The Secrets of Pyrotechnic Whistles

Stargate 2000

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Who Was That Masked Man?

- Crackerjacks, Inc
  - Vice President
  - Publications
  - Webmaster: www.crackerjacks.org
- Department of the Army
  - Chief, Pyrotechnics Team (26 years)
  - LTC Maryland Army National Guard
Vibrational Burning
### Major Chemicals for Pyrotechnic Whistles

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gallic Acid</td>
<td>C$_7$H$_6$O$_5$</td>
</tr>
<tr>
<td>Sodium Salicylate</td>
<td>C$_7$H$_5$NaO$_3$</td>
</tr>
<tr>
<td>Potassium Picrate</td>
<td>C$_6$H$_2$KN$_3$O$_7$</td>
</tr>
<tr>
<td>Potassium Benzoate</td>
<td>C$_7$H$_5$K$_0$2</td>
</tr>
<tr>
<td>Potassium Dinitrophenate</td>
<td>C$_6$H$_3$N$_2$O$_5$K</td>
</tr>
<tr>
<td>Potassium Hydrogen Phthalate</td>
<td>KC$_8$H$_5$O$_4$</td>
</tr>
</tbody>
</table>
Potassium Benzoate : Potassium Perchlorate

For Carbon Monoxide Only:

\[ 2 \text{K}C_7\text{H}_5\text{O}_2 \cdot 3 \text{H}_2\text{O} + 4 \text{KClO}_4 \rightarrow \text{K}_2\text{O} + 4 \text{KCl} + 11 \text{H}_2\text{O} + 14 \text{CO} \]

yields stoichiometric fuel:oxidizer ratio of \textbf{44:56}

For Carbon Dioxide Only:

\[ 4 \text{K}C_7\text{H}_5\text{O}_2 \cdot 3 \text{H}_2\text{O} + 15 \text{KClO}_4 \rightarrow 2 \text{K}_2\text{O} + 15 \text{KCl} + 22 \text{H}_2\text{O} + 28 \text{CO}_2 \]

yields stoichiometric fuel:oxidizer ratio of \textbf{29:71}
Typical Whistle Design

Air Void

Whistle Composition

Solid Acrylic Rod

Potassium Benzoate 27 PBW

Potassium Perchlorate 73 PBW
40mm Whistle
Typical Noise Levels

<table>
<thead>
<tr>
<th>Noise Source</th>
<th>dBA</th>
<th>dBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whisper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conversation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alarm Clock</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5/4 Ton Truck</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disc Sander</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Powersaw</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chainsaw</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pneumatic Hammer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Firecracker</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cap Pistol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shotgun</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOW Missile</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Discomfort: Tickle, Pain

0 50 100 150 200 dBA (85) dBPL (140)
Current uses

Incoming artillery shell

Training booby trap

Entertainment fireworks
Artillery Simulator
(small whistle....loud blast)
<table>
<thead>
<tr>
<th>Composition</th>
<th>Cal per gram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Whistle Composition</td>
<td>3,394</td>
</tr>
<tr>
<td>Photoflash</td>
<td>2,491</td>
</tr>
<tr>
<td>Bullseye Smokeless Powder</td>
<td>1,753</td>
</tr>
<tr>
<td>A1A Ignition Mix</td>
<td>903</td>
</tr>
<tr>
<td>Red Smoke Mix</td>
<td>895</td>
</tr>
</tbody>
</table>
## Ignition Temperatures

<table>
<thead>
<tr>
<th>Composition</th>
<th>(degrees C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bullseye Smokeless Powder</td>
<td>192</td>
</tr>
<tr>
<td>Red Smoke Composition</td>
<td>198</td>
</tr>
<tr>
<td>Pyrotechnic Whistle Composition</td>
<td>432</td>
</tr>
<tr>
<td>A1A Ignition Composition</td>
<td>437</td>
</tr>
<tr>
<td>Photoflash Composition</td>
<td>545</td>
</tr>
</tbody>
</table>
## Possible Formulations

<table>
<thead>
<tr>
<th>Compound</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gallic Acid</td>
<td>24</td>
</tr>
<tr>
<td>Sodium Salicylate</td>
<td>28</td>
</tr>
<tr>
<td>Potassium Picrate</td>
<td>50</td>
</tr>
<tr>
<td>Potassium Benzoate</td>
<td>30</td>
</tr>
<tr>
<td>Potassium Dinitrophenenate</td>
<td>70</td>
</tr>
<tr>
<td>Potassium Chlorate</td>
<td>73</td>
</tr>
<tr>
<td>Potassium Perchlorate</td>
<td>75</td>
</tr>
<tr>
<td>Potassium Nitrate</td>
<td>50</td>
</tr>
</tbody>
</table>
Pyrotechnic Whistle Fuels

- Potassium Benzoate
- Potassium Dinitrophenenate
- Gallic Acid
- Sodium Salicylate
- Potassium Hydrogen Phthalate
- Potassium Picrate

Increasing Hazard
Detonation Tendency

- **High**
  - Gallic Acid
  - Sodium Salicylate
  - Potassium Benzoate
  - Potassium Dinitrophenate
  - Potassium Picrate

- **Low**
Oxidizer Substitution

All Band Pass Comparison
Potassium Benzoate / Oxidizer

- Amplitude (dB)
- Time
- Percent Fuel
- Potassium Chlorate
- Potassium Perchlorate
## Equipment Information

<table>
<thead>
<tr>
<th><strong>Company</strong></th>
<th>RION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model</strong></td>
<td>NA-29</td>
</tr>
<tr>
<td><strong>Measurement Range</strong></td>
<td>27-130 dB(A)</td>
</tr>
<tr>
<td><strong>Frequency Range</strong></td>
<td>20-8000 Hz (9 octaves)</td>
</tr>
<tr>
<td><strong>Dynamic Range</strong></td>
<td>50 dB (80-130)</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td>1500 screens</td>
</tr>
<tr>
<td><strong>Store period</strong></td>
<td>2 ms to 10 sec</td>
</tr>
<tr>
<td><strong>RS-232 Interface</strong></td>
<td>9600 baud rate</td>
</tr>
<tr>
<td><strong>Battery life (AA)</strong></td>
<td>4 hours</td>
</tr>
</tbody>
</table>
Frequency Band Comparison

Control Whistle

Stainless Steel
Frequency Band Comparison

Control Whistle

Aluminum Flake
Frequency Band Comparison

Control Whistle

Guanidine Nitrate
Burn Rate Reduction

Frequency Band Analysis

2K Band Response vs Percent Red Gum
Burning Rate Reduction

- Base
- Sulfur
- Clay
- Red Gum
- PVA
- Cornstarch
- Mekon White
- MP 12
- Acrawac C
Amplitude Increase by Diameter

- 6mm (0.25"") with 19mm (0.75"")
- 13mm (0.50"") with 32mm (1.25"")
- 19mm (0.75"") with 44mm (1.75"")
- 32mm (1.25"") with 57mm (2.25"")

Values:
- 1
- 4
- 9
- 25
- 49
- 81
Actual Diameter Effect
UAV Whistle Submunition
Typical Whistle Design

Air Void

Whistle Composition

Solid Acrylic Rod

Potassium Benzoate
27 PBW

Potassium Perchlorate
73 PBW
High - Low Whistle Design

- Air Void
- Expelled Insert
- Whistle Composition
- Solid Acrylic Rod

Potassium Benzoate
27 PBW

Potassium Perchlorate
73 PBW
Hi-Lo Whistle Design

- Air Void
- Expelled Insert
- Whistle Composition
- Solid Acrylic Rod

Potassium Benzoate 27 PBW
Potassium Perchlorate 73 PBW
Step Whistle Design

Air Void

Whistle Composition

Solid Acrylic Rod

Potassium Benzoate 27 PBW

Potassium Perchlorate 73 PBW
Step Whistle Design

Air Void

Whistle Composition

Potassium Benzoate
27 PBW

Potassium Perchlorate
73 PBW
35mm Whistle Grenade
Small E.G.A.D.

- 4 inches high
- M201A1 fuze
- Reduced effects
Binder Effect

5% Binder

Burn Rate (mm/sec)

Baseline  Sulfur  Clay  Red Gum  Cornstarch  MP12 Wax
Binder Effect

5% Binder

Peak Amplitude (dB)

Baseline Sulfur Clay Red Gum Cornstarch MP12 Wax
Binder Effect

Average Amplitude (dB)

5% Binder

Baseline, Sulfur, Clay, Red Gum, Cornstarch, MP 12 Wax
Peak vs Average Amplitude

Amplitude (dB)

Baseline  Sulfur  Clay  Cornstarch  Red Gum  MP12 Wax

5% Binder

Peak

Average
Whistle Quality

Smoothness Factor

Baseline  Sulfur  Clay  Red Gum  Cornstarch  MP 12 Wax

5% Binder

(Peak Amplitude Minus Average Amplitude)
Burn Rate vs Binder Percent vs Amplitude

- Burn Rate (mm/sec)
  - 2
  - 3
  - 4
  - 5
  - 6

- Binder Percent
  - 5%
  - 10%
  - 15%

- Peak Amplitude (dB)
  - 100
  - 105
  - 110
  - 115
  - 120
  - 125
  - 130

- Binder Types:
  - Baseline
  - Sulfur
  - Clay
  - Red Gum
  - Cornstarch
  - MP 12 Wax
Burn Rate Comparison +10%
Burn Rate Comparison +10%
Smoothness Factor

(Maximum - Average) Amplitude

Decibels (dB)

- BaNO3
- GuNO3
- NaNO3
- SrNO3
- Control
- Sulfur
- Ss Powder
- Al Flake Crs
- MgAl
Amplitude Increase

Oxidizer Highlights

Peak Amplitude (dB)

Burn Rate (in/sec)

ZnO

Control

FeO

Fe₂O₃

Cu₂O

Pb₃O₄

PbO

CuO

MnO₂
Fuel Effect on Burn Rate

Burn Rate Comparison
10% Additive

Burn Rate (mm/sec)

Control
MgAl
SS Powder
Sulfur
Al Flake Crs
Inorganic Fuel Highlights

- Mg
- Zn
- Cu
- Ti
- Al
- Si
- Fe(–)
- Mn
- Fe(+)
Organic Fuel Results

Burn Rate (in/sec) vs. Peak Amplitude (dB)

- Control
- Red gum
- Terephthalic acid
- Stearic acid
- Charcoal
- Sucrose
Fine Powdered Iron

**High Loading Results**

- **Burn Rate (in/sec)**
- **Additional Percent**
- **Peak Amplitude (dB)**
Black Copper Oxide

High Loading Results

Burn Rate (in/sec)

Additional Percent

Peak Amplitude (dB)
Flame Reduction
Spark Comparison

- Fe 100
- Fe 325
- Control
- 10% Metal Powder
- Ti
- SS
Spark Comparison

10% Powder

Red Gum

Control

Charcoal
Flame Shape Comparison

- Control
- Zinc
- Magnesium
- Charcoal
- Coarse Iron
- Fine Iron
- Titanium
- Strontium Nitrate
Spark Comparison

- Al
- Mg
- Control
- B
- 10% Metal Powder
- Zn
Increased Compaction Pressure

- 2000 psi
- 3000 psi
- 4000 psi
- 5000 psi
- 6000 psi
- 7000 psi
- 8000 psi
- 9000 psi
- 10,000 psi
Whistle vs Blast Comparison

![Amplitude vs Time Graph]

- Magnesium
- Airburst
- Titanium
- Concussion
- ITLX
- Flash
- BP Class 8
- Pyro Whistle
Amplitude Increase by Diameter

6mm

13mm

19mm

32mm

44mm

57mm

0.25"

0.50"

0.75"

1.25"

1.75"

2.25"
3 Inch Diameter Test Whistle