Test	Mfg	Furnace Temp (°F)	Exposure Time (minutes)	Activated in Furnace	Able to Initiate After Cooled
1	P-B	70-600	109	No	No
2	P-B	70-600	60	No	No
3	P-B	500	60	No	Yes
4	P-B	500	60	No	Yes
5	P-B	600	38	Yes	-
6	P-B	600	60	No	No
7	P-B	600	60	No	No
8	P-B	550	60	No	No
9	P-B	550	60	No	No
10	P-B	400	60	No	No
11	P-B	400	60	No	No
12	P-B	400	60	No	No
13	P-B	700	36	Yes	-
14	P-B	700	34	Yes	-
15	Scott	700	60	Yes[1]	-
16	Scott	700	60	No	No
17	P-B	70-800 (700 at activation)	82	Yes	-
18	P-B	70-800 (778 at activation)	65	Yes[2]	-
19	P-B	70-800 (771 at activation)	64	Yes	-
20	P-B	400	180	No	No
21	P-B	400	180	No	No
22	Scott	500	180	No	No
23	P-B	500	180	No	No

P-B = Puritan Bennet
Scott = Scott Aviation

1. Activated after 5 minutes but flow rate was much lower than normal.

2. Flow rate through normal outlet was much lower than normal. Oxygen also leaked out of primer cap end and generator body bulged outward due to internal pressure.

CONCLUSIONS

1. Exposure to furnace temperatures at or above 600°F was necessary to cause the self-activation of sodium chlorate oxygen generators.

2. Exposure to a furnace temperature of 500°F for 3 hours did not cause activation of the particular generator designs used in this test project.

3. Due to the uncertainty of the self-activation temperature of primer caps or electrically activated ignition squibs in other generator designs not tested in this project and the literature data stating that decomposition could occur as low as 482°F, it is recommended that generators not be exposed to ambient temperatures above 400°F.

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