Barium chloride based pyrotechnic compositions for green color emissions

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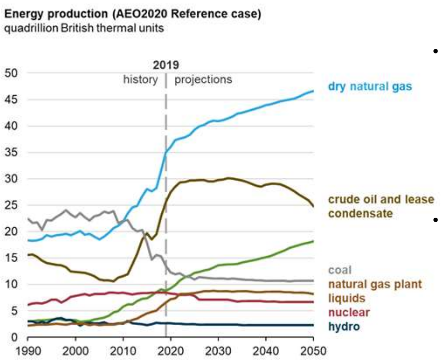
SUMMARY

Here, we present research focusing on the green light emission using Barium chloride dihydrate ($BaCl_2.2H_2O$) as an emitter contrary to commonly used $Ba(NO_3)_2$, $Ba(ClO_3)_2$, $BaCO_3$ etc. For this work, different compositions containing $BaCl_2.2H_2O$ and other components acting as oxidant, fuel, etc. were made and analyzed using TGA and burning tests. The flame intensity was captured using a photocell attached with a green color filter. It was observed that the decomposition behavior and the flame intensity were strongly influenced by the ratio of barium chloride to the oxidizer and by the particle size of the pyrotechnic composition powder. Compositions having a higher amount of oxidizer were found to decompose faster and have a more intense flame color.

Energy production in the US – conventional vs. renewable



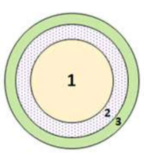
- Energy from Coal constitutes 14% of the total energy production in the United States and will continue to remain an important source for the foreseeable future.
- It is imperative to operate existing coal-fired boilers and other conventional energy sources in the most-efficient manner

*Reproduced from Annual Energy Outlook 2020 (US EIA)

Coal-fired boilers

- Development of cold/hot spot locations inside substantially affect the overall efficiency of the boiler.
- Improved knowledge of the 3-D spatial distribution of temperature will allow tuning, validation of detailed models of combustion, and optimization of the boilers to make them more efficient.
- Mapping of the boiler through gas-temperature sensing measurements. Pyrotechnics can play an important part in this

Reactive particle design



1 – reactive core
2 – first protective layer
3 – second protective layer

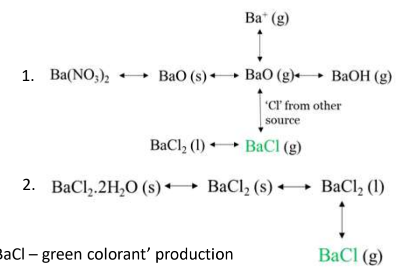
- Reactive pyrotechnic core
- Light emission at a particular temperature
- Outer layers to protect the core through different temperature zones in the boiler

- Green light emission – distinctive from the red-yellow background inside the boiler
- Emitted green light capture through camera and images will help in mapping temperature profile

Reactive core – green light emission

- Some common green colorants: $Ba(NO_3)_2$, $Ba(ClO_3)_2$, $BaCO_3$
- Oxidizers: $KClO_4$, NH_4ClO_4, KNO_3 etc.
- Common metal fuels: aluminum, magnesium, tin etc.
- Binders: some polymer that will hold everything together
- Additional materials: chlorine source such as PVC, dextrin, parlon etc.

$Ba(NO_3)_2$ vs. $BaCl_2.2H_2O$

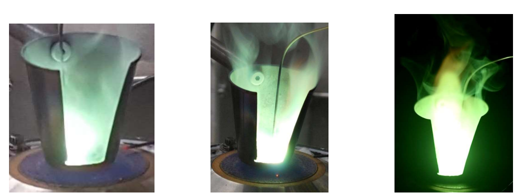


*Mechanisms for 'BaCl – green colorant' production

$BaCl_2.2H_2O$ based compositions

- $KClO_4$ (safer to handle than NH_4ClO_4, KNO_3).
- Sn (less heat of combustion than Mg, Al)
- Ethyl cellulose (cellulose in general is a good binder and fuel for many systems)
- $BaCl_2.2H_2O$ as green colorant

Results from burner tests (flat flame burner)



Sn Co Mg

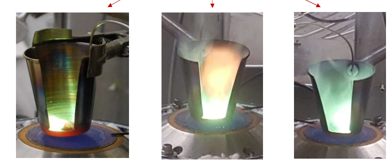
Different metals with $BaCl_2.2H_2O$

Effect of ratio of $BaCl_2.2H_2O$ to $KClO_4$

- Adding more oxidizer ($KClO_4$) lead to more intense and brighter green flames.
- This might be due to higher temperatures achieved by the oxidizer rich compositions allowing more BaCl2 to get into the gas phase forming BaCl specie needed to generate the green color emission.

	wt(%)	wt(%)	wt(%)
$KClO_4$	16.13	31.08	50.23
$BaCl_2.2H_2O$	48.98	33.11	16.77
Tin (Sn)	18.85	22.40	16.41
Eth. Cell.	16.03	13.40	16.57
Total	100	100	100

Burner tests →



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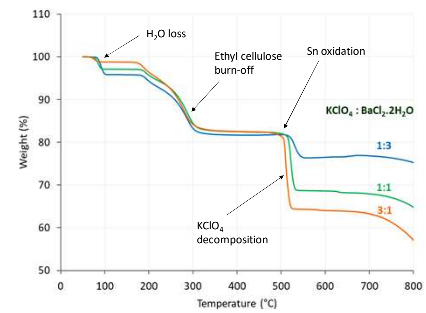
$BaCl_2.2H_2O$: $KClO_4$

- Compositions having more oxidizer decomposed faster.
- TGA plots corresponded to the individual compounds.
- Initial drop in weight corresponded to $BaCl_2.2H_2O$ losing water.
- Mid-temperatures (200-400 °C), ethyl cellulose decomposition
- Higher temperatures (400 – 600 °C), $KClO_4$ decomposition, and Sn oxidation

TGA analysis →



Conclusions

- $BaCl_2.2H_2O$ based pyrotechnic compositions were effective in emitting green light.
- Ratio of oxidizer to colorant significantly influenced the light output and the overall performance of compositions.
- Higher oxidizer content released more heat and thus could ionize more of $BaCl_2$ into BaCl (g) species emitting more green light.

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