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DOT Exemption for Display Fireworks with Electric Matches Attached

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Background

Several years ago the US Department of Transportation granted an exemption[1] that, under certain conditions, "*authorizes the transportation in commerce of Division 1.3 and 1.4 display fireworks with igniters (electric matches) attached to either the fuse or the lift charge.*" Because of concern regarding one of the specific provisions of that exemption, a brief study was undertaken. This short article discusses that concern and reports on the results of the study. (A restatement of the full set of conditions that must be met is beyond the scope of this article, see reference 1.)

The specific provision that gives rise to concern is the requirement that the electric match attached to the firework must have its safety shroud in place if the electric match is in the lift charge, but the safety shroud is not required if it is securely attached to the shell leader fuse (see Reference 1, paragraphs 8f and g). The concern is that, assuming one of the two electric match locations should not require the presence of the safety shroud, it seems that the requirement for when the safety shroud is to be in place is reversed.

It would seem that the safety shroud is most needed when the electric match is attached to shell leader fuse. This is the case where the electric match is most exposed to the potential for impact that could produce an accidental ignition. This is illustrated in Figure 1. The upper left sketch attempts to illustrate the potential problem of two shell casings (or one shell casing and another rigid object) coming together in such a manner as to pinch a portion of one shell's leader fuse between them. In this case, see the lower left sketch, the full impact force is delivered to the fuse. Were there to have been an electric match inserted into the fuse at the point of impact, there is potential for the impact to cause the electric match to be crushed and to ignite as a result of the impact. (The amount of impact energy needed to cause the ignition of the most common electric matches in use today is uncomfortably low.[2])

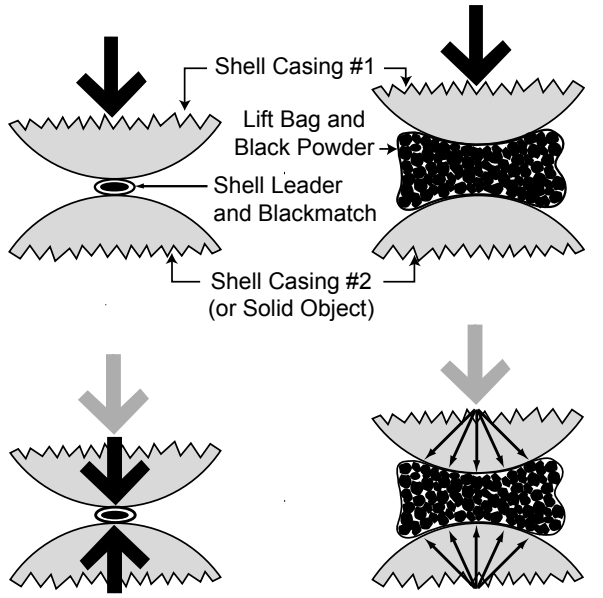

Figure 1. Sketches illustrating two possible impact scenarios occurring between two aerial shells: left, an impact with a shell leader at the point of contact; right, an impact with a bag of lift powder at the point of impact.

In contrast, consider the case where the impact occurs such as to catch the bag of lift powder between the colliding shells. The upper right sketch of Figure 1 attempts to illustrate this situation. In this case, because of the very nature of the granulated lift powder, the impact force comes to be distributed fairly evenly across a much larger area, see the lower right sketch. Accordingly, were there to have been an electric match inserted into the lift charge at the point of impact, there is substantially reduced potential for its being crushed and igniting as a result of the impact.

Testing

While the reduction in impact force for the lift bag case seems obvious, because of the important safety implications, it was thought to be worth confirming by testing. Two series of tests were undertaken. In the first tests, the relative impact forces for the two cases illustrated in Figure 1 were measured. For these tests an impact sensitiveness tester, with a 0.5 kg (1.1 lbf) drop hammer, was used to provide the impact force. To simulate the approximate rigidity of aerial shell casings, the end of both the drop hammer and the impact surface of the calibrated piezoelectric force gauge were covered with a 3-mm (1/8-in.) thick Kraft paper disk. For the case where the aerial shells impact against shell leaders, a short section of quick match was placed between the drop hammer and force gauge. The data from the impacts were recorded and stored using a digital oscilloscope. The result of an impact from a height of 300-mm (1-ft) is documented in the upper graph of Figure 2, where it is the much taller of the two peaks.

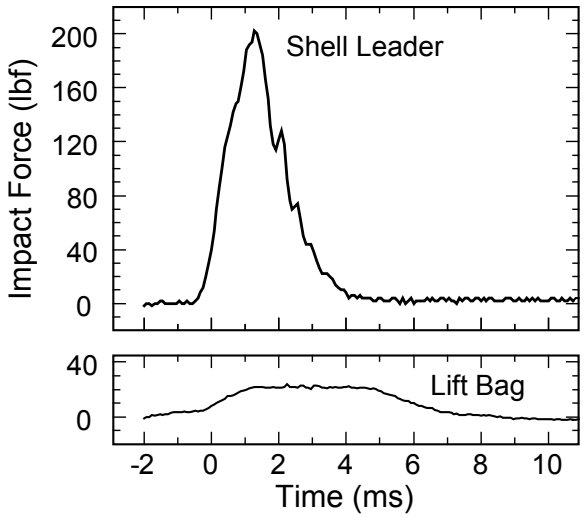

Figure 2. A graph of data demonstrating the substantial difference in the impact forces delivered to an electric match size object in collisions between two aerial shells with a shell leader and with a bag of lift powder at the point of contact.

Aerial shell impacts against bags of lift powder were simulated using much the same method; however, small plastic bags filled with silica sand were used as a substitute for Black Powder. (This was done to limit the amount of fire that would be produced in the laboratory in the case of an ignition.) The recorded impact force from a test is shown in Figure 2 as the curve with the much lower peak force. The ratio of peak impact forces developed for the two cases examined is approximately 10 to 1. This confirms the prediction of much greater impact force against electric matches in shell leaders caught between aerial shells as compared with impacts against electric matches in lift bags, where the force is distributed over a much greater area.

As a final test, a series of impacts were made to occur when actual electric matches were used to determine the relative ease of their accidental ignition in the two scenarios being investigated. The electric matches used in these tests were the Daveyfire A/N 28 B matches with their safety shrouds removed. For these tests the same impact sensitiveness tester was used; however, this time it was fitted with a 5 kg (11 lbf) drop hammer. As in the earlier tests, the approximate rigidity of aerial shell casings was simulated by covering both the end of drop hammer and the lower impact surface with a 3-mm (1/8-in.) thick Kraft paper disk. A short section of quick match shell leader with an electric match attached was placed between the drop hammer and the lower impact surface at the point of impact. After some initial experimentation to discover the approximate sensitiveness of the electric matches in this configuration, four tests were performed using an impact height of 0.45-m (18-in.). Each time it was found that the electric match (and shell leader) ignited from the impact.

In the lift bag test configuration, silica sand was again used as a substitute for Black Powder. (This was done to limit the amount of fire that would be produced in the laboratory in the case of an ignition.) In deciding on the appropriateness of the use of silica sand, it was considered that: 1) the sand grains are both stronger and more abrasive than Black Powder; and 2) for the electric matches being used, an earlier study found that they did not exhibit greater sensitiveness in the presence of Black Powder. Accordingly, the electric matches should be at least as likely to ignite in these tests in the presence of silica sand as they would had Black Powder been used. Four tests were performed using the 5-kg (11-lbf) drop hammer, the most massive available, and an impact height of 1.5 m (60 in.), the maximum convenient height for the impact tester. It was found that no ignition of the electric match occurred in any test. Accordingly, the un-shrouded electric match in the shell

leader configuration was found to be at least 3.3 times as sensitive to accidental ignition from impact as compared to the un-shrouded electric match in the lift bag configuration.

Discussion

The DOT exemption of shipping display fireworks, with electric matches attached, requires that the safety shroud be in place when the electric match is in the lift charge, but not when the electric match is in a shell leader fuse. It seemed that the requirement for when safety shrouds were required to be in place was reversed from what it should have been considering accidental ignition from impact. This was readily confirmed even with the very limited amount of testing performed, in which the sensitiveness due to impact was at least 3 times greater (and perhaps 10 times greater) for un-shrouded electric matches in the shell leader fuse as compared with electric matches inserted into the lift charge.

Certainly, there are possibilities for accidental ignition during transportation other than impact. However, the authors can think of no case where there is greater need for the presence of the shroud when the electric match is in the lift charge as compared to the shell leader. For this reason, and because safety shrouds do provide substantial reductions in both impact and friction sensitiveness,[2] it is strongly recommended that shippers of display fireworks with electric matches installed in shell leader fuses, only do so with the safety shrouds left in place.

Acknowledgment

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References

1) US Department of Transportation, DOT–E 11685.

2) K. L. and B. J. Kosanke, “Studies of Electric Match Sensitiveness”, *Journal of Pyrotechnics*, No. 15, 2002; also appearing in this collection of articles.