NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

October 15, 2008

MATERIALS LABORATORY FACTUAL REPORT | Report No. 08-108

A. ACCIDENT

Place	:	St. Louis, Missouri
Date	:	September 28, 2007
Vehicle	:	MD-80
NTSB No.	:	DCA07MA310
Investigator	:	Lorenda Ward

B. COMPONENTS EXAMINED

Primary and secondary fuel manifold fittings from the left and right hand side of a JT-8D 200 series engine (figure 1). New (figure 2) and used elastomeric packings and nylon packing retainers for the fuel manifold fittings.

C. DETAILS OF THE EXAMINATION

Tests were planned and conducted to examine the susceptibility of the fittings to leaking when subjected to a high temperature environment. The stainless steel fittings are assembled using a Butadiene-Acrylonitrile rubber (NBR) elastomeric packing and a nylon packing retainer on the inside of the fuel fitting. The elastomeric packing is the component in the fuel fitting assembly that creates the liquid tight seal. There is no metal-to-metal contact to create the seal and thus loss of the packing's integrity could lead to a leak. The specification for the service temperature of the elastomeric packing is stated to be –40C to 100C. Three series of tests were conducted: (1) Tests using a laboratory oven, (2) Tests with an oil burner used in engine component certification testing, and (3) Tests with a forced air combustion heater. The fuel fittings that were used were the actual fittings from the accident engine. These fittings were cleaned using an ultrasonic part cleaner and returned to serviceable condition before testing began.

LABORATORY OVEN TESTS

Two laboratory oven tests were conducted. One test involved the elastomeric packing alone and one test involved the packing and packing retainer assembled inside one of the fuel manifold fittings. The test on the packing alone consisted of exposing the packing to an oven temperature of 600 degrees Fahrenheit for three minutes after which it was removed from the oven for a brief examination and then reinserted into the oven for an additional 6 minutes, removed for examination again and then reinserted into the oven for an additional 12 minutes. Half of a packing was used for this test during which the sample mass and physical characteristics were noted each time the sample was removed from the oven. These notes are shown in table 1.

Figure 1: Primary (3/8" OD) and secondary (1/2" OD) fuel manifold fittings from the left hand side of the engine

Figure 2: New elastomeric packing (black) and nylon packing retainer (white)

Oven tests on small packing @ 600F				
Exposure Time (min)	**Sample Mass (g)**	**Mass Loss (g)**	**Mass Loss (%)**	**Material Characteristics**
0	0.572	0.000	0.00	Flexible & Resilient
3	0.547	0.025	4.37	Flexible & Less Resilient
9	0.539	0.033	5.76	Hard & Brittle (fractured under light pressure)
21	0.538	0.034	5.94	Very Hard & Brittle

Table 1: Observations and mass measurements taken during packing oven test

After the initial three minute exposure the packing was still flexible but slightly harder than what it was before the test. Additionally, the surface of the packing developed check marks and fine lines as depicted in figure 3. Measurement of the sample's weight indicated that it had lost 4.37 percent of its mass.

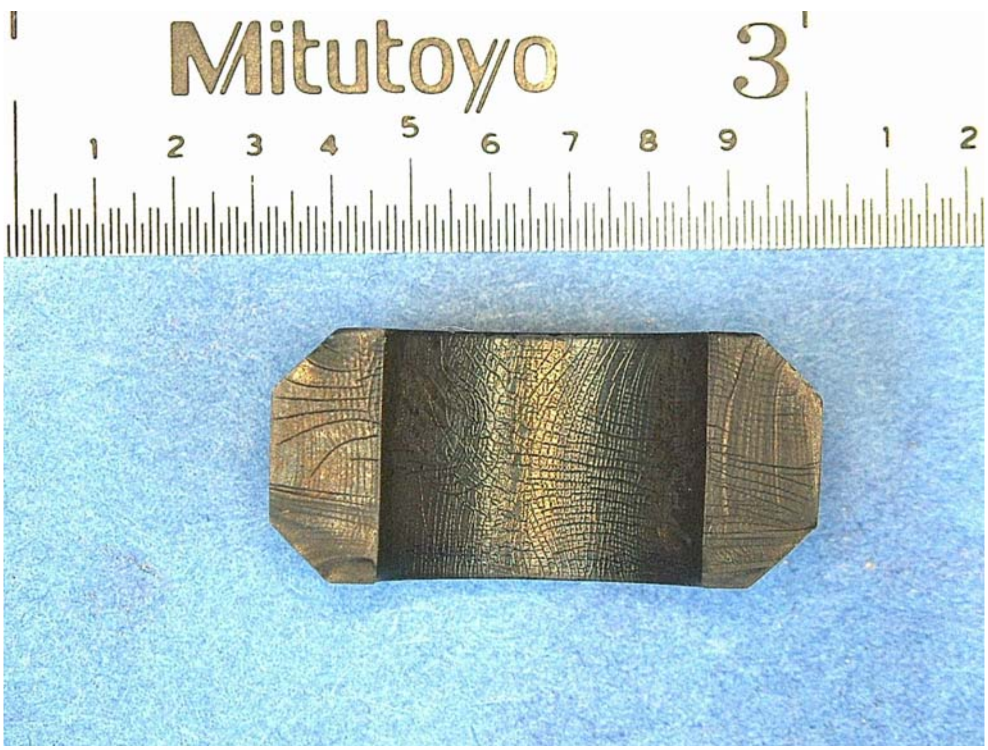

Figure 3: Elastomeric packing (half) after 3 minute exposure to 600 degree F oven

The sample was reinserted into the oven for an additional 6 minutes at 600 degrees Fahrenheit and then removed for inspection. The sample had become hard and brittle and the check marks had become more pronounced. Gently squeezing the sample caused it to fracture in the middle (figure 4). Measurement of the sample weight indicated that it had lost 5.76 percent of its original weight.

Figure 4: Fractured elastomeric packing after squeezing. The packing had been exposed for a total of 9 minutes to the 600 degree F environment.

The two fractured pieces of the sample were reinserted back into the oven and exposed to the 600 degree Fahrenheit environment for an additional twelve minutes. Upon removal from the oven the pieces of the packing remained hard and brittle with no perceptible change in appearance. At this point the mass loss was 5.94 percent.

The next oven test consisted of assembling the primary fuel manifold fitting with a packing and packing retainer by following the assembly procedure outlined in the maintenance manual and then exposing it to a 600 degree Fahrenheit environment in the laboratory oven for two hours. The assembly of the fitting consisted of lubricating the packing and retainer with petrolatum, assembling the fitting and then tightening to a torque of 35 inch-pounds. The assembled fuel fitting was then secured with safety wire. The fitting was pressurized with air and found to be airtight. After the fitting was exposed in the oven for two hours it was removed and found to no longer be airtight. The fitting assembly felt like there was some play at the union and upon disassembly it was found that the packing retainer had melted and the packing was fractured (Figure 5).

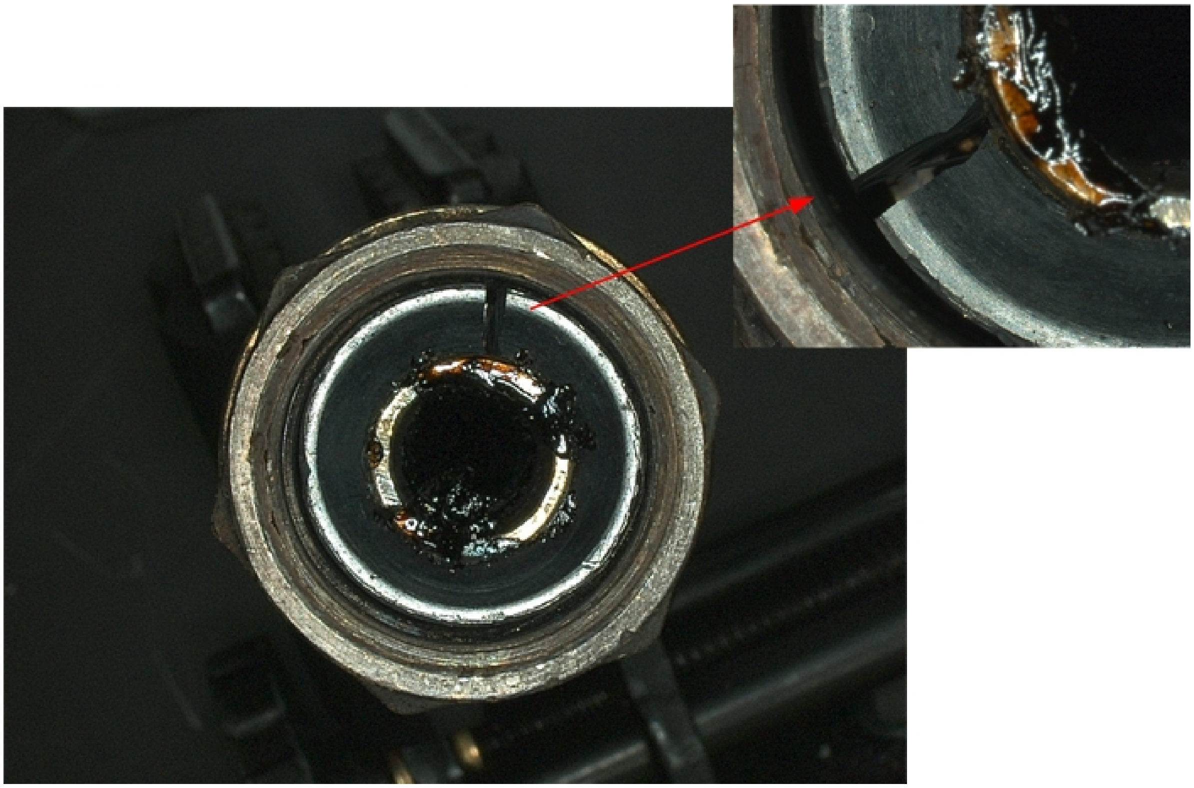

Figure 5: Fractured packing in fuel fitting assembly after 2 hour oven test at 600 degrees Fahrenheit

After removing the fractured packing from the fitting it was found to be hard and brittle resembling the condition of the packing in the first oven test after the 9-minute cumulative exposure.

OIL BURNER TESTS

The tests conducted using the oil burner were performed at the FAA Tech Center in Atlantic City, NJ. The tests were made to resemble as close as possible the actual engine component fire resistance certification tests. The heating conditions and placement of the test article were done as prescribed in the certification test. The mechanism for inducing a vibration into the test article was not available and thus omitted from the test. A fuel recirculation system was set up to provide fuel flow through the fitting at 0.3 gallons per minute (GPM) and an approximate pressure of 20 psi. Additionally, provisions were made to stop the fuel circulation and impose a condition of static pressure at 300 psi. The oil burner was set up such that a temperature of 2000 degrees Fahrenheit was measured by 5 type K thermocouples located at a distance of 4 inches from the burner's exit nozzle as prescribed in the certification standard. The heat flux[1] at this location was 11 Btu/ft^2-sec (124.9 kW/m^2). The testing procedure was to first establish that the fitting was liquid tight by imposing the 300-psi static pressure and then to begin fuel circulation in the fitting while letting the oil burner run for 2 minutes to reach a steady

[1] The heat flux, or rate of heat flow was measured using a Gardon type heat flux gauge. This gauge measures the total, convective and radiative, heat flow from the heat source to the room temperature gauge.

state (figure 6). During the warm up period the test article was sufficiently far away as to not be heated by the oil burner. The fuel fitting would then be moved into position 4 inches in front of the burner's exit nozzle and kept there for a duration of five minutes (figure 7). After the five-minute period the burner would be shut off and fuel recirculation would be stopped and a static pressure of 300 psi would be imposed.

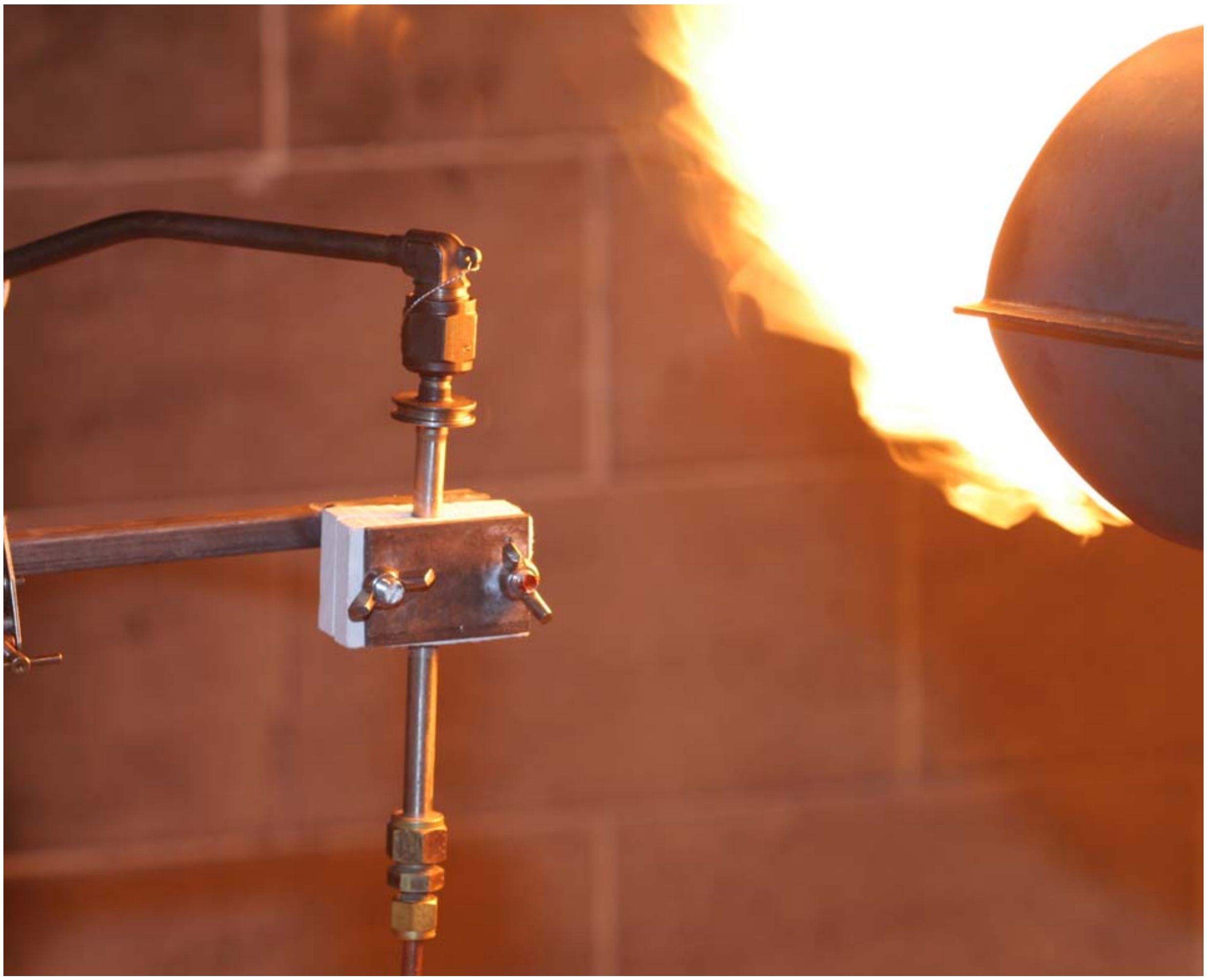

Figure 6: Assembled fuel fitting prior to exposure to burner flame

Figure 7: Fuel fitting exposed in oil burner flame

The first test employed a used packing and packing retainer that had been previously in service for 11,115 hours. At the conclusion of the five-minute period the fitting showed evidence of a leak, which then became more pronounced when the fuel recirculation was transitioned to static pressure at 300 psi (figure 8). The leak occurred at the end of the test and did not cause a fire. Disassembly of the fitting revealed that the packing had become friable along its outer perimeter, exhibiting a tendency to crumble when handled (figure 9). The packing had not hardened throughout as in the oven tests and remained somewhat pliable. The packing retainer was partially melted and had separated at one section of its circumference (figure 10).

Figure 8: Fuel fitting leaking under 300 psi static pressure at the end of the test.

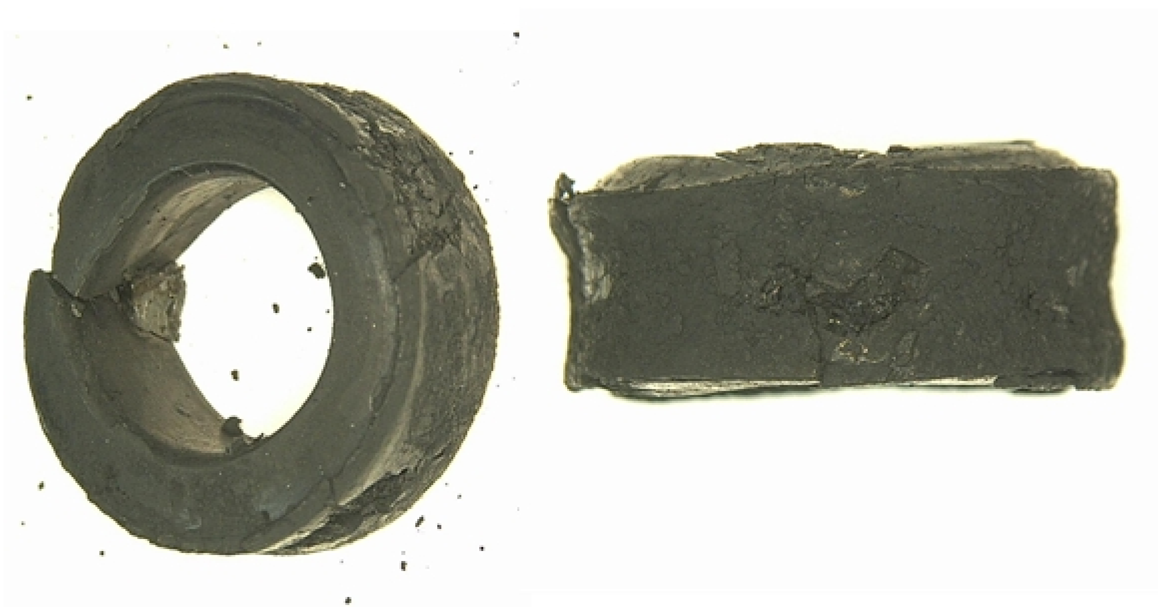

Figure 9: Two views of the packing removed from the fuel fitting after the first oil burner test

Figure 10: Nylon packing retainer after the first oil burner test

The second test was done using a new packing and new packing retainer. The procedure was the same as described above. At the conclusion of the 5-minute period when the burner was shut off the fuel fitting was on fire, indicating that it had begun to leak before the test was over. When the fuel recirculation was stopped and the static pressure was imposed, the fire became significantly larger and flaming droplets of fuel were observed (figure 11). After disassembly of the fuel fitting, the packing exhibited the same characteristics as were observed in the first oil burner test, although slightly less severe (figure 12). The packing retainer had discolored and exhibited minor indications of melting but had not separated as in the first oil burner test (figure 13).

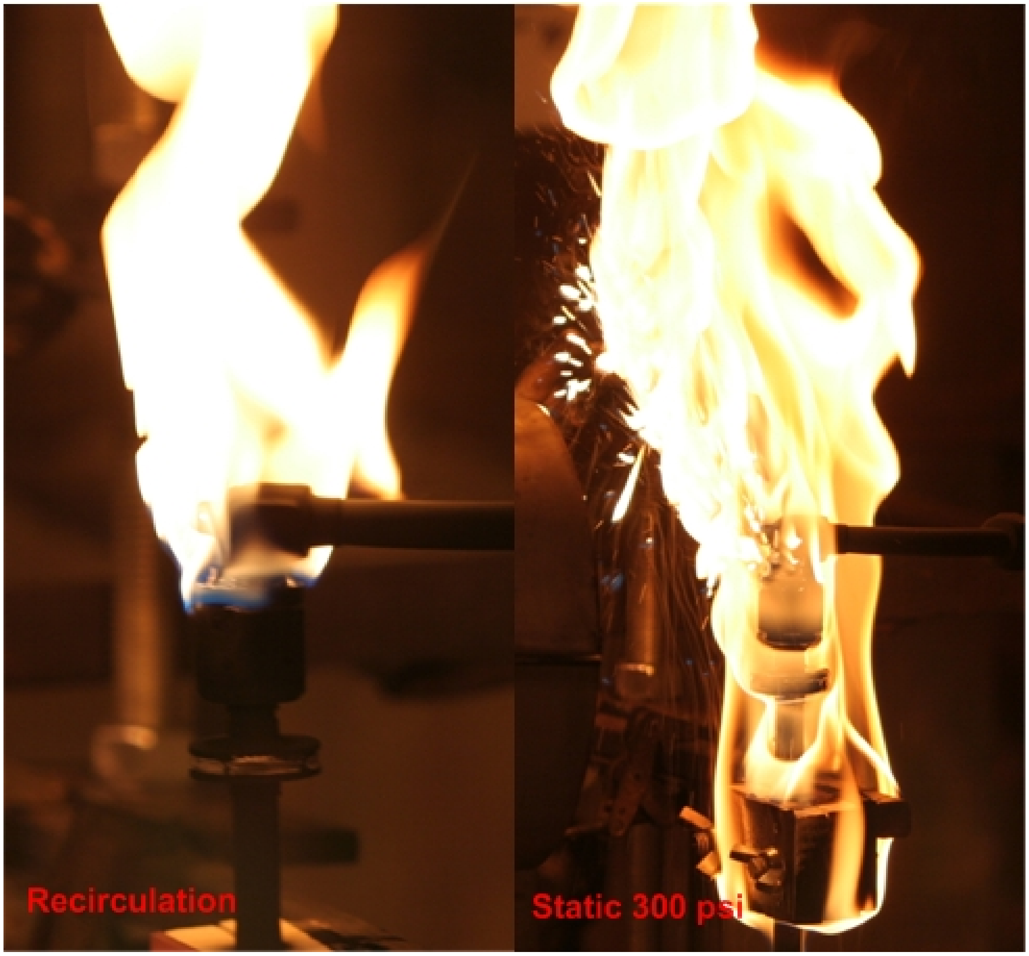

Figure 11: Fuel fitting at the conclusion of the second oil burner test, 0.3 GPM recirculation at 20 psi and static pressure at 300 psi shown

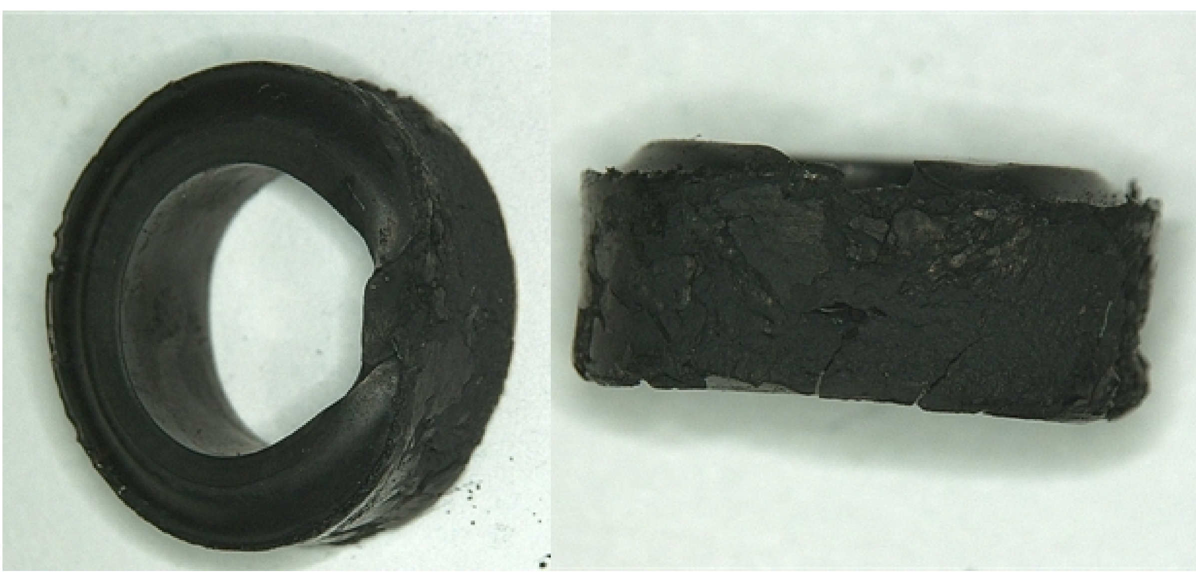

Figure 12: Two views of the packing removed from the fuel fitting after the second oil burner test

Figure 13: Nylon packing retainer after the second oil burner test

FORCED AIR COMBUSTION HEATER TESTS

The following tests were conducted using a forced air combustion heater. This heater was kerosene fueled and was rated at 300,000 btu/hr. A location in front of the heater was found that registered 600 degrees Fahrenheit by measurement with a type K thermocouple. This location was 13.5 inches downstream of the heater's exit nozzle. A heat flux measurement at this location gave a reading of 19 kW/m^2. The procedure for these tests was to let the heater warm up for a period of two minutes and then place the fuel fitting in front of the heater at the location of the 600 degree Fahrenheit temperature (figure 14). As in the previous tests the fuel fitting was assembled per the manufacturers specifications. The same fuel recirculation and static pressure scheme was employed in these tests as was done in the oil burner tests. Three different tests were conducted and are described in the following paragraphs.

The first combustion heater test was done using a used packing with 11,115 hours of service. The fuel fitting was pressure tested for leaks by subjecting it to the 300-psi static pressure; the fitting did not leak. After the heater had warmed up for two minutes the fuel fitting, with fuel recirculating through it, was placed in front of the heater at the predetermined location where the 600 degree Fahrenheit temperature was measured. The fuel fitting was exposed to the heater for five minutes and thirty seconds after which it was removed, the fuel recirculation was stopped and the static pressure was imposed. The fuel fitting did not leak and the fuel recirculation was restarted and the fuel fitting was placed in front of the heater for an additional five minutes. After the second five-minute period the fitting was removed from in front of the heater and the static pressure was re-applied. The fuel fitting still did not leak. Disassembly of the fuel fitting revealed that the packing had not become friable and susceptible to crumbling when handled. The packing was still flexible and only exhibited what could be described as a ragged edge along its outer circumference (figure 15). The outer circumference also exhibited some minor striations. The packing retainer did not have any signs of melting or other damage (figure 16).

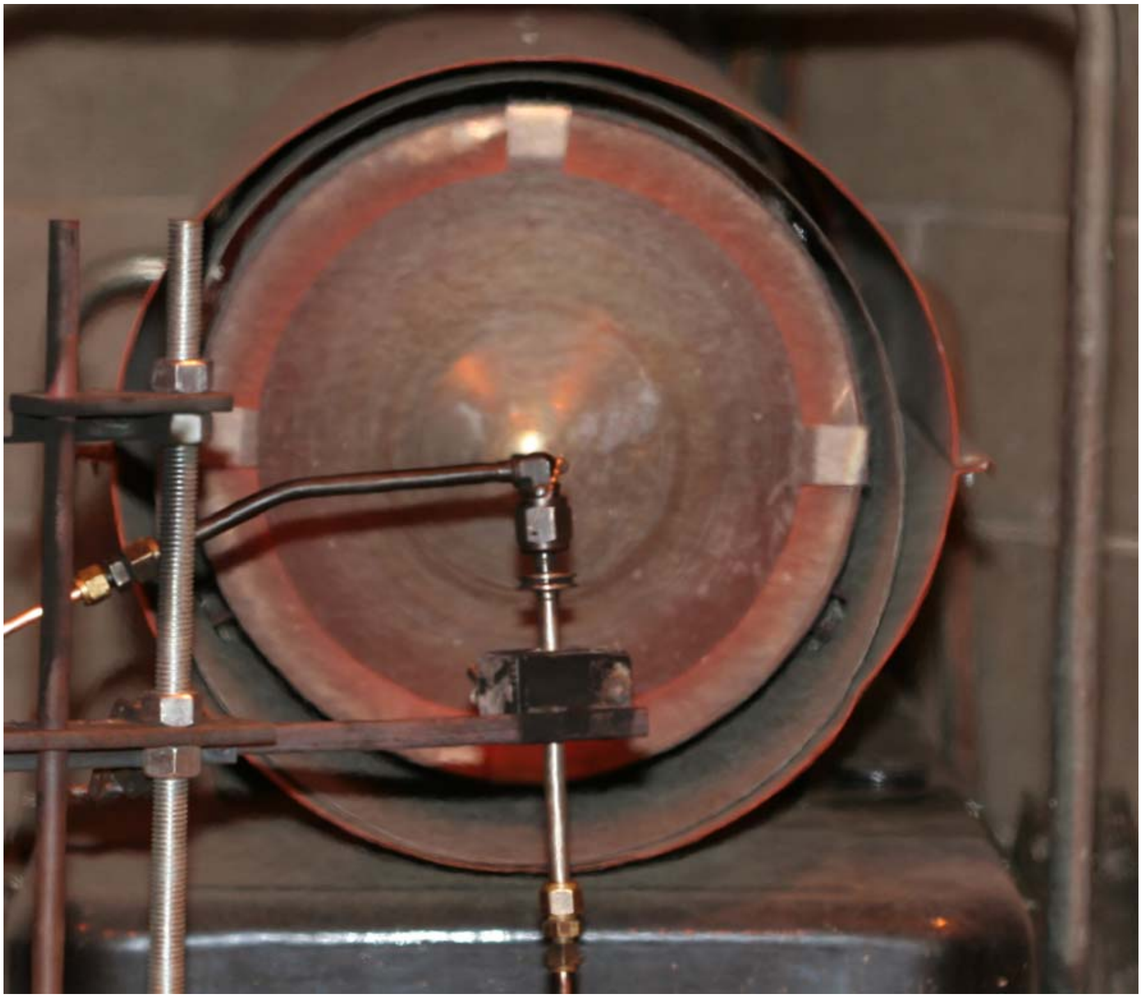

Figure 14: Forced air combustion heater test setup

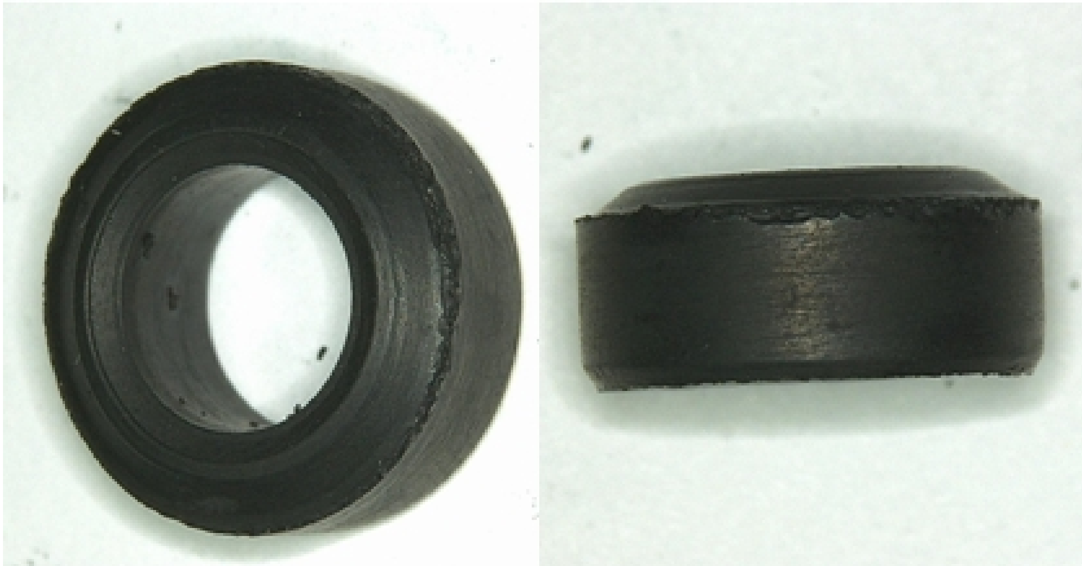

Figure 15: Two views of the packing removed from the fuel fitting after the first combustion heater test

Figure 16: Nylon packing retainer after the first combustion heater test

The second combustion heater test was done using a new packing and new packing retainer. The fuel fitting was pressure tested for leaks by subjecting it to the 300-psi static pressure; it did not leak. After the heater had warmed up for two minutes the fuel fitting was placed in front of the heater at the predetermined location where the 600 degree Fahrenheit temperature was measured. For the duration of this test the fuel fitting was maintained at the 300-psi static pressure and fuel recirculation was not done. The fuel fitting was exposed to the heater for ten minutes after which it was removed and checked for leaks. The fuel fitting was found to not have any leaks at the end of the test. After disassembly the packing resembled the condition of the packing after the first combustion heater test but the ragged edge was significantly more pronounced especially on one side of the packing. There was a slightly ragged edge on the inner circumference of the packing also. The packing retainer was severely melted and deformed and had taken on a brown color. Both the packing and packing retainer can be seen in figure 17.

Figure 17: Packing and packing retainer after disassembly of the fitting at the conclusion of the second combustion heater test

The third combustion heater test was done using a new packing and new packing retainer. The fuel fitting was pressure tested for leaks by subjecting it to the 300-psi static pressure; it did not leak. After the heater had warmed up for two minutes the fuel fitting was placed in front of the heater at the predetermined location where the 600 degree Fahrenheit temperature was measured. In this test the fitting was tightened to a torque of 15 inch-pounds, which was half of the manufacturer’s specification. For the duration of this test the fuel fitting was maintained at the 300-psi static pressure and fuel recirculation was not done. The fuel fitting was exposed to the heater for ten minutes after which it was removed and checked for leaks. The fuel fitting was found to not have any leaks at the end of the test. After disassembly of the fitting the packing was found to have a ragged inner and outer circumference, and it was still flexible. The inner circumference was more ragged than in the previous combustion heater test. The packing retainer was found to be severely melted and had become deformed but it had not turned brown. Instead it had portions that had become charred and were brittle, taking on a black appearance. Both the packing and packing retainer can be seen in figure 18.

Figure 18: Packing and packing retainer after disassembly of the fitting at the conclusion of the third combustion heater test

Joseph Panagiotou
Fire & Explosion Investigator