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

January 13, 2009

FIRE TESTING FACTUAL REPORT Report No.08-136

A. ACCIDENT

Place	:	San Francisco, California
Date	:	6/28/2008
Vehicle	:	Boeing 767-200 Freighter
NTSB No.	:	DCA08MA076
Investigator	:	Lorenda Ward

B. COMPONENTS TESTED

Exploratory fire tests were conducted at the FAA Technical Center in Atlantic City, NJ, on conductive flexible oxygen hose assemblies to determine the propensity for fire ignition when the hose assembly is carrying electrical current while pressurized with oxygen. Additionally, pressurized flexible oxygen hoses were forced to ignition to observe their burning behavior.

C. DETAILS OF THE TESTS

A series of tests were performed to evaluate the propensity of a conductive flexible oxygen hose to catch on fire by passing electrical current through it, while it is pressurized with oxygen. The flexible oxygen hose assemblies that were used (figure 1) were comprised of clear polyvinyl chloride (PVC) tubing with an olive green over-braid and an internal stainless steel helical coil. Both ends of the flexible hose assembly were terminated with threaded aluminum fittings. The internal stainless steel coil spanned the entire length of the PVC hose and was loosely attached at the ends to the aluminum fittings creating an electrical path between the aluminum end-fittings. This loose attachment at the end-fittings caused a variable resistance depending on how the hose assembly happened to be resting. In the experiments discussed in this report, not all of the hose assemblies tested were of the same length (due to part availability).

Five tests were conducted in which electrical current was passed through the flexible hose assembly while it was pressurized with 100% oxygen at 70 psig. Both 120 VAC, and 28 VDC voltages were used. A fixture (figure 2) was made to hold the flexible oxygen hose by the ends, from which the electrical current was introduced. The flexible hose, while held in the fixture, was placed in a series circuit containing the power source, a rheostat and an ammeter.

Additionally, two tests were done using the remnants of the hose assembly from the first test. In these tests the flexible hose was forced to ignite using an energized Nichrome resistance wire heat source.

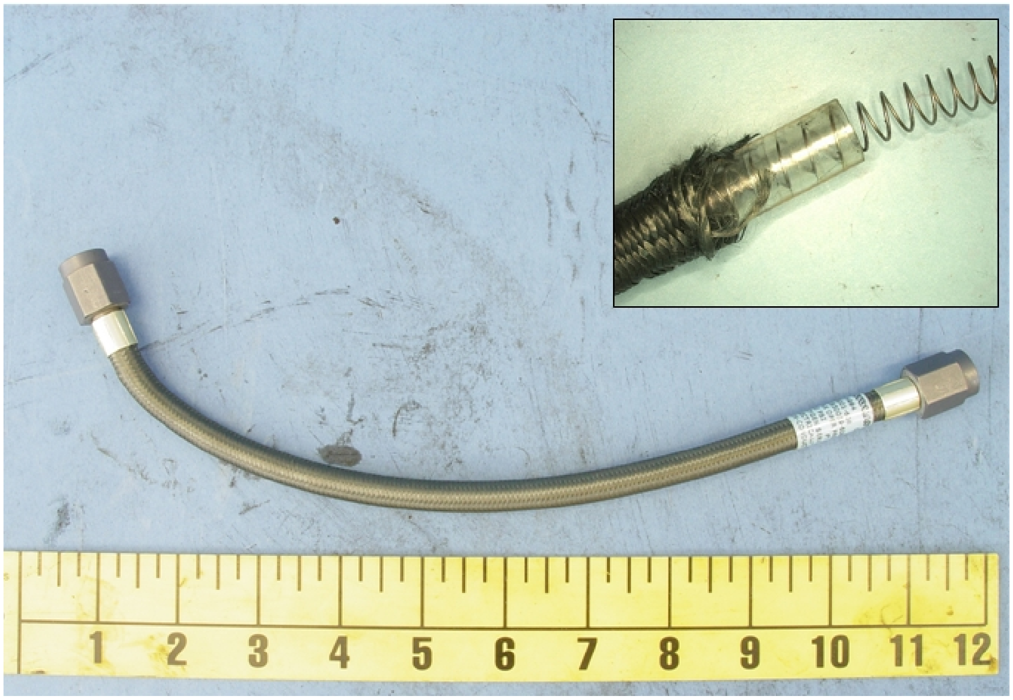

Figure 1: Exemplar flexible hose assembly. Inset shows flexible hose assembly construction.

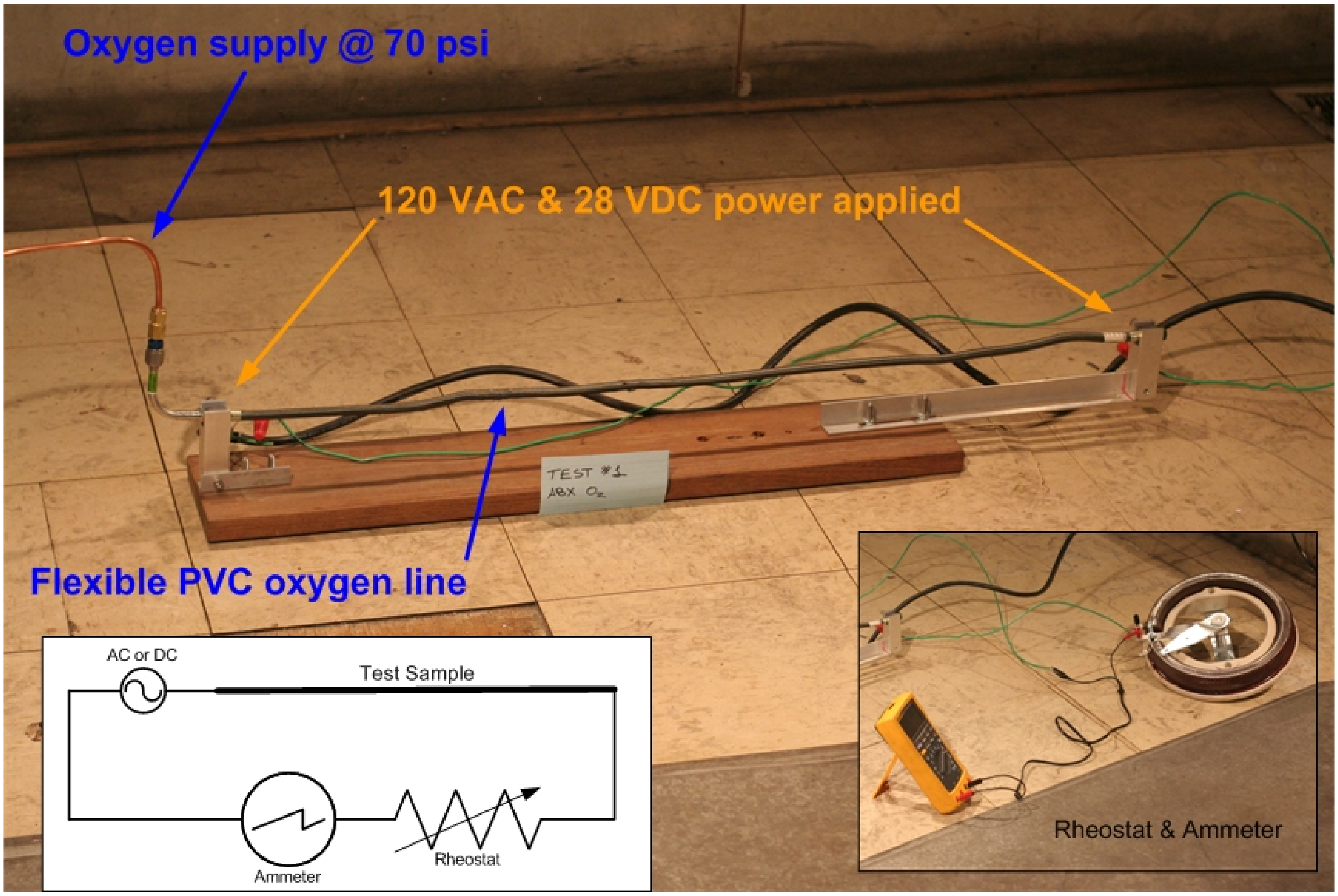

Figure 2: Fixture and setup used in the tests. Inset shows rheostat and ammeter used to control and monitor the applied current.

TEST #1—120 VAC, 2.3 A

In Test #1, the conductive flexible hose assembly was exposed to 120 Volts AC and a current of 2.3 Amperes. From the time of current application, it took 120 s for the hose to fail with a mid span rupture of the PVC tube in the hose assembly causing a loud hissing sound. The electrical current continued flowing after the hose failed until the test was terminated. No fire resulted. Immediately after the test was concluded, the hose was found to be warm and very pliable. After testing, a transverse cross sectional cut of the hose revealed that the inner hose surfaces were not damaged or noticeably discolored (figure 3).

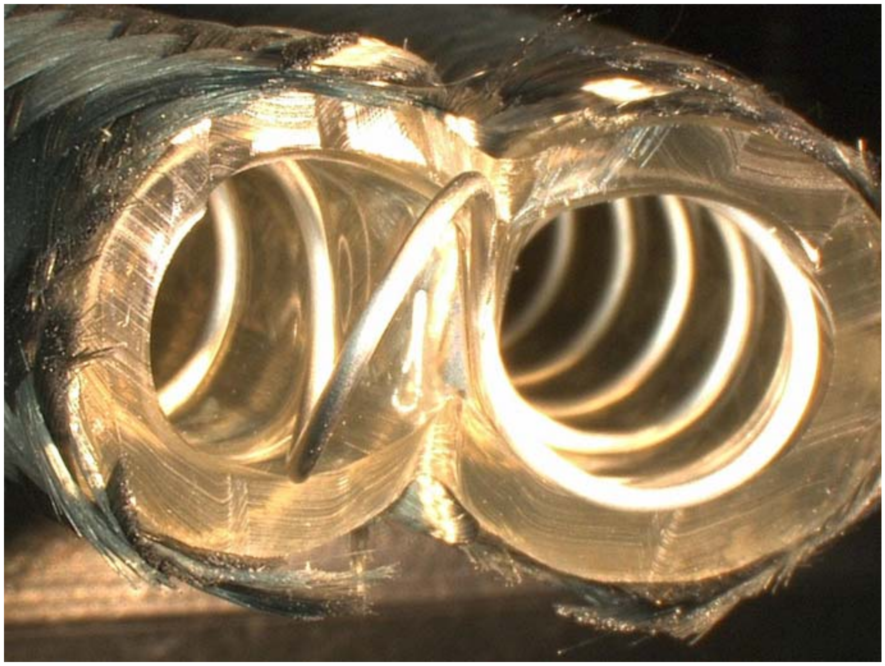

Figure 3: Interior of flexible hose after Test #1

TEST #2—120 VAC, 3.0 A

In Test #2, the conductive flexible hose assembly was exposed to 120 Volts AC and a current of 3 Amperes. From the time of current application, a slight hissing sound occurred after 60 s. At approximately 80 s, a light white smoke was observed rising from the entire length of the hose. At approximately 90 s, the hose failed at the upstream end with a loud bang/pop, ejection of incandescent particles, a short duration fire, and a loud hissing sound (figure 4). The fire self-extinguished once the hose was severed at the upstream aluminum fitting. After the test, examination of the hose remains revealed the presence of small beads of resolidified plastic material which adhered to the over-braid component of the hose assembly. The source of the material for the plastic beads appears to have been the PVC tube inside the over braid. A transverse cross-sectional cut was made in the hose, revealing that the inside surfaces of the hose had charred and intumesced creating a sponge-like material (figure 5).

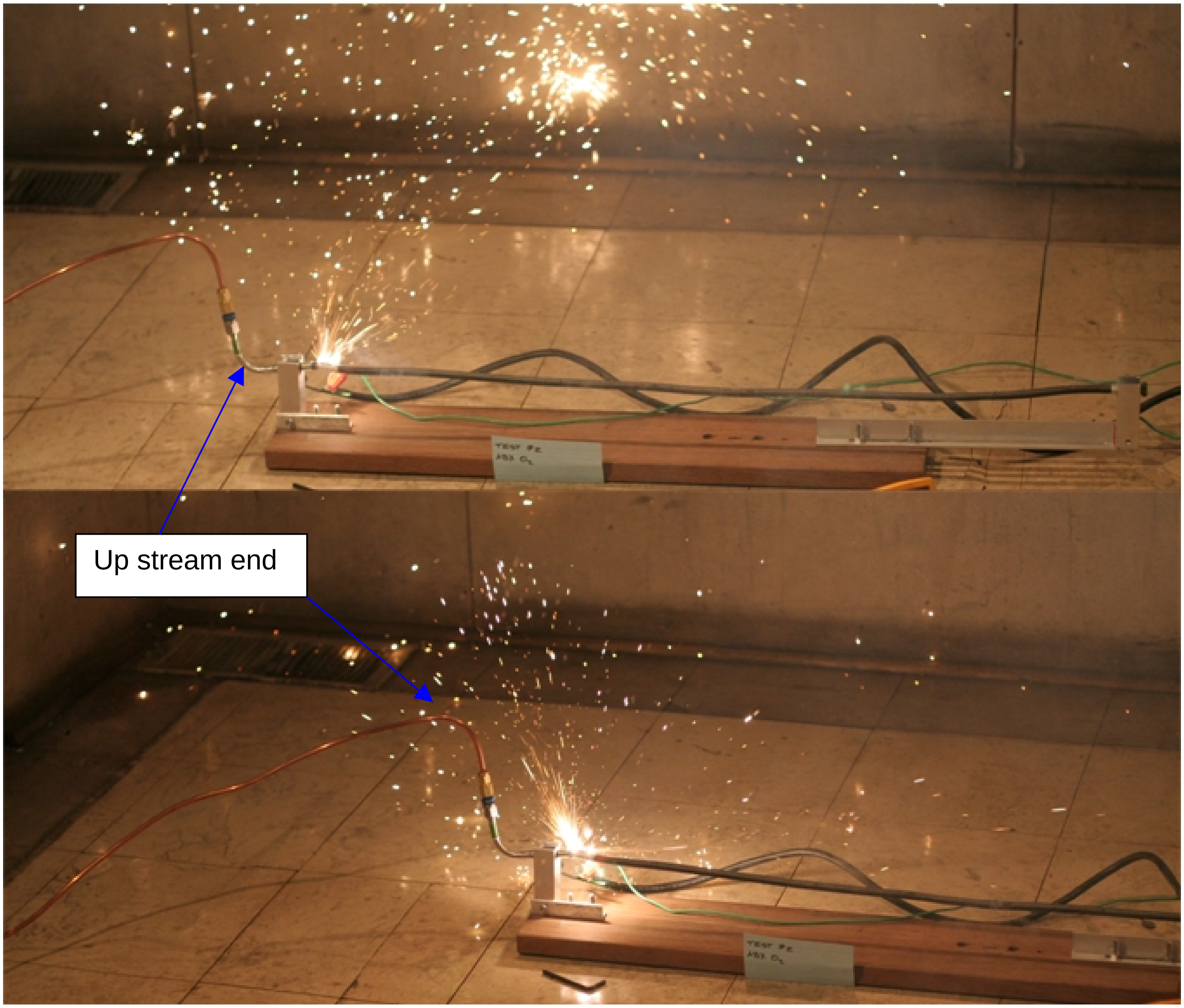

Figure 4: Two photos at the time of ignition in Test #2.

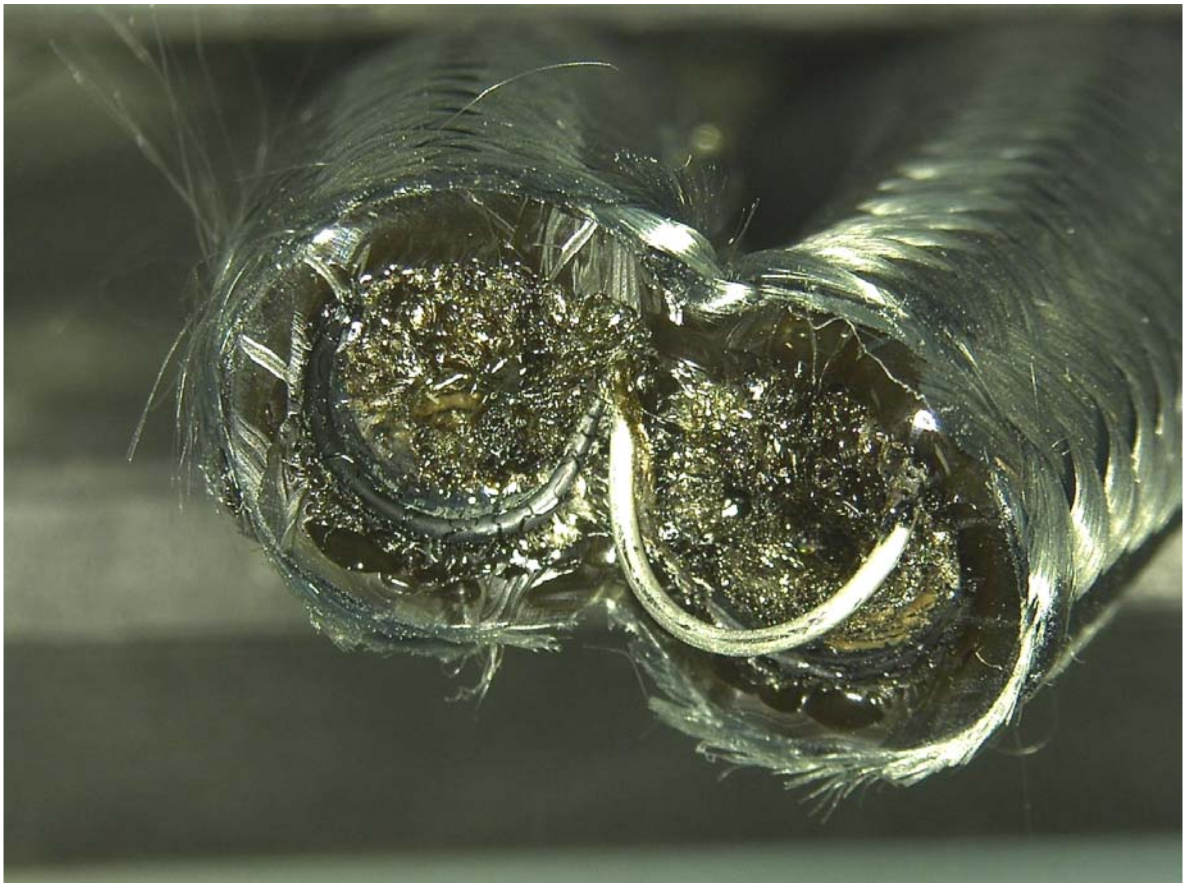

Figure 5: Sponge like material on inside of flexible hose after Test #2

TEST #3—120 VAC, 4.7 A

In Test #3, the conductive flexible hose assembly was exposed to 120 Volts AC and a current of 4.7 Amperes. From the time of current application, it took 11 s before a white flash was observed and an explosion with a sharp crack was heard that seemed to originate from the inside of the hose assembly. After 19 s, a hissing sound was heard followed immediately by an explosive bursting of the hose with a loud bang and the ejection of incandescent particles. A fire at the upstream end of the hose assembly followed (figure 6). The fire self-extinguished once the hose was severed at the upstream aluminum fitting. After the test, a transverse cross-sectional cut was made in the hose revealing a thick coating of soot adhering to the inner surfaces of the hose (figure 7).

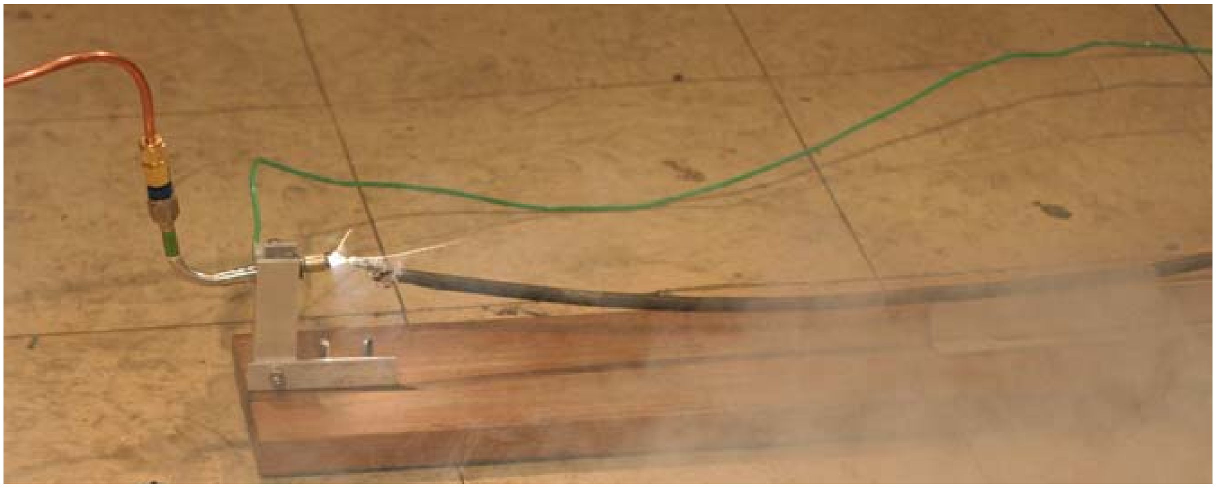

Figure 6: Hose failure during Test #3.

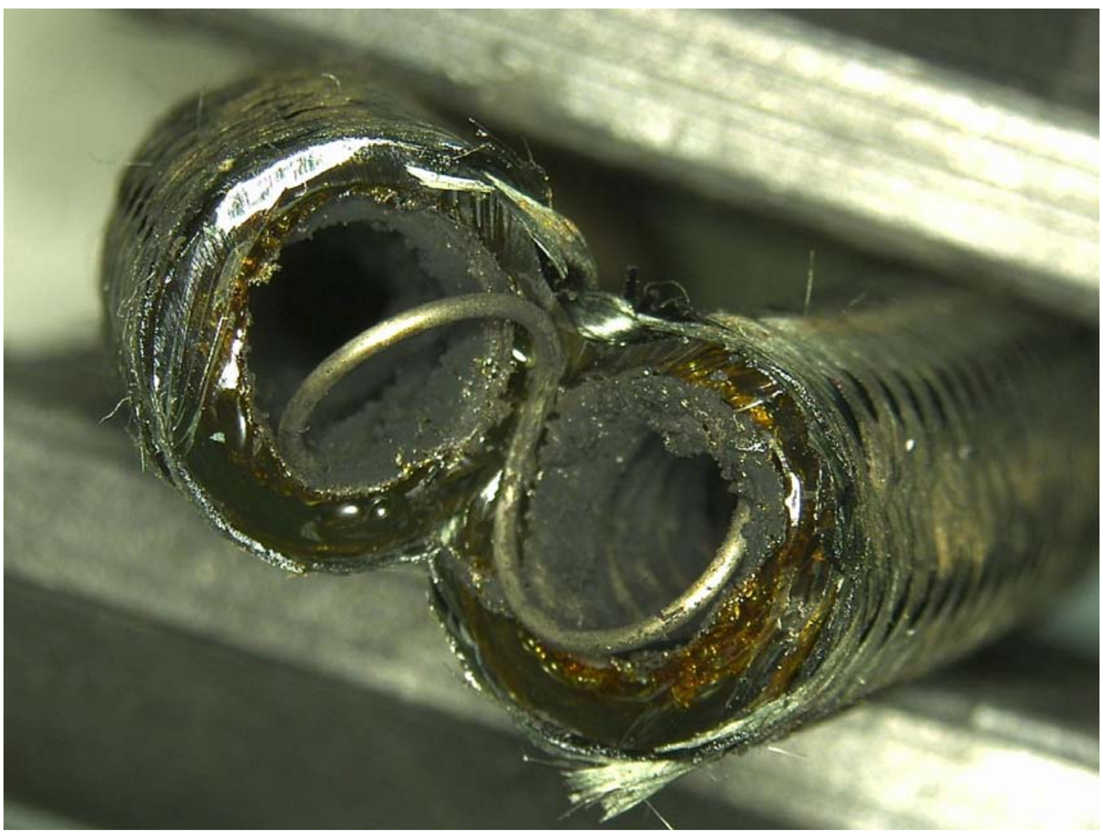

Figure 7: Soot coating the inner surface of the hose from Test #3

TEST #4—28 VDC, 3.0 A

In Test #4, the conductive flexible hose assembly was exposed to 28 Volts DC and a current of 3 Amperes. From the time of current application, it took 80 s for the hose to fail causing a light hissing sound. This hissing sound gradually grew in volume over a 60 s duration. No fire resulted. Immediately after the test, the hose was found to be hot and pliable. After the test, a transverse cross-sectional cut was made in the hose revealing that the inside of the hose had become yellow/amber in color but no char or soot-like material had developed (figure 8).

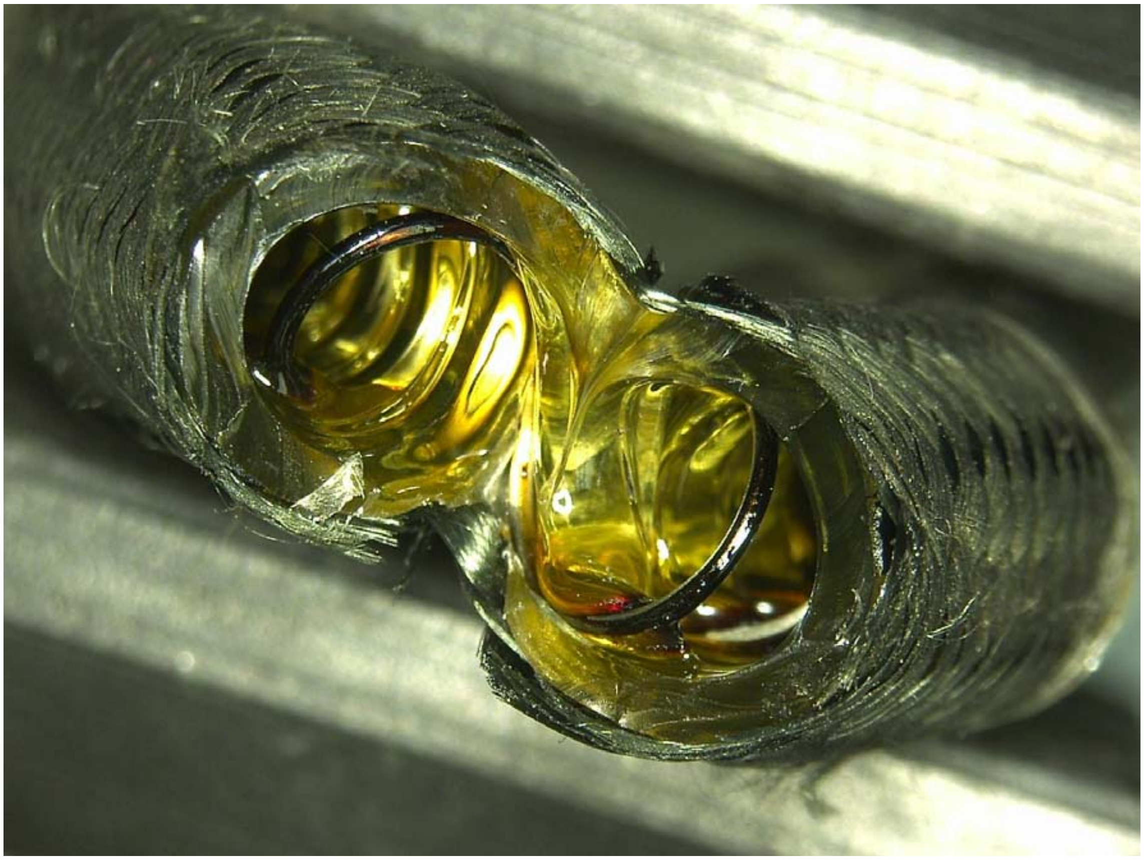

Figure 8: Inside surface of hose after Test #4

TEST #5—120 VAC, 9 A

In Test #5, the conductive flexible hose assembly was exposed to 120 Volts AC and a current of 9 Amperes. After 4 s, a flash resembling an electrical arc was observed from the upstream end of the hose extending to approximately mid span of the hose. The hose also began to contort. After 6 s, the hose ignited (figure 8) with a loud pop and hissing sound. The hose failed nearly simultaneously at the downstream end, the upstream end, and at approximately mid-span. At the downstream end, the hose burst with a white flash and ejected a jet of thick black smoke followed by bursting and flaming ignition. A small jet of fire and black smoke emanated from a failure point at the mid-span location, and flaming ignition with the ejection of incandescent particles took place at the up stream end. From the upstream end, a bright white glow extended to about mid-span for about a second after the failure. This portion of the hose that was glowing white is seen in figure 9 as a purple region. This region eventually changed to white as the reaction ensued.

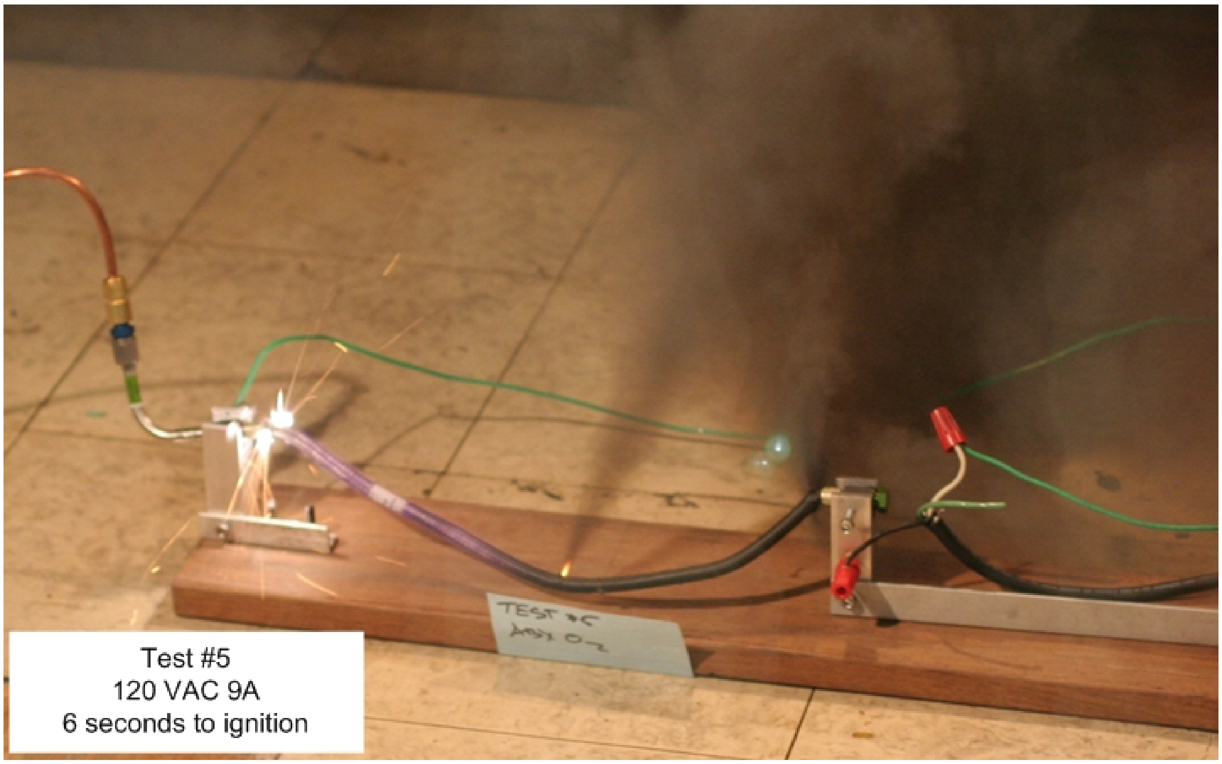

Figure 9: Hose failure during Test #5.

Examination of the hose remains after the test revealed that the hose had been heavily consumed from the upstream end to the mid span location (figure 10). What remained along this section of the hose was a c-shaped channel as seen in the inset of figure 10. From the upstream fitting to approximately the mid-span location, the helical coil that would have been on the inside of the hose was missing. A longitudinal cross sectional cut was made on the remaining down stream portion of the hose and the interior of the hose was found to have a heavy coating of soot adhering to the surface (figure 11).

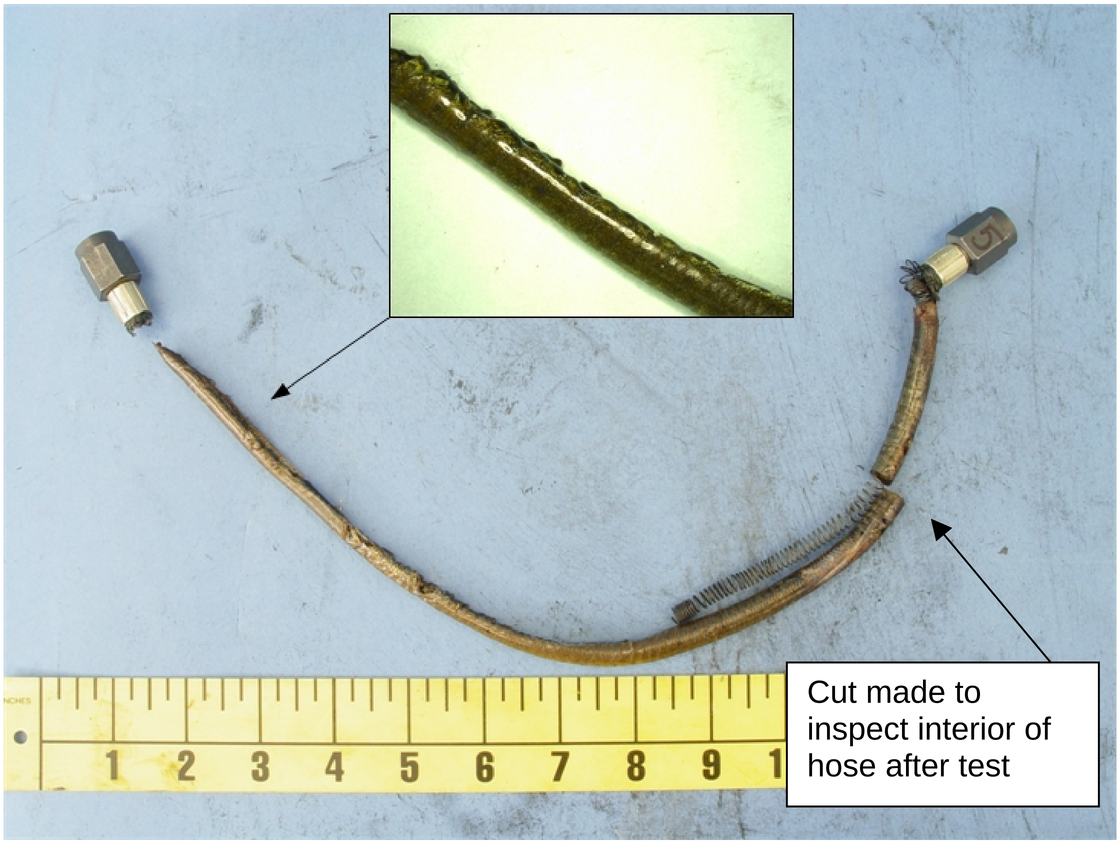

Figure 10: Hose assembly after Test #5 (over braid removed for clarity)

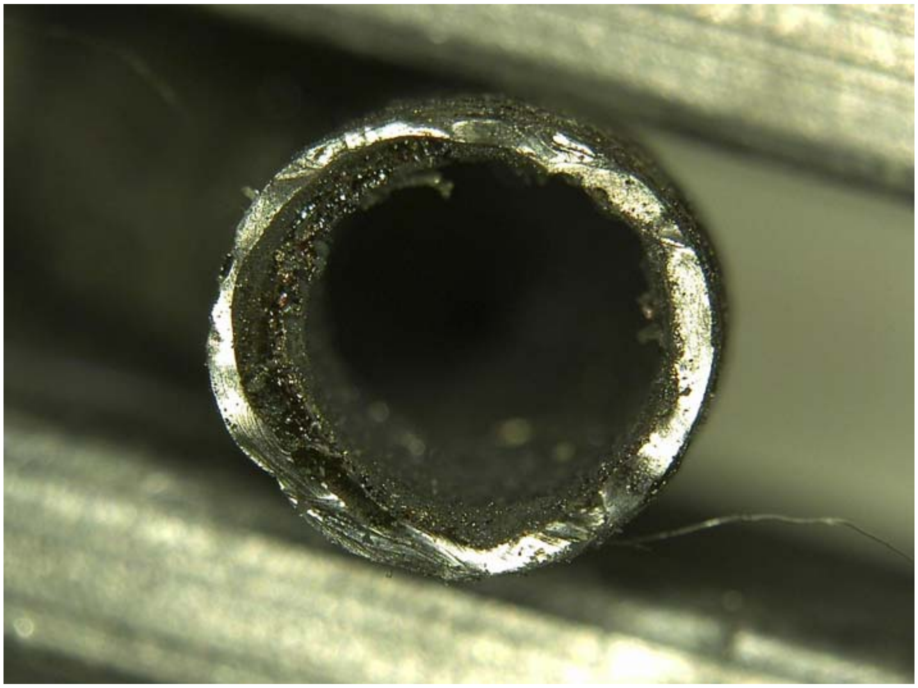

Figure 11: Inside of hose after Test #5 (cut made near down stream end)

Test #6—forced burn using a Nichrome heater

In addition to Tests #1 through #5, where current was passed through the hose assembly; Test #6 evaluated the behavior of the flexible hose when exposed to a concentrated external heat source (via windings of resistance-heated Nichrome wire around the OD of the hose) while the hose was pressurized with oxygen. The remnants of the hose assembly from Test #1 were used for Test #6.

To conduct Test #6, one threaded end of the Test #1 hose-assembly remnant was connected to the oxygen supply line and the other end of the hose was capped with a plug fitting. Nichrome wire was wrapped around the OD of the hose at approximately mid span, where the hose had failed during Test #1. The Nichrome wire was resistively heated via electrical current, and the oxygen valve was opened allowing 70-psig oxygen to pressurize the hose. After about 40 s, the hose began to smoke and ignition occurred. As the ignition ensued, the volume of the hissing sound from the flowing oxygen increased. The fire burned white hot and bursts of incandescent particles were periodically ejected from the fire (figure 13). The fire burned for about 180 s before it was intentionally stopped. The fire resembled an oxyacetylene cutting torch. While the fire was burning, the hose remained relatively stationary and did not flail around. After the test was stopped, small particles consisting of portions of the helical coil originally inside the hose assembly were found on the floor (figure 12). The ends of these small sections of the stainless steel coil were melted and some had small beads on them.

Test#7—flame impingement evaluation

A forced ignition test was conducted where the burning end of the flexible oxygen hose was aligned so that the resulting fire impinged on a 90-degree elbow made from stainless steel tube (figure 14) (same type of tube used on the aircraft oxygen system). The test was stopped once the flexible hose deflected far away from the elbow. Upon termination of the test, the elbow was glowing but had not melted. The heat-affected zone on the elbow was quite narrow as seen in figure 14, indicating that the burning hose produces a concentrated and directional heat output.

Figure 12: Small portions of helical coil with melted and beaded ends

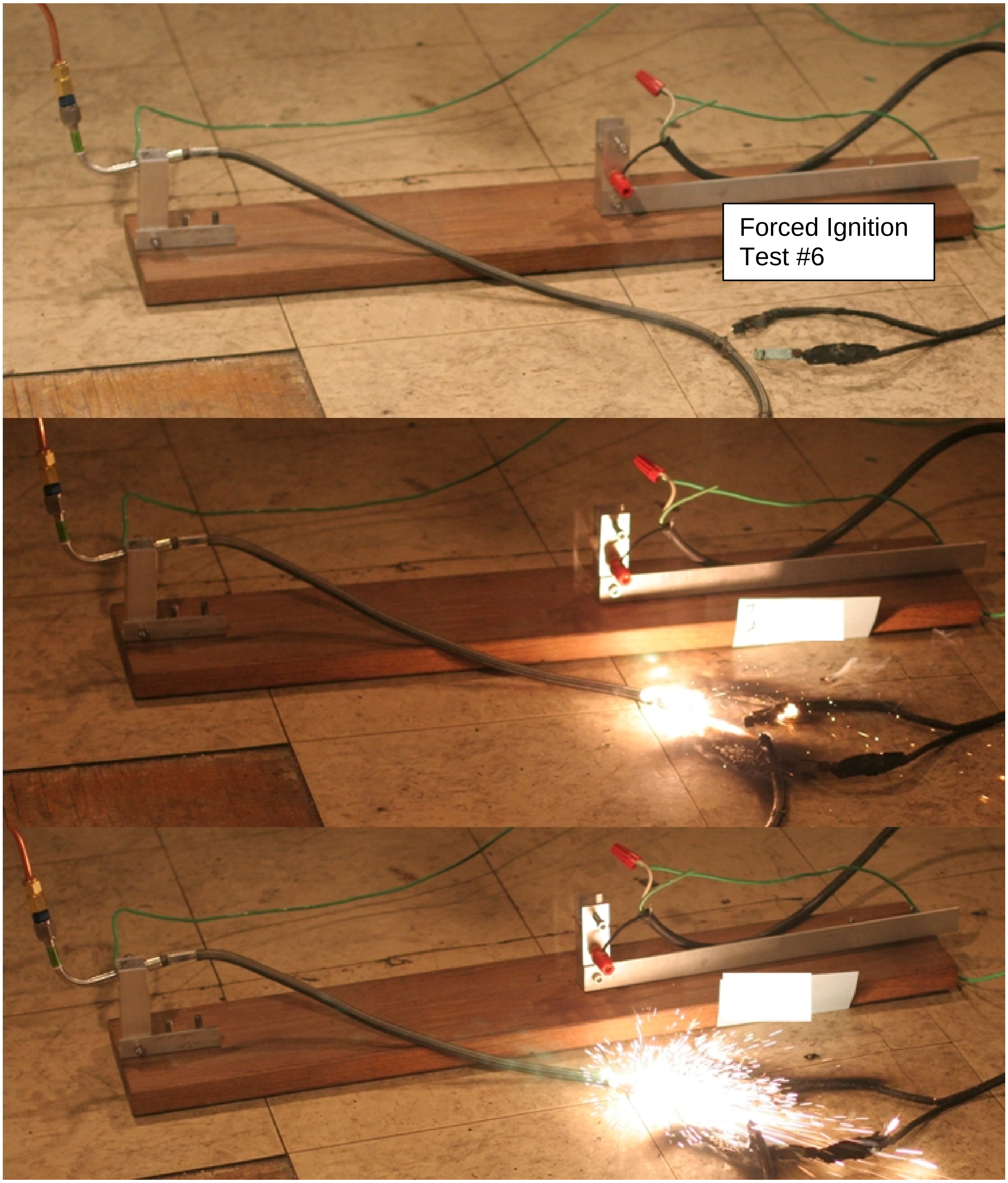

Figure 13: Burning oxygen hose resulting from forced ignition

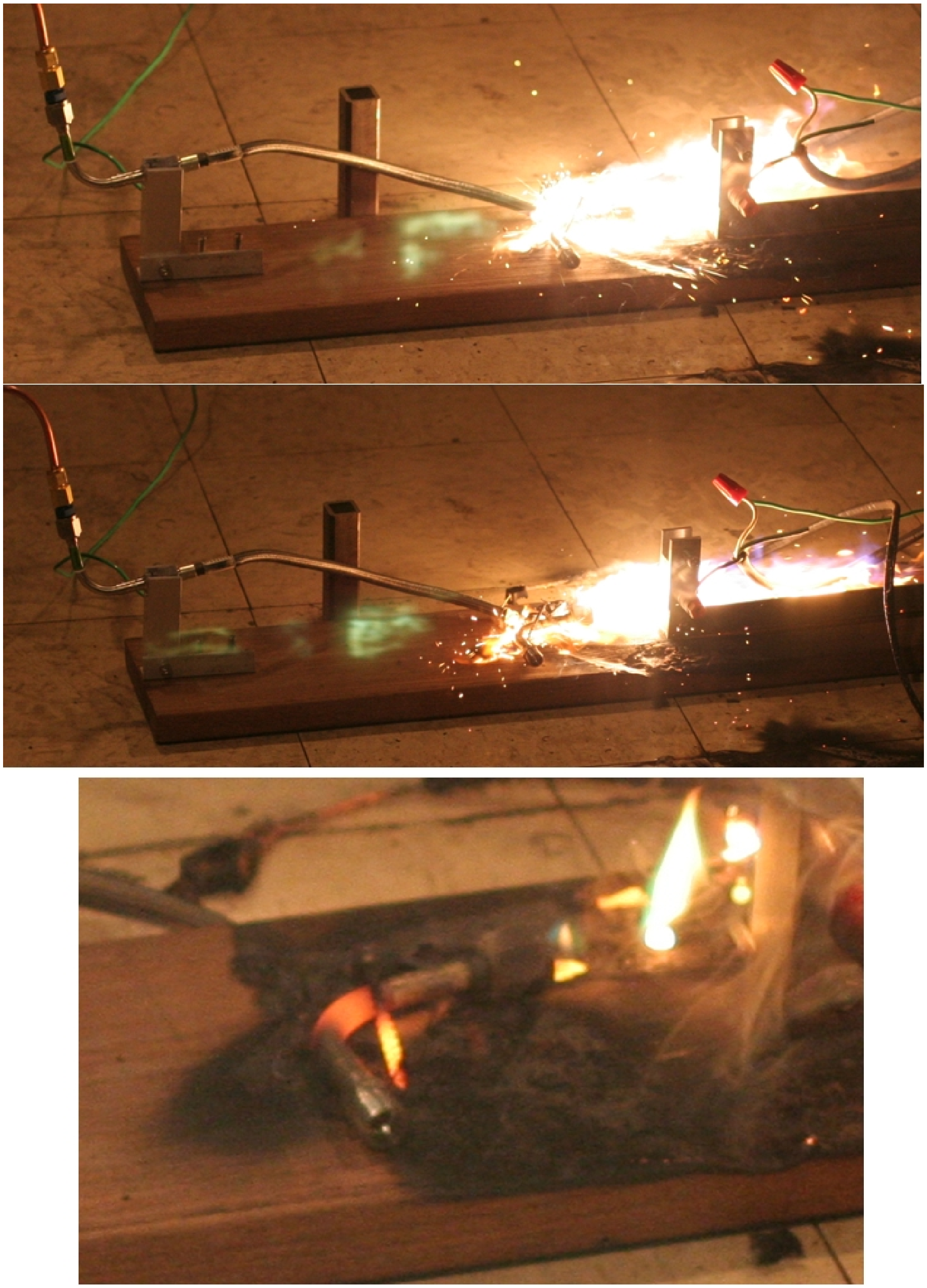

Figure 14: Forced flexible oxygen hose fire impinging on stainless steel tube

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