Nitrate-based Igniters

The reliability and performance of a solid composite rocket motor depends partially on the composition and design of the electrical igniter. **Ignition Powder** (KNO_3/Charcoal) based igniters, referred to as IP igniters, continue to be used successfully in potassium nitrate/sucrose (and other sugar-based) motors because they are easy to make, relatively safe, reliable and provide for fast start-up of the motor, but fall short when used with RNX and other composite propellants that are harder to ignite by their very nature.

Potasium chlorate or ammonium perchlorate is frequently used as an oxidizer in igniter composition because of the low melting point, low ignition point and high caloric value with thermic fuels. However, an igniter composition based on potassium chlorate can be sensitive to impact, friction and heat stimuli, and as such, possess certain inherent hazards in their fabrication and usage. Potassium chlorate and the other energetic oxidizers may also be hard to obtain in some countries. Therefore, two igniter compositions based on **potassium nitrate** and other non exotic chemicals that are also reasonably safe to prepare were developed. Both types, despite their different designs, provide satisfactory results, particularly when used to initiate composite motors.

Igniter design #1, the **HotFlash** igniter is based on a high-energy composition that liberates a high heat of reaction. As such, grain ignition can be reliably counted upon due to highly effective localized heating of the propellant grain. Reasonably rapid motor start-up results from flame spread following combustion initiation of the grain.

Igniter design #2, the **MacFire** igniter is based on the fact that good igniting action can otherwise be achieved from a less energetic, albeit longer burning composition that effectively heats the propellant grain. Heat transfer to the grain is less rapid, but occurs over a larger surface area for a longer duration, leading to similarly rapid motor start-up.

The HotFlash igniter

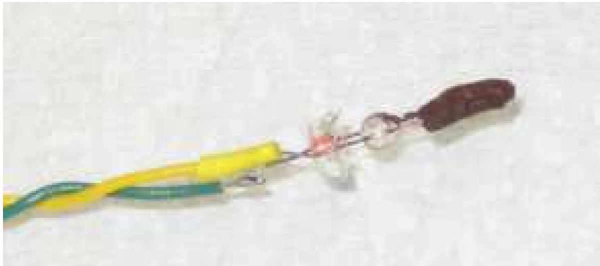
Design requirements for the HotFlash igniter:

- Potassium Nitrate oxidizer, non-exotic other components
- Good heat output with a hot radiant flame
- Reasonably slow burn rate for good heat transfer
- Solid reaction products for better heat retention
- Possible to ignite reliably from a nichrome wire (or similar) stimuli with low-medium current requirement
- Sustained burning, once ignited

An igniter composition that readily meets these requirements is comprised of the following formulation:

Potassium nitrate	**60%**
Aluminium,	
(German dark or small flakes)	**30%**
Sulfur	**10%**
Boric acid	**(1-2%)**
Contact cement (neoprene)	
or NC lacquer	**to slurry consistency**

Conventional electrical bridgewire made from nichrome wire, minibulb or Xmas bulb is used to initiate the composition which is coated onto the bridgewire.



The **HotFlash** igniter based on Xmas bulb

The low melting point of sulfur (119°C) provides a highly reactive liquid phase that enhances the ignitability of the composition as a whole. Sulfur is also used to trigger the high-energy reaction between potassium nitrate and aluminum. The large amount of aluminum increases the thermal conductivity of the composition and as such aids in good burning behaviour. Solid Al_2O_3 residue aids in ignition of the rocket propellant by direct and instantaneous heat transfer from the residue to the propellant.

Compositions that include nitrates and aluminum have, under certain conditions, potential for undesirable side reactions that evolve heat and ammonia gas. The reaction can be described by the following expression:

$$3\,KNO_3 + 8\,Al + 12\,H_2O \rightarrow 3\,KAlO_2 + 5\,Al(OH)_3 + 3\,NH_3$$

1-2 % of boric acid should be added to counter the reaction. Boric acid is readily available at pharmacies as a mild antiseptic.

The **HotFlash** igniter generates hot flame & sparks

The MacFire Igniter

The **MacFire** igniter is a formidable alternative to the HotFlash igniter, and is based on **RNX** composite propellant left over from the grain casting process, and **Ignition Powder** (IP). IP is a tailored form of Black Powder consisting of 80% Potassium Nitrate and 20% Charcoal.

Design requirements for the MacFire igniter are similar to that of the HotFlash igniter:

- Potassium Nitrate oxidizer, non-exotic & minimal other components
- Good heat output with a sustained flame
- Reasonably long burn time for good heat transfer
- Solid reaction products for better heat retention
- Possible to ignite reliably from a nichrome wire stimuli with low-medium current requirement
- Sustained burning, once ignited

It has been found that the heat and residue from an IP based igniter is not sufficient to reliably ignite an RNX based propellant grain, mainly due to the short burn time. In order to ensure reliable ignition of RNX or other composite propellant it is necessary to use a combination of IP and a granular/flake form of RNX propellant. Granular/flake RNX can effectively be prepared by using a kitchen grater. The resulting granular product has sharp ragged edges and a large surface area. The finer flakes also have less neighbouring material that can act as heat conductors, hence making it easier for the flakes to be raised to the ignition temperature.

Conventional electrical bridgewire made from nichrome wire, minibulb or Xmas bulb is used to initiate the composition.

A typical igniter of this type is comprised of a drinking straw tube 40 or 50 mm in length and 8 mm internal diameter (McDonalds straws are ideal, hence the moniker). Into this straw a well-blended mixture of IP and granular RNX is loaded. The bridgewire is positioned in the centre of the straw. On initiation, by passing a current through the nichrome wire, the heat of reaction from the ignition powder will ignite the combined IP and granular form of the RNX propellant, which ignites the propellant grain.

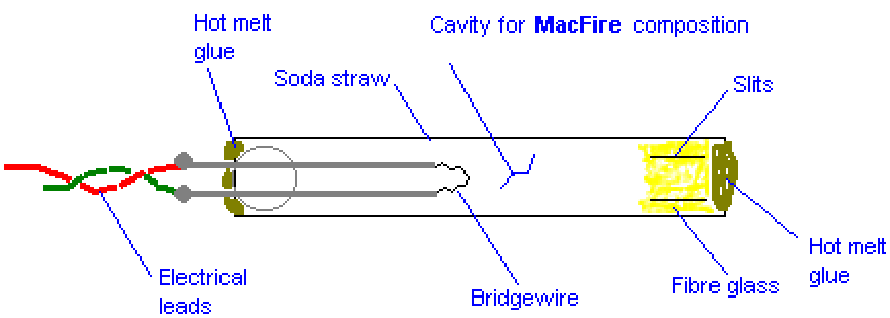
Kitchen grater works well to produce granular RNX

The **MacFire** composition is made from

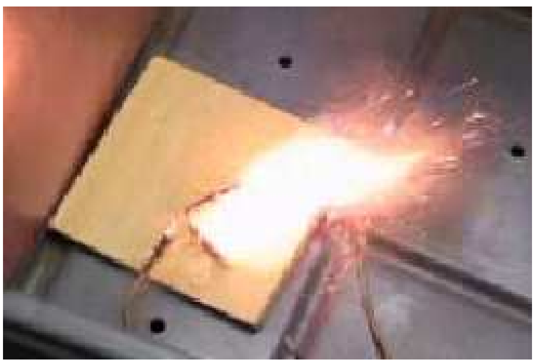
Ignition Powder (IP)	**X%**
RNX, flake or granular	**Y%**

The percentages X and Y are intentionally not fixed. Successful testing has been conducted with X being as high as X=70% , and as low as X=0%. More rapid & energetic burning is achieved with higher values of X, more sustained burning is achieved with X=0%. Of course, with X=0%, the formulation becomes even more simple (single component), which is a design goal. A good starter composition would be X=Y=50%. Note for all prospective formulations, Y=100-X

To avoid rapid (nearly instantaneous) burning of the composition associated with burning under confinement, such as that which occurs with the standard IP straw igniters, the straw is **slit lengthwise** at 3 or 4 locations around the tube. The slits, which should be about 5 mm in length, are easily made using a sharp Xacto knife. This prevents pressure build-up associated with confinement and results in more gradual burning of the composition, which is exactly that is required to ignite a composite propellant grain. The burn time (at 1 atm.) for the slitted **MacFire** igniter is approximately 4 seconds.



MacFire igniters.



The **MacFire** igniter in action