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NEW INFRARED FLARE
AND HIGH-ALTITUDE
IGNITER COMPOSITIONS (U)

CHARLES A. KNAPP

JULY 1959

FELTMAN RESEARCH AND ENGINEERING LABORATORIES
PICATINNY ARSENAL
DOVER, N. J.

ORDNANCE PROJECT TSS-5200 (AIR)
DEPT. OF THE ARMY PROJECT 504-01-301

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NEW INFRARED PLANE AND
HIGH-ALTITUDE IGNITER COMPOSITIONS (U)

by

Charles A. Knapp

July 1959

Peterson Research and Engineering Laboratory
Phenix Annex
Dover, N. J.

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Technical Report 2662

Ordnance Project 738-6569 (Air)

Dept of the Army Project 536-01-391

Approved
S. Sago
Chief, Pyschemlron
Laboratory
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OBJECT

To conduct research on and to develop infrared flare decoy systems with energy output rich in the 1.8 - 2.8 \( \mu \) spectral region for the protection of jet aircraft against infrared-seeking missiles. (This work is being conducted under Air Force contract (34-616) 58-45.)

SUMMARY

Breakthroughs have been achieved with both infrared flare compositions and high-altitude igniter compositions. Preliminary tests of a new flare composition (SI-119) show that its burning rate and high ignitability are unaffected by increasing altitude up to 100,000 feet (6 mm Hg) and that its peak infrared energy output (watts) and efficiency (joules/g and cc) increase with increasing altitude. The new composition, which consists of molybdenum trioxide/chromic oxide/zirconium, shows considerable promise for use in decoy systems for jet aircraft. Both the currently used teflon/magnesium/nitrocellulose compositions and the older, less efficient sodium nitrate/magnesium/Laminac compositions are adversely affected by increasing altitude: peak energy output and efficiency decrease severely, burning rate decreases greatly, and the flares become very difficult to ignite. At high altitude the SI-119 composition is far superior to teflon compositions, especially during the first 12 seconds of burning.

New high-altitude igniter compositions containing molybdenum trioxide/chromic oxide/zirconium (SI-122 and 131) have also been formulated which ignite teflon compositions at altitudes up to 100,000 feet (highest altitude simulated). These new igniter compositions should perform as well or better with sodium nitrate compositions. They are superior to the 99/10/1 barium chromate/boron/nitrocellulose composition which, unless partially confined, is unreliable above 40,000 feet altitude and is more sensitive to frictional forces.

RECOMMENDATIONS

In view of the encouraging results with respect to burning characteristics and energy output obtained with new infrared flare compositions containing molybdenum trioxide/chromic oxide/zirconium further research and development should be conducted. With higher energy oxidizing agents this type of composition may equal or exceed the total efficiency of the teflon composition at lower altitudes as well as at 100,000 feet. It is also expected that the advantages of burning rates unaffected by decreasing pressure plus excellent ignitability could be maintained.

It is further recommended that more extensive tests be conducted with the new high-altitude igniter compositions (\( \text{MoO}_3/\text{Cr}_2\text{O}_7/\text{Zr/NC} \)) to determine optimum composition and reliability. The use of coarser zirconium should be investigated to further reduce sensitivity to friction and impact.

The use of conductive igniter
characteristics at the high altitudes.

Although research and development of projection systems (for use with jet aircraft) are also continuing, only the most outstanding flare and igniter compositions are discussed in this report.

(C) RESULTS AND DISCUSSION

Development of Flare Composition

4. Composition formulations with heats of reaction and heats of combustion data are listed in Table 1 (p.7). Since the calorimetry tests were conducted under confined conditions, these results probably represent upper energy limits. At high altitudes where vacuum conditions exist, combustion efficiency and reaction energy are reduced due to lower flame temperatures and much slower burning rates. This was shown in a previous report (Ref 2) where a composition consisting of 54% magnesium, 50% teflon, and 16% Kell gave an average heat of reaction in one atmosphere of helium of 1521 calories/gram and at 5 milliseconds of helium of 1212 calories/gram.

5. Further evidence of the deleterious effects of reduced pressure on burning characteristics can be seen in Table 2 (p. 8) and Figure 1 (p. 112). The efficiency of sodium nitrate/magnesium/Laminac and teflon/magnesium/nitrocellulose compositions in the form of pressed flares decreases sharply with increasing altitude (decreasing pressure). The peak infrared energy output of the teflon composition decreases 70% from sea level to 60,000 feet and 95% from sea level to 100,000 feet. In addition, the burning rate decreases approximately 2 and 7 times, respectively. Nevertheless, the teflon/magnesium/nitrocellulose system is far superior to the sodium nitrate system. This may be due to the large quantity of incandescent carbon (high emissivity) produced by the reaction of the teflon composition.

6. A radical departure from the above trends occurred with a composition consisting of MoO3/Cr2O3/Zr (SI-119). This composition became significantly more efficient with increasing altitude. Peak energy output and efficiency increased up to 60,000 feet and tapered off slightly at 100,000 feet. The burning rate of the SI-119 composition remained essentially unchanged at the higher altitudes. These effects can be seen in Table 2 (p. 8) and Figure 2 (p. 13). It is important to note that whereas at sea level composition SI-119 was much less efficient and produced a much lower peak energy output (in watts) than the teflon system, at 60,000 feet the peak energy of SI-119 was about 4 times higher than that of the teflon system (although efficiency was still lower). At 100,000 feet (simulated altitude) the peak energy level of SI-119 was about 20 times greater than that of the teflon system, and its efficiency (in joules/cc) was approximately the same (over the entire burning period). If only the first 12 seconds of burning are considered it can be seen from Table 3 (p. 9) that composition
Ni 119 is far superior to the teflon system in peak energy output at 60,000 and 100,000 feet, and efficiency at 100,000 feet. All flares in the above study were end burning and had approximately the same burning surface area.

7. Table 1 (p. 7) shows Composition SI-119 to have a relatively low heat of reaction and combustion. It is anticipated that its reaction energy can be greatly increased by incorporating chemicals producing higher energy. One approach is the use of perchlorates as oxidizing agents. For example, KClO₄ with zirconium produces 1610 calories/gram and 6150 calories/cc (based on calculated true density). Other perchlorates can give even higher energies (Ref 3). Another approach is the use of superoxides of the first two periodic groups. For example, the calculated heat of reaction for K₂O₃ and zirconium is 1170 calories/gram. The use of higher oxygen complex compounds of molybdenum (M₄MoO₄) with the alkali metals should also be investigated. In addition, the use of excess zirconium may also be of value. Composition SI-119 is approximately stoichiometric, assuming ZrO₂, Mo, and Cr as products. Still another approach to the optimum composition is a mixture of the zirconium (SI-119) and the teflon compositions.

8. Another important advantage of Composition SI-119 is that it is highly ignitable. It is also used as an igniter composition and can be initiated directly by an M1A1-type squib (containing 90/10 barium chromate/boron) up to 100,000 feet. It is believed that squibs or primers could be eliminated if desired, since this new composition can probably be ignited by hot wires (squib principle). Simplifying the system by eliminating components might logically lead to increased reliability. To slow down the relatively fast burning rate of SI-119 and to reduce its sensitivity to friction, use of zirconium (Ref 4) and binders could be used.

9. Composition SI-119, which contains no binder, was pressed into a paper flare case for testing. If necessary, it can be converted into a caseless flare by means of binders in the same manner as the sodium nitrate/magnesium and teflon/magnesium compositions. To meet requirements, binders can also be used to adjust the burning rate. It is anticipated, however, that even with the incorporation of binders the burning rate of composition SI-119 will remain relatively unaffected by changes of altitude over the range of sea level to 100,000 feet.

Development of Igniter Composition

10. Two new igniter compositions containing MoO₃/Cr₂O₃/Zr/nitrocellulose (SI-122 and SI-131) have been developed for use with teflon/magnesium/nitrocellulose flare formulations. Although these igniter compositions were not tested with sodium nitrate/magnesium/nitrocellulose flare compositions, the results of Reference 4 indicate that they should
perform even better with flares of thin type. Static ignition test results with flare compositions are given in Table 4 (p 10). Ignition of the flare compositions was accomplished over the simulated altitude range of sea level to 100,000 feet with completely unconfined systems. At 100,000 feet, however, ignition of the flares by the igniter was erratic. Preliminary tests with these igniters indicate that at 100,000 feet the type of surface of the flare may be critical. Flares with porous surfaces ignited consistently while those with hard glazed surfaces did not. It should be pointed out that when the standard Ria igniter composition, SI-56 (barium chromate/boron/nitrocellulose), is completely unconfined, it performs erratically between 40,000 and 60,000 feet. Above 60,000 feet it fails completely to ignite the flare composition.

13. (U) Binderless compositions were blended in an Abbe ball mill for ½ hour. Rubber stoppers were used to insure proper blending.

14. (C) SI-122 and 131 were blended by stirring with a wooden rod in a mortar. The nitrocellulose was used as a 10% solution in acetone. Excess acetone (up to 30 cc/100 g mix) was used for blending. While still wet with acetone these compositions were applied to the flare sides with a paint brush.

15. (C) Caseless flares were pressed in one increment at 7,000 psi. Cased flares were pressed in 1-inch increments at 15,000 psi.

16. (C) Materials

- NaNO₃, USP, DR. 23 micron
- MgO, 12.5 micron
- Ca₃(SO₄)₂, less than 1 micron
- Teflon, reprocessed, 23, 52, and 92 micron
- Kel-F, pulverized, 28 micron
- Mg, oxidized, 23 micron, granulation 200/325
- Mg, oxidized, 100 micron, granulation 90/100

A small amount of acetone (10 cc/100 g of mix) was used to insure proper blending. Blending time was approximately 20 minutes.

(C) EXPERIMENTAL PROCEDURE

12 (U) Compositions containing binder were prepared in a Lancaster blender.
Conferences 2.3 micron Focus Minerals Co., Grade Z. Lot 70262
Nitrocellulose, 12.6% nitrogen, lime 
Laminar Resin Nos. 4116 American Cyanamid Corp.
and 4134, commercial grade

17. (C) All flares were tested in an upright position (Fig 4, p 15) in the Picatinny high-altitude test chamber (Fig 3, p 14). Energy measurements were taken from a horizontal side-on position, using lead sulfide detection equipment.

REFERENCES

TABLE 1

Composition Formulas and Reaction Energies

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<td>23</td>
<td>47.6</td>
<td>33.5</td>
<td>60</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>MoO₃</td>
<td>12</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>31.3</td>
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<td>Cr₂O₃</td>
<td>0.5</td>
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<td>-</td>
<td>-</td>
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<td>Teflon</td>
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<td>46</td>
<td>46</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Kel-F</td>
<td>28</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mg</td>
<td>23</td>
<td>47.6</td>
<td>61.7</td>
<td>46</td>
<td>54</td>
<td>54</td>
<td>54</td>
<td>54</td>
<td>48.7</td>
<td>48.7</td>
<td>51</td>
</tr>
<tr>
<td>Zr</td>
<td>2.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
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<td>Laminac</td>
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<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>48.7</td>
<td>48.7</td>
<td>51</td>
</tr>
<tr>
<td>Nitrocellulose,</td>
<td>12.6%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>2</td>
<td>2.6</td>
<td>2</td>
<td>-</td>
<td>-</td>
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Reaction Energies

AH₁c = 19/2 1608 1877 - - - 1684 510 -
AH₂c = 2908 3745 2010 - - - 3756 1203 -

*a=1 microns
*b=100 microns
*c=Heat of reaction, 1 atm helium
*d=Heat of combustion, 30 atm oxygen
### TABLE 2

**Emission and Burning Characteristics of Flare Compositions At Various Simulated Altitudes**

<table>
<thead>
<tr>
<th>Composition</th>
<th>Approximate Altitude</th>
<th>No. Items</th>
<th>Burning Time, sec</th>
<th>Burning Rate, sec/in.</th>
<th>Peak Energy, 10^3 watts</th>
<th>Total Energy, 10^6 joules</th>
<th>Total Efficiency, joules/sec</th>
<th>Dimensions, in.</th>
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<tr>
<td>FY-719</td>
<td>1.35 x 1.5</td>
<td>S L</td>
<td>2</td>
<td>5.3</td>
<td>3.5</td>
<td>2.3</td>
<td>12</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>FY-698</td>
<td>1.35 x 1.5</td>
<td>S L</td>
<td>60</td>
<td>16.0</td>
<td>10.7</td>
<td>0.4</td>
<td>6</td>
<td>110</td>
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<td></td>
<td>150</td>
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<td>FY-893</td>
<td>1.3 x 3.0</td>
<td>SL</td>
<td>60</td>
<td>22.8</td>
<td>15.2</td>
<td>0.4</td>
<td>8</td>
<td>110</td>
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<td></td>
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<td></td>
<td>150</td>
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<td>FW-168</td>
<td>1.35 x 1.5</td>
<td>SL</td>
<td>60</td>
<td>30.5</td>
<td>33.6</td>
<td>0.1</td>
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<td>150</td>
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<td>SI-119</td>
<td>1.3 x 6.2</td>
<td>SL</td>
<td>60</td>
<td>4.8</td>
<td>6.8</td>
<td>20.0</td>
<td>91</td>
<td>210</td>
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<td></td>
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<td></td>
<td></td>
<td>300</td>
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<td></td>
<td>1.3 x 6.5</td>
<td>SL</td>
<td>100</td>
<td>4.0</td>
<td>6.8</td>
<td>20.0</td>
<td>91</td>
<td>210</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>300</td>
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---

*All flares burned from one end in cigarette fashion. To achieve this, Compositions FY-719, FY-698, and FW-168 were made as caseless flares and the curved sides were coated with Laminac resin (80/20, Nos. 4116 - 4134). FY-893 and SI-119 were pressed into thin-walled (1/4 inch) wax-coated paper cases.*

*b Composition formulas are given in Table 1 (p 7).*

*c Sea level*
### TABLE 3

A Comparison of the FW-168 and SI-119 Compositions for the First 12 Seconds of Burning

<table>
<thead>
<tr>
<th>Composition</th>
<th>Altitude 10^3 feet</th>
<th>Burning Time, sec</th>
<th>Approximate Length, in.</th>
<th>Peak Energy</th>
<th>Total Energy</th>
<th>Efficiency</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10^8 watts in 1st 12 sec</td>
<td>Watts/in. In Burning Surface</td>
<td>10^8 joules in 1st 12 sec</td>
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<tr>
<td>FW-168</td>
<td>7.6</td>
<td>1.5</td>
<td>19.0</td>
<td>13.3</td>
<td>144</td>
<td>2,440</td>
</tr>
<tr>
<td></td>
<td>16.5</td>
<td>1.5</td>
<td>6.0</td>
<td>4.2</td>
<td>72</td>
<td>1,220</td>
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<tr>
<td></td>
<td>56.0</td>
<td>1.5</td>
<td>0.9</td>
<td>.63</td>
<td>7</td>
<td>120</td>
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<tr>
<td>SI-119</td>
<td>3.0</td>
<td>6.2</td>
<td>8.0</td>
<td>6.0</td>
<td>40</td>
<td>90</td>
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<td>4.8</td>
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<td>22.0</td>
<td>16.6</td>
<td>126</td>
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<td>5.3</td>
<td>20.0</td>
<td>13.1</td>
<td>91</td>
<td>210</td>
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Composition formulas:

- **FW-168**: Teflon 46 pts, Mg 54 pts, NC 2 pts
- **SI-119**: MnO₂ 31.3 pts, Cr₂O₃ 20.0 pts, Zr 40.7 pts

---

a) Composition formulas:

b) Sea level
TABLE 4

Static-Ignition Test Results of New Igniter Compositions

<table>
<thead>
<tr>
<th>Igniter Composition</th>
<th>Flare Composition</th>
<th>No. of Items Iced</th>
<th>Approximate Dimensions, In.</th>
<th>Altitude, 10^3 ft</th>
<th>Remarks</th>
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<tr>
<td>SI-122</td>
<td>FW-155</td>
<td>4</td>
<td>1.35 × 1.6</td>
<td>51</td>
<td>All ignited</td>
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<td>SI-122</td>
<td>FW-155</td>
<td>3</td>
<td>&quot;</td>
<td>60</td>
<td>All ignited</td>
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<tr>
<td>SI-122</td>
<td>FW-155</td>
<td>13</td>
<td>&quot;</td>
<td>80</td>
<td>FW-155 ignited in 6 cases</td>
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<tr>
<td>SI-122</td>
<td>FW-155</td>
<td>12</td>
<td>&quot;</td>
<td>100</td>
<td>FW-155 ignited in 6 cases</td>
</tr>
<tr>
<td>SI-122</td>
<td>FW-156</td>
<td>1</td>
<td>1.35 × 1.75</td>
<td>SL</td>
<td>All ignited</td>
</tr>
<tr>
<td>SI-122</td>
<td>FW-156</td>
<td>3</td>
<td>&quot;</td>
<td>60</td>
<td>All ignited</td>
</tr>
<tr>
<td>SI-122</td>
<td>FW-156</td>
<td>1</td>
<td>&quot;</td>
<td>80</td>
<td>All ignited</td>
</tr>
<tr>
<td>SI-122</td>
<td>FW-156</td>
<td>1</td>
<td>&quot;</td>
<td>100</td>
<td>All ignited</td>
</tr>
<tr>
<td>SI-122</td>
<td>FW-160</td>
<td>2</td>
<td>2.5 × 4.3</td>
<td>60</td>
<td>All ignited</td>
</tr>
<tr>
<td>SI-131</td>
<td>FW-155</td>
<td>7</td>
<td>1.35 × 1.6</td>
<td>SL</td>
<td>All ignited</td>
</tr>
<tr>
<td>SI-131</td>
<td>FW-155</td>
<td>2</td>
<td>&quot;</td>
<td>60</td>
<td>All ignited</td>
</tr>
<tr>
<td>SI-131</td>
<td>FW-155</td>
<td>5</td>
<td>&quot;</td>
<td>80</td>
<td>All ignited</td>
</tr>
<tr>
<td>SI-131</td>
<td>FW-155</td>
<td>15</td>
<td>&quot;</td>
<td>100</td>
<td>FW-155 ignited in 8 cases</td>
</tr>
</tbody>
</table>

*The igniter compositions were applied to the circular surface of the casseous flares. The flat ends were not coated.

Composition formulas are given in Table I (p. 7).

Sea level

All flares in this group had hard glazed surfaces.

All flares which failed to ignite had a rough, glazed surface. All flares (5) having rough, porous surface did ignite.

One flare having hard, glazed surface also ignited.

These flares had rough, porous surfaces.

All flares which failed at site had hard, glazed surfaces.
Fig 1. Effect of Altitude on the Infrared Emission and Burning Rate of FW-168

(titanium/magnesium/nitrocellulose)
Fig 2  Effect of Altitude on the Infrared Emission and Burning Rate of SI-19

(MoO$_3$/Cr$_2$O$_3$/x2x)
Fig 3  Pyrotechnic High-Altitude Test Chambers for Dynamic Testing at Altitudes up to 130,000 feet (Tank volume: 8000 cubic feet)
Fig 4  Static Burning Test Fixture for Caseless Flare
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