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Avail and/or Special
DETERMINATION OF METAL SPARKING CHARACTERISTICS
AND THE EFFECTS ON EXPLOSIVE DUST CLOUDS

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ABSTRACT

Of major concern in industry are hazards posed by metal-to-metal sparking in environments where potentially explosive dusts are present. The probability of ignition of a dust cloud by metal sparking is dependent on many factors including the type of metal, the contact speed of the metal surfaces, the contact time of the metal surfaces, the pressure on the contact surface and the type and concentration of the dust cloud present.

Metal sparking tests were performed as part of a hazard analysis program, Safety Consulting Engineers, Inc. conducted for ICI Americas, Inc.

The purpose of the test was to determine the sparking characteristics of a series of metals and the effects of the sparks produced on several types of dust clouds.
INTRODUCTION

Explosibility tests have been performed in the past to determine the relative destructive output of various types of dusts. Test chambers were used to simulate dust explosion. Figure 1 is a sketch of Bureau of Mines 20-liter chamber equipped with a sample dust dispersion mechanism. The 20-liter chamber was modified to contain the mechanical sparking system. Figure 2 is a sketch of the modified Bureau of Mines 20-liter chamber.

The spherical shape of the 20-liter chamber helps provide a uniform dust suspension. A 7.62 cm (3-inch) diameter by 0.635 cm (1/4-inch) thick 304L stainless steel contact wheel mounted on a shaft, which protrudes through the side wall of the chamber, is driven by an electric motor located outside the chamber. A 0.635 cm (1/4-inch) diameter by 5.08 cm (2-inch) long rod is held by a lever bar against the circumference of the metal wheel. A dead weight of 1362 grams (3 pounds) is located at the outside portion of the lever bar. A viewing window and mirror allowed remote observation of the tester.

PROCEDURE

Each rod material/dust combination test was performed as follows. The preweighed dust sample was first placed in the bottom of the chamber. The rod material was raised using a pulley mechanism before the test chamber was closed. The electric motor was turned on to start the contact wheel. Pressurized air from the test chamber nozzle dispersed the sample dusts uniformly while the rod material was dropped to make contact with the rotating wheel. Ignition of the dust cloud was then observed through the view mirror. The setup is illustrated in Figure 3.

TEST RESULTS

The first series of tests consisted of testing six metal rods to determine the minimum contact wheel speed which would produce sparking for each rod. The following metal rods were tested: 1018 Mild Steel, 316 Stainless Steel, 304 Stainless Steel, 304L Stainless Steel, 3003-H14 Aluminum and 6061-T6 Aluminum. By determining the minimum wheel rotation speed that produced sparking for each one of the metal rods tested, the types of metals more likely to produce sparking were identified. Table 1 contains results of these tests and shows that 304 Stainless Steel rod produced sparking at the lowest wheel speed. Neither aluminum rods produced no sparking at the maximum wheel speed available.
Figure 1. U. S. Bureau of Mines 20-liter chamber.
Figure 2. Modified Bureau of Mines 20-liter chamber.
Figure 3. Metal sparking test setup.
After the minimum sparking speeds were found, five different propellant dusts, M6, M30A1, M31A1, CBI, Black Powder, one carbonaceous dusts, Pittsburgh coal dust and one commercial product, cornstarch, were tested to determine the minimum sparking speed for each rod type that would ignite each sample dust. The sample materials tested were ground and sieved through mesh screen (-200 and -100). Table 2 lists the minimum sparking speed for each rod tested that would ignite each sample dust. Results of testing indicated that 1018 Mild Steel was the material aluminum rods failed to produce sparking at low speeds, these materials did not ignite the sample dusts.

The third test series was conducted at a peripheral wheel speed of 14.0 meter/sec (=45.8 ft/sec) for all rod material-sample dust combinations. This test series allowed a ranking of the sample dusts based on ignition sensitivity. The most sensitive dust was M6 propellant with sensitivity decreasing respectively for CBI, cornstarch, M30A1, M31A1, Black Powder and Pittsburgh coal dust. The test rod materials, in order from the most likely to least likely to produce ignition were 1018 Mild Steel, 304L Stainless Steel, 304 Stainless Steel, 316 Stainless Steel, 3003-H-14 Aluminum and 6061-T6 Aluminum. Table 3 illustrates the decreasing ignition sensitivity for the dust samples tested with rods in the order of least likely to produce ignition.

The fourth series of tests consisted of testing all rod material sample dust combinations that produced ignition in the third series of tests, at a peripheral wheel speed of 14.0 meter/sec. The contact time of the rod material and wheel was limited to 0.5 sec. Again this test series allowed a ranking of the sample dusts based on ignition sensitivity during a relatively short exposure to sparking. Table 4 shows that all sample dusts tested ignited when 1018 Mild Steel was used. Cornstarch, CBI, M6 and Black Powder also ignited when tested with 316 Stainless Steel rod.

CONCLUSIONS

Metal sparking tests, on various metals in several dust cloud environments, showed a distinction between metals that are relatively safer to handle in an explosive dust cloud atmosphere and those that may be unsafe.

Metals found to present a lower sparking hazard include both 3003-H14 and 6061-T6 Aluminum.

Metals tested that are not well suited to an explosive dust cloud atmosphere include 1018 Mild Steel, 304L Stainless Steel, 304 Stainless Steel and 316 Stainless Steel because of their greater tendency to produce sparking.
The potential for explosive dust initiation appears to be greater when contact speed with metals exceeds 9.2 meter/sec (30.1 ft/sec) for 1018 Mild Steel, 8.4 meter/sec (27.5 ft/sec) for 304L Stainless Steel, 7.2 meters/sec (23.6 ft/sec) for 304 Stainless Steel, 7.2 meters/sec (23.6 ft/sec) for 304 Stainless Steel, 8.4 meter/sec (27.5 ft/sec) for 316 Stainless Steel.

At longer metal contact times (with speed greater than the minimum contact speed which would produce sparking for each metal), a greater potential hazard of ignition may also be possible.
### TABLE 1

**MINIMUM CONTACT WHEEL SPEED WHICH WOULD PRODUCE SPARKING FOR EACH ROD**

Contact Force: 13.3 N (3 lbf)

<table>
<thead>
<tr>
<th>MATERIAL ROD</th>
<th>MINIMUM CONTACT WHEEL SPEED (m/s)</th>
<th>(rpm)</th>
<th>(ft/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>.018 Mild Steel</td>
<td>9.2</td>
<td>2300</td>
<td>30.1</td>
</tr>
<tr>
<td>304L Stainless Steel</td>
<td>8.4</td>
<td>2100</td>
<td>27.5</td>
</tr>
<tr>
<td>304 Stainless Steel</td>
<td>7.2</td>
<td>1800</td>
<td>23.6</td>
</tr>
<tr>
<td>116 Stainless Steel</td>
<td>8.4</td>
<td>2100</td>
<td>27.5</td>
</tr>
<tr>
<td>3003-H14 Aluminum</td>
<td>No visible spark at maximum speed of 19.9</td>
<td>5000</td>
<td>65.4</td>
</tr>
<tr>
<td>3061-T6 Aluminum</td>
<td>No visible spark at maximum speed of 19.9</td>
<td>5000</td>
<td>65.4</td>
</tr>
<tr>
<td>SAMPLE DUST TEST</td>
<td>DUST PARTICLE SIZE (μm)</td>
<td>SAMPLE DUST CONC. (g/liter)</td>
<td>1018 MILD STEEL</td>
</tr>
<tr>
<td>------------------</td>
<td>-------------------------</td>
<td>-----------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>M6</td>
<td>75</td>
<td>0.0029</td>
<td>12.4 (40.6)</td>
</tr>
<tr>
<td>M30Al</td>
<td>75</td>
<td>0.0029</td>
<td>11.2 (36.6)</td>
</tr>
<tr>
<td>M31Al</td>
<td>150</td>
<td>0.0059</td>
<td>10.4 (34.0)</td>
</tr>
<tr>
<td>CBI</td>
<td>150</td>
<td>0.0059</td>
<td>8.8 (28.9)</td>
</tr>
<tr>
<td>Black Powder</td>
<td>75</td>
<td>0.0029</td>
<td>11.6 (37.9)</td>
</tr>
<tr>
<td>Pittsburgh coal dust</td>
<td>75</td>
<td>0.0029</td>
<td>10.0 (32.7)</td>
</tr>
<tr>
<td>Cornstarch</td>
<td>75</td>
<td>0.0029</td>
<td>8.0 (26.2)</td>
</tr>
</tbody>
</table>

- showed no ignition up to a maximum speed of 19.9 m/s (65.4 ft/s)
<table>
<thead>
<tr>
<th>SAMPLE DUST TESTED</th>
<th>DUST PARTICLE SIZE (µm)</th>
<th>SAMPLE DUST CONC. (g/liter)</th>
<th>1018 MILD STEEL</th>
<th>304L STAINLESS STEEL</th>
<th>304 STAINLESS STEEL</th>
<th>316 STAINLESS STEEL</th>
<th>3003-H14 ALUMINUM</th>
<th>6061-T6 ALUMINUM</th>
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</thead>
<tbody>
<tr>
<td>M6</td>
<td>75</td>
<td>0.25</td>
<td>20</td>
<td>19</td>
<td>18</td>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CBI</td>
<td>150</td>
<td>0.41</td>
<td>19</td>
<td>17</td>
<td>18</td>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cornstarch</td>
<td>75</td>
<td>0.35</td>
<td>20</td>
<td>9</td>
<td>7</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M30Al</td>
<td>75</td>
<td>0.41</td>
<td>19</td>
<td>18</td>
<td>15</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M31A+</td>
<td>150</td>
<td>0.32</td>
<td>14</td>
<td>13</td>
<td>11</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black powder</td>
<td>75</td>
<td>0.25</td>
<td>17</td>
<td>8</td>
<td>6</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pittsburgh coal dust</td>
<td>75</td>
<td>0.35</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
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</tr>
</tbody>
</table>

- showed no ignition
### TABLE 4

**METAL SPARKING TEST RESULTS AT METAL WHEEL SPEED OF 14.0 m/s (45.8 ft/s) WITH ROD MATERIAL CONTACT TIME OF 0.5 SEC.**

<table>
<thead>
<tr>
<th>SAMPLE DUST TESTED</th>
<th>DUST PARTICLE SIZE (µm)</th>
<th>DUST CONC. (g/liter)</th>
<th>1018 MILD STEEL</th>
<th>316 STAINLESS STEEL</th>
<th>304 STAINLESS STEEL</th>
<th>304L STAINLESS STEEL</th>
<th>3003-H14 ALUMINUM</th>
<th>6061-T6 ALUMINUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cornstarch</td>
<td>75</td>
<td>0.0029</td>
<td>0.35</td>
<td>15</td>
<td>10</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M6</td>
<td>75</td>
<td>0.0029</td>
<td>0.25</td>
<td>12</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CBI</td>
<td>150</td>
<td>0.0059</td>
<td>0.41</td>
<td>10</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Black Powder</td>
<td>75</td>
<td>0.0029</td>
<td>0.25</td>
<td>10</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>M31Al</td>
<td>150</td>
<td>0.0059</td>
<td>0.32</td>
<td>9</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>M30Al</td>
<td>75</td>
<td>0.0029</td>
<td>0.41</td>
<td>8</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pittsburgh coal dust</td>
<td>75</td>
<td>0.0029</td>
<td>0.35</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

- showed no ignition