High Temperature Test of Spring Return Actuators for Tunnel Ventilation Applications

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Introduction

In underground structures, such as tunnels and passenger platforms, air handling devices such as electric motor operated dampers need to function in emergency situations, particularly in the case of a fire inside the structure. The dampers can act to suppress spreading of the fire as well as clearing smoke from areas away from the fire[1]. In many instances, motorized actuators that operate the dampers are required to be “fail-safe”, which means they are equipped with mechanical springs that close (or open) the damper upon loss of power at the actuator. Furthermore, the motorized dampers must function at elevated temperatures to be effective[2].

There are several specifications, standards and guidelines for the operation of electrically operated ventilation systems[3], such as dampers, for use in tunnels and underground structures for motor vehicle, rail and pedestrian traffic. While a few of the specifications have exactly the same standards and contain variations, often in regard to emergency situations. These variations usually are dependent on regional requirements by country, province or city. The most common specification is for the damper and motorized actuator to be functional after exposure to minimum of 250°C (482°F) for 45 minutes (Sweden[3]), 60 minutes (Korea[3], United States[4,5], Austria[6], Netherland[6],) or 120 minutes (United Kingdom[3], Switzerland[7], Toronto[8]). The regulation for France calls for fan and equipment operation for 120 minutes at 200°C (392°F).

The high temperature test described herein was designed to certify functionality of spring return electric actuators for the locations mentioned above. Other more severe specifications, guidelines or standards are not addressed here.

Test Devices

Electrical connections were made between specially designed local control consoles for a 50 Nm (450 in lb) spring return actuator (PA-CW-1202N4, ProMation Engineering, Brooksville, FL) and a 260 Nm (2300 in lb) spring return actuator equipped with a manual override mechanism (PDO-CW-1202N4, ProMation Engineering, Brooksville FL). The control consoles provide power and control to the motor to drive the actuator to the open position. A motor brake then holds the motor in position until power is interrupted either by the switch in the control console or loss of power. Upon loss of power the motor brake releases and the springs drive the actuator to the closed position. The control station monitors the actuator’s position, open or closed, by indicator lights. Thermocouples were placed inside each actuator approximately 2 inches from the motor in air (TC A1 and TC D1).

Each actuator was fitted with a thermal blanket (Insultech, Shannon Industries, North Tonawanda NY). The thermal blankets were designed to protect the actuator for 120 minutes at 250°C (482°F). The drive motor is rated NEMA Class F where motor lifetime is reduced after exposure to temperatures above 155°C (311°F). An electronic logic circuit in the actuator controls the motor after loss of power, delaying operation of the motor for 5 seconds after restoration of power. The motor, gearing, springs and electronics are housed in a NEMA 4/4X enclosure. The actuator is rated to operate up to 65°C (150°F) without degradation of the actuator or components. Thermocouples were placed between the actuator housing and the thermal blanket near the EMT entry points for each actuator (TC A2 and TC D2). An additional thermocouple was placed on the PDO actuator between the actuator housing and the thermal blanket near the mechanical override mechanism (TC D3).

Methods

A 430,000 BTU oven (Controlled Pyrolysis, Pollution Control Products, Dallas, TX) was brought up to test temperature, 250°C (482°F), per the oven temperature control readout. The oven heat sources are two liquid propane burners located longitudinally at the top and bottom of the back wall of the oven. The oven thermocouple is located at the top of the oven. Oven temperature control was shifted from the oven thermocouple to a test control thermocouple (TCC) placed between the two test units because the oven thermocouple was too distant from the test units to ensure that proper test temperature was maintained. An additional thermocouple (TCL) was placed between the PA test unit and the door of the oven.

After the oven was heated to temperature, the test units were placed inside the oven on a raised oven bed. Figure 1 shows the position of the test units, the oven burners, and thermocouples.

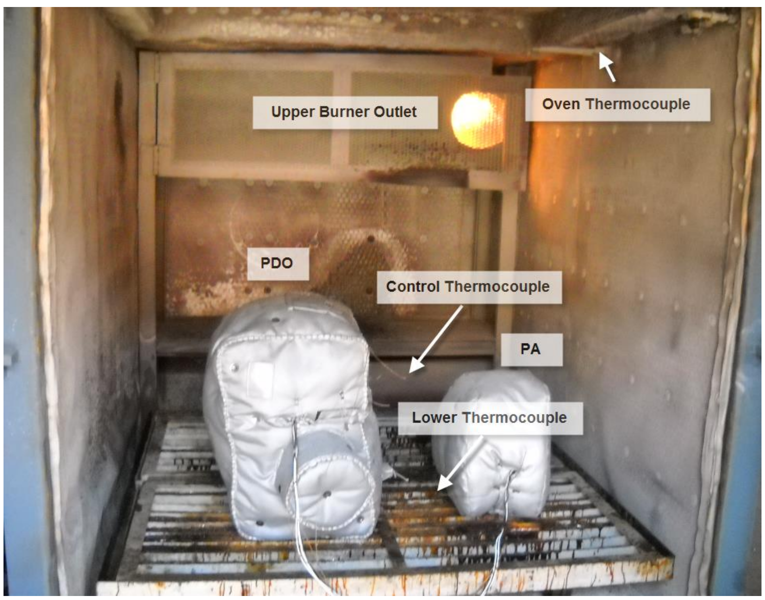

Figure 1 Position of the test units, the oven burners and thermocouples.

Temperature measurements were recorded every 10 to 15 minutes. A functional test was completed prior to placing the units in the oven, at the time they entered the oven and at the time the control thermocouple reached test temperature of 250°C (482°F) (Time = 0). Functional test were completed at 30, 60, 110 and 120 minutes after reaching temperature. A functional test is defined as one Open – Closed – Open cycle. A final test of 5 cycles at a 25% duty cycle was performed at 120 minutes after reaching test temperature. The cycle times were recorded at each functional test. A functional test was considered successful when the open and closed cycle times met the product specification: 12 seconds to open; 3 seconds to close and 18 seconds to open; 12 seconds to close for the 50 Nm test unit (PA) and 130 Nm test unit (PD), respectively.

The test units were functionally tested and inspected after returning to ambient temperature.

Results

The test units successfully completed all functional and final tests and completed the open and closed cycles per their operating specifications.

Tables 1 and 2 show the results of the temperature and functional tests as a function of time for the 50 Nm actuator (PA) and the 260 Nm actuator (PDO), respectively. Time = 0 is the time the oven reached the high temperature set point on the control thermocouple. The cycle times were all within the operating specifications: 3 seconds open to close (spring return) and 12 second for the motor to drive open the actuator for the 50 Nm unit (PA) and 12 seconds open to close (spring return) and 18 seconds for the motor to drive open the actuator for the 260 Nm unit (PDO).

Table 1 Temperature and cycle testing for the 50 Nm test unit (PA)

Elapsed Time (min)	Test Temp-erature TCC (°C)	Inside Unit TC A1 (°C)	Outside Unit/ Inside Blanket TC A2 (°C)	Inside Oven near Unit TCL (°C)	Cycle Time Open to Close (sec)	Cycle Time Close to Open (sec)
-12	154	41	41	153		
0	254	46	52	242	3	12
15	274	53	65	252		
30	270	62	77	254	3	12
40	254	66	83	254		
50	263	73	90	247		
60	266	77	94	243	3	12
70	252	83	99	239		
80	256	90	104	241		
90	255	94	108	253		
100	258	97	112	251		
110	251	101	114	238	3	12
120	255	104	117	243	3*	12*

* Five cycles at 120 minutes

There was a power interruption at minute 72. The test was suspended until power was restored and oven temperature returned to 250°C (482°F). The interruption lasted 9 minutes. The net time at temperature excludes the interruption.

The maximum control temperature was 274°C (525°F) at minute 15; the minimum control temperature was 251°C (485°F) at minute 110. The average control temperature for the 120 minute test was 259°C (498°F).

The maximum temperature for the interior of the 50 Nm (450 in lb) test unit (PA) of 104°C (219°F) was reached at the end of the test at 130 minutes. For the 260 Nm (2300 in lb) test unit (PDO), the maximum temperature of 106°C (223°F) was also reached at the end of the test. The test units were brought to ambient temperature (27°C) and five cycle functional tests were repeated. Each unit performed per their specifications.

Table 2 Temperature and cycle testing for the 260 Nm test unit (PD)

Elapsed Time (min)	Test Temp-erature TCC (°C)	Inside Unit TC D1 (°C)	Outside Unit/ Inside Blanket TC D2 (°C)	Outside Unit/ Inside Blanket TC D3 (°C)	Cycle Time Open to Close (sec)	Cycle Time Close to Open (sec)
-12	154	41	42	41		
0	254	47	74	45	12	18
15	274	54	94	51		
30	270	64	104	56	12	18
40	254	71	109	58		
50	263	76	113	62		
60	266	81	116	64	12	18
70	252	87	121	71		
80	256	93	122	74		
90	255	96	126	79		
100	258	99	127	81		
110	251	102	129	84	12	18
120	255	106	131	88	12*	18*

* Five cycles at 130 minutes

Discussion

The type of oven used provided a mixture of radiative and convectional heating, similar to what may be found in a fire situation. While the oven had a considerable temperature variation within the oven with a maximum difference of 31°C (55°F) between the uppermost and lowest sensors, the temperatures within the test units were much more consistent with a maximum difference of 5°C (8°F). At the end of the test there was a 2°C (4°F) difference between the interiors of the test units.

It is not felt that the power interruption impacted the outcome of the test. When the temperatures observed during the power interruption are included, the average temperature for the entire 130 minutes of the test is 257°C (495°F) compared to an average of 259°C (498°F) when those temperatures are excluded. Furthermore, while the oven decreased in temperature, the interior temperature of the test units did not decrease. This is due to the thermal mass of the units and the insulating blanket holding internal temperature constant while the external temperature decreased.

Some of the internal components of the actuator are rated for a maximum of 80°C (176°F). While the components may not fail, their lifetime or performance may be compromised or unpredictable. The internal temperature of the test units reached their rated temperature at approximately 70 minutes. The motor has a temperature sensor that will interrupt power to the motor at 155°C (311°F). This temperature was not reached during the test. Extrapolating the internal temperature curves show that the motor would reach cut off temperature between 225 minutes (linear extrapolation) and 300 minutes (exponential extrapolation).

The two test units represent the smallest (PA at 27 kg, 65 lb) and largest (PDO at 135 kg, 297 lb) spring return actuators offered by ProMation Engineering. We assume that scaling the thermal blanket to fit the intermediate sizes of other spring return actuators would provide similar results in a high temperature test, reaching a maximum internal temperature of 106°C (223°F) after two hours at temperatures averaging 259°C (498°F).

Conclusion

ProMation Engineering fail-safe spring return actuators, fitted with a thermal blanket remain functional, able to perform multiple open and closing cycles, after 120 minutes at temperatures averaging above 259° C. They meet the standards and guidelines for functionality at one hour at 250°C (482°F), 90 minutes at 250°C (482°F), 2 hours at 250 °C (482°F) and 2 hours at 200°C (392°F).

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