Jacobs' Rocketry

"Caramel Candy" or "Rcandy" Propellant

Caramel Candy or Rcandy

This propellant got its name because it has the appearance and characteristics of caramel candy. It is made with table sugar, it is heated, and though we all would (at least I would) like it to be pure white, it usually ends up the color of caramel. It is thick and gooey like the candy in the making, too. The difference, of course is the real candy won't burn like a propellant and the real propellant doesn't taste like candy, and of course isn't to be eaten. It is also known as R-candy or rcandy rocket propellant or fuel. It should be obvious that the "R" stands for rocket.

Components

The basic formula is made from just two components, an oxidizer and a fuel. The oxidizer is potassium nitrate. Its chemical formula is KNO_3. (note: "K" is the official chemical designation for potassium). You will often see in rocketry web sites "KN" used for potassium nitrate. The fuel is table sugar -- sucrose. Its chemical formula is $C_{12}H_{22}O_{11}$. Like **KN**, a shortened designation **Su** will often be used on rocketry web sites like those related to homemade rocket engines (motors) or homemade rocket fuel or propellant. The fuel on these web sites will often be referred to as **KNSu** rocket fuel or propellant.

Sucrose, or table sugar, was the first sugar to be used. Dextrose is a better choice as it has a little lower melting point. Sorbitol is quickly becoming the most serious sugar used because of its lower melting point and slower curing time (and so longer pot life). It is also less prone to cracking in larger motors. Sucrose when used with corn syrup such as Karo can also be made less brittle and is becoming more popular primarily through the efforts of Jimmy Yawn (the originator of using corn syrup in propellant???) and Dan Pollino who has made J & K motors with it. Examples of other sugars and sugar substitutes that have been experimented with are: fructose, maltose, lactose, erythritol and xylitol. Scott Fintel successfully launched an "O" motor rocket using erythritol as the sugar. Discussions on this page refer only to sucrose unless specified otherwise but much on this page is applicable to any sugar/potassium nitrate propellant.

Basic Formula

Propellant formulas (as are all chemical formulas) are determined by weight. The theoretical best performance is 66% KN, 34% Su. However, the standard formulation that most everybody uses (including myself), is 65% KN, 35% Su. According to Richard Nakka, a formula of 60% KN, 40% Su, can be used and he suggests people new to the propellant should start with this ratio. This lower KN percentage formula is thinner and so easier to load into grain forms and also has less tendency to caramelize. I haven't experimented with the lower KN percentage formula yet (as of 9-9-06) but it is on my to-do list.

Alternate Formulas

When searching the internet you will find a variety of slight variations to the percentages of Potassium Nitrate and Sugar. You will also find additional components added.

Corn syrup

Corn syrup used in sugar propellant could (and may in the future) have its own dedicated web page. It is a bit mysterious but definitely has an interesting effect when used as an ingredient in sugar propellants.

Why use corn syrup?

Corn syrup is used in baking in place of sugar to make the baked item softer where sugar would make the product more crisp. The reason is that corn syrup resists crystallizing. When propellant is made, crystallizing is part of the process. It is heated either with water or dry but either way, the sugar becomes molten or dissolved and is in an uncrystallized state. If water is used, the water is first driven off. Then in either case, when it cools, the propellant recrystallizes. When Jimmy Yawn talks about his recrystallization process, it is not something unique to his method. All heated sugar propellants uncrystallize, then are cast, and at that point recrystallize.

The fact that corn syrup does not crystallize in the normal state is the very reason it is used in sugar propellants. The grains need to be solid but the undesirable aspect is their brittleness which comes about because both the sugar and potassium nitrate are crystalline at normal temperatures. By introducing corn syrup which at normal temperatures is not only not crystalline but not solid, the brittleness is reduced.

One note is that sucrose and dextrose both start the caramelization process at 320°F so to prevent loosing the advantages of corn syrup, temperatures during processing should be held below that temperature. Caramelization is a process that breaks down sugar into other chemicals and turns a darker yellow-brown color. Caramelization somewhat degrades the power of the propellant. See my caramelization page for more details.

What is corn syrup?

If the answer to that was easy, it might eliminate some experimentation. You would think that you could just look it up somewhere and find that it was composed of certain ingredients in certain amounts but that isn't the case. It isn't made in a chemistry lab from specific ingredients, it is derived from an organic source (corn is only one possibility) and its exact makeup can vary between manufacturers and products. Essentially, it is a combination of dextrin, maltose, and dextrose. Glucose and dextrose are the same thing, just different names. As a matter of fact, corn syrup is sometimes called glucose syrup, especially outside the USA. Dextrin is not the same as dextrose, it has one less water molecule in the formula. There are also different kinds of dextrose depending on how the molecules are arranged. Corn syrup can have sucrose added to it. Corn syrup can be processed further to create fructose (which has the same chemical formula as dextrose but with a different arrangement of the atoms) and then that can be added to regular corn syrup. Other sugars like maltose are also found in lesser amounts in corn syrup. So, how much dextrose, how much dextrin, how much sucrose, and how much fructose is in the corn syrup you are using? You will never know. My Karo© light corn syrup has as ingredients: light corn syrup, high fructose corn syrup (there are several types ranging from 90% fructose, 10% dextrose down to 45% fructose), salt, vanilla. How much of each? Who knows. The salt and vanilla can probably be ignored because the quantity would be very small. Oh, and by the way, don't bother trying to get any information out of Karo or other manufacturers as to what the quantities of ingredients are in their product. A number of us have asked and they won't say. So though straight corn syrup is 93% to 96% dextrose, which itself makes an excellent sugar propellant, it is impossible to know what exactly is in any specific corn syrup product. That is why a certain amount of experimentation will be required when using corn syrup. In reality, the results probably will not vary much from one corn syrup to another.

Moisture content

Corn syrup also contains water. It can be dried commercially to form a crystalline substance. This should be kept in mind when deriving formulas because that portion that is water adds to the weight but does not contribute as a fuel. The formula for the propellant when using corn syrup should have a higher percentage by weight of corn syrup to account for the moisture in it.

I did an experiment to see if heating would drive off the water in the corn syrup. I weighed a Pyrex container, added a weighed amount of corn syrup, then put it in the oven at 300 degrees. By the time it quit loosing weight four hours later, the corn syrup had lost 20% of its weight so I conclude that Karo© Light Corn Syrup is 20% water. This can also be derived by determining the specific weight and the grams/serving of carbohydrates (see explanation below in "Corn Starch Content?"). A formula for sucrose propellant that would use the standard 65:35 ratio and split up the sugar half and half with corn syrup would calculate like this:

Not accounting for the water in the corn syrup:

65% potassium nitrate
17.5% sucrose
17.5% corn syrup

Accounting for the water in the corn syrup:

62.2% potassium nitrate
16.8% sucrose
21% corn syrup

When the water is boiled off, these initial percentages will end up with 65% KNO3 17.5% sucrose, 17.5% corn syrup without water, which is what you want.

Corn Starch Content?

It is interesting that when looking at the "nutrition facts" on the *Karo© Light Corn Syrup* bottle I see the following: Serving size 2 Tbsp (1/8 cup, 1 liquid oz), amount per serving: total carbohydrates 31g, sugars 12g. I did some weighing and calculations and found that the specific weight (weight compared to water) of the corn syrup is 1.37. One ounce = 28.35 grams so one fluid ounce of corn syrup would weigh 28.35 * 1.37 = 38.8 grams. So if only 31 grams are carbohydrates, that means only 79.9% is carbohydrate. That means the rest, or 20.1% is water -- almost exactly what I found when I drove off the water in the oven. However, if only 12 grams are sugars, then what is the other 19 grams of carbohydrates? What seems obvious to me is that it is corn starch. Corn syrup is made by processing corn starch and they can stop at any point they want to get whatever amount of conversion they want with some ratio of corn starch and dextrose and a few other sugars in small amounts. It appears to me that corn syrup (this brand) is probably the following:

> 49% corn starch
> 30.9% sugars*
> 20.1% water
>
> * The sugars would be a mixture of dextrose and fructose depending on what type of high fructose corn syrup was in the mix and what percentage was added to the light corn syrup. There is no way short of an organic chemistry lab and chemist to find out what the sugar ratios are.

By comparison, Western Family© Light Corn Syrup Contains only: corn syrup, water, potassium sorbate (preservative), vanilla and citric acid. It contains no high fructose corn syrup. It still has a similar ratio of total carbohydrate grams and sugar grams. The serving size is twice as much, 1/4 cup. The specific weight is the same but for that quantity, it has 61g carbohydrates and 21g sugar. Since this is two fluid ounces, there is 28.35 * 1.37 * 2 = 77.7g total leaving 16.7g of water. This corn syrup would figure out to be the following

> 51.5% corn starch
> 27% sugars*
> 21.5% water
>
> * In this case, we could assume the "sugars" are primarily dextrose since there is no high fructose corn syrup listed as an ingredient.. There is about 4% less sugars in this corn syrup and just slightly more water but the ratios look very similar.

If this is the case, that corn syrup has a large percentage of corn starch in it, the effects become a bigger unknown and trying to figure out the best formula mathematically becomes impossible. I experimented with a fuel with corn starch, dextrose, and water in the same ratios as has been calculated. The result was a mixture that would not sustain burning at atmospheric pressure. It was worse than using corn syrup the same way.

I also am curious what effect corn starch has on the brittleness of cured sugar propellant. Is it the corn starch that makes the propellant less brittle, the water left in or the specific combination of compounds in the corn syrup? Sucrose syrup will crystallize over time. Would similar syrup made with dextrose crystallize over time or would it be like corn syrup and not crystallize?

The only difference in the two is the Western Family, to my taste buds, tastes slightly sweeter and is amber in color where the Karo is lighter with less amber color.

James Yawn

James Yawn was probably the first to use corn syrup as an additive. Others that also use it probably got the idea from his web site. The corn syrup (such as Karo®) may decrease the performance but only very slightly since it too is a mixture of sugars. The decrease in performance will depend on the final ratio of sugars (fuel) to KN (oxidizer). Actually, his formulas are fairly fuel rich and so you should expect performance several percent below the optimal 64-36 (or 65-35) formula. Currently, you will find quite a number of ratio variations on various pages of his web site. Here is one of his formulas:

> 59.5% KN
> 29.8% Su
> 10.7% light corn syrup
> To this he adds 47.6 % water (figured as a percentage of the total of the above).

The numbers don't end up in whole percentages because I converted his actual formula which is given in specific gram quantities and tablespoons of water. Here is his specific formula:

> 100g KN
> 50g Su
> 18g light corn syrup
> 5 tablespoons water

His formula is used with his "recrystallization" method (a form of wet mixing). The corn syrup makes the mix more pliable and workable for his method. It remains soft at a lower temperature than without it. I have tried this formula and it has merit.

In my own experiments with Jimmy's formulas, when I made it, it would barely burn when made into test strands. (maybe I did something wrong). This is obviously at atmospheric pressure and at operating pressures, it burns better but still, in my tests, below normal expected specific impulse values. I tried varying the ratios to more standard ratios with better results myself. That being said, "the proof is in the pudding" -- he has been flying these in rockets for a long time.

Dan Pollino and "Flexible" Sugar Propellant

Dan Pollino's "flexible" propellant is just a variation of Jimmy's propellant but he mixes it differently. Where Jimmy's formulas are a little fuel rich, Dan's "flexible" sugar propellant is a little oxidizer rich when you take into account the amount of water in Corn syrup. His formula is:

> 65% Potassium Nitrate
> 15% Sucrose (Powdered Sugar)
> 19% Corn Syrup

His mixing method is: First mix thoroughly the potassium nitrate (ground fine) and powdered sugar. Next, heat up the Corn Syrup to 180° F, then stir in the potassium nitrate and powdered sugar. Stir constantly. When the mix is at 210 degrees, it is ready for casting.

It is interesting that Dan's process never heats the propellant or components above 212, the boiling point of water, so little of the water in his mix is driven off. The effect could be similar to leaving some water in a standard formula. I tried that in the process of my caramelization experiment. As would be expected, it burned slower and the specific impulse was less. However, when plugging the numbers from Dans K450 PVC rocket engine into FPRED motor design software and using a straight 65/30 KNO_3/sugar fuel the total impulse was nearly identical to Dan's listed value. Fuel behaves differently under operating pressures and there his fuel allows a grain to case bond and be cast in one shot in a 24" long motor, it doesn't crack as a large grain, and it has carried at least one of Dan's rockets supersonic so as with Jimmy's, "the proof is in the pudding."

Glycerin

Glycerine has a similar affect as corn syrup but I think may reduce performance a little more. The place I ran into it was on Dan Pollino's "Inverse Engineering" web site. He was using corn syrup in his J300 (J size motor) but was having a problem with what is called "chuffing" (oscillations in the thrust) and a pressure (and so thrust) spike where he figured the propellant grain cracked. Richard Nakka suggested he try glycerine in place of the corn syrup. That solved his problem. Dan's formula is:

> 59% KN
> 29% Su
> 3% Glycerin
> 10% Water
>
> This works out to:
>
> 65% KN
> 32% Su
> 3% Glycerin
>
> when you ignore the water which boils out anyway.

Iron Oxide

Richard Nakka experimented with a number of other ingredients as "burn rate modifiers." Jimmy Yawn uses red iron oxide to increase the burn rate and effectively uses it in a motor the same size as the standard A to C size commercial black powder motors. It appears that red iron oxide increases the burn rate somewhat uniformly at all pressures (increases the burn rate coefficient) and with brown iron oxide the burn rate increases more at higher pressures (increases the burn rate exponent). I am currently (9-9-06) experimenting with iron oxides to make end burners. See BrIO Propellant & End Burners. Richard's experiments added 1% iron oxide. For example for 100 grams of propellant, he added 1 gram of iron oxide.

A person could use other ingredients to slow the burn rate but this is seldom a requirement and this could be done by increasing the nozzle throat diameter and so decreasing the pressure and it would accomplish the same thing.

Methods

There are a number of different methods for preparing sugar propellant but the most variation is in the heating method. Other than the dry compressed method which is not used by serious experimenters, all methods require heating the propellant. The temperatures used range from around 180° F to 400° F

Dry Compressed

This method is mentioned also on the general propellant page. As stated above, this method is not used by serious experimenters though it can be a novel experiment to compare the repeatability and impulse to other methods. The sugar and KN are ground as fine as possible and then mixed thoroughly in a ball mill or tumbler of some kind to make sure the ingredients are mixed completely and uniformly. This mixture is then compressed into the motor tube in the same way as black powder is done. See the 1979 manual for details (pay attention to it's revision). Note: this paragraph is included here only for a complete coverage of all methods. Dry heated or dissolved and heated methods should be used for serious experimenting.

Dry Heated

This is the most common method that has been used for caramel candy propellant for decades and is still the preferred method by many. At the writing of this, it is the method still used by Richard Nakka and other well known people to the AER sugar propellant community.

The KN is ground or milled to a fine powder if it is not already that way which it seldom is unless it is a higher priced and higher quality such as lab grade or as purchased from pvconly.com. It should then be thoroughly mixed with powdered sugar. See a diagram of Richard Nakka's mixer he made on his sugar propellant page.

This mixture does not melt both the KN and sugar. KN melts at 631 degrees. What this method actually does is melt the sugar and then with lots of stirring, it coats the KN grains with the melted sugar. So the finer the KN is ground, the more intimate contact the sugar will have with the KN and the better the propellant will be.

Dissolved & Heated

Just enough water is added to dissolve completely the KN and sugar. Actually, you can use more and it doesn't take that much longer. I heat the water first, then dissolve the KN and then add the sugar but it doesn't really matter. You could do either first or both together. The mixture is brought to a boil and the water quickly evaporates off. it goes through several stages that are distinctive. First it boils like boiling water, then as most of the water is driven off, it starts bubbling and spitting. Then that stops and it just hisses a little. At last it turns to a mashed potato consistency. The mixture should be stirred a lot after the fist boiling stage. The more it is stirred, the faster it comes up to temperature and reaches completion. The temperature first stays around 212 until most of the water is driven off. Once it gets to the hissing stage where the last of the water is being driven off, the temperature starts to climb and you are getting close. When it gets to around 350 degrees it is ready to cast.

In contrast to the dry heated method which coats the KN particles with sugar, the dissolved and heated method actually dissolves both ingredients which then mix intimately together. When the water is driven off, the two stay in intimate contact and then as they cool, they both recrystallize together providing a better mixture. In reality, if in the dry mix method, the KN is ground to a fine talc-like powder and mixed very thoroughly before heating, the resulting grains will be comparable in performance.

Dissolving the sugar and KN in water first
and then heating the mixture has many advantages.

- **The KN and sugar do not have to be finely powdered**. They both dissolve in water completely. You don't have to use powdered sugar, you can use granulated sugar which is cheaper and less messy. My KN was a 100 pound sack that sat for years and turned into one solid chunk. All I have to do is chip off small enough pieces to weigh and it dissolves in the water. If you heat them dry, they must be finely powdered and thoroughly mixed before heating.
- **You don't have to pre mix the components**. Once they are dissolved in water, they mix easily and completely.
- **The mixture heats very rapidly** and thoroughly because it is in complete contact with the bottom of the container and the heat is transferred efficiently through the mixture. The mixture heats much, much more rapidly than dry ingredients. The dry ingredients particles are not in intimate contact with each other because there is air space between them. Air does not conduct heat well. Imagine a jar full of marbles and all the air between them. The same is true of the dry material but at a much smaller scale. The finer it is ground, the better the contact but it is still considerably less efficient than with water. Similar batches (250 grams) in my deep fryer took more than an hour to heat dry and only 20 minutes to heat to completion with water.
- **Lower temperature**. Because of the above effect, the dry mixture needs a higher temperature at the bottom to transfer the heat through the mixture and this ends up causing the whole mix to be at a higher temperature to get to the same consistency. The dry heated method needs to be about 380 degrees. When the mixture is heated dry, you have to get it hot enough to turn one of the ingredients to liquid. KN has a very high melting temperature, 631°F, sucrose melts between 320°F and 367°F. So 380°F will melt the sucrose and then the KN will dissolve into the liquid sucrose. Actually, the sucrose isn't really liquid, it is more like putty and that is why both must be finely ground and intimately mixed before heating. When you dissolve the components in water, they are thoroughly mixed even before they are heated or at least soon after. Then all you have to do is drive off the water and what is left is good propellant. The temperature is not critical, the higher the temperature, the faster the water will be driven off, but a lower temperature works fine. To start with, even 250°F is enough to boil the mix. The thermostat causes the element to either be on or off so as long as the mixture is below the thermostat set point, the element will be on. Until the majority of the water is boiled off, the temperature will not go much above 212°F anyway. Once the majority of the water is boiled off, the temperature will start rising. Then it is just a matter of bringing the temperature up to the point where the mixture is the least viscous (thinnest) which will be 300°F to 350°F.
- **Longer pot life**. Because the mixture is ready quicker, you actually have longer to cast the mixture into propellant grains than with the dry heated method. Caramelization will occur with either method but it is a function of temperature and time. You have already used up a larger portion of your pot life with the dry heat method simply because it has taken longer to reach temperature and has actually already started to caramelize some before it reaches that temperature. The higher temperature of the dry mix method also decreases the pot life. The dry heat method also requires a higher temperature on the bottom to get the temperature up on the top of the mixture so this causes a quicker caramelization.
- **Less stirring**. Although the more you stir the mixture in either method, the faster it is ready, you actually don't have to stir any where near as much with the dissolved method. You can just let it cook until it is into the "blurping" stage past the boiling stage before you start stirring it. With the dry heat method, you have to stir it almost constantly and from the very beginning. If you don't, it will just burn on the bottom before it melts the top of the mix.
- One possible negative to this method is that the resultant propellant is a little thicker (more viscous). It is not a pourable mixture no mater how you prepare it. It must be scooped and packed either way, especially with smaller molds. The more finely the sugar and KN are ground in the dry mix method, the thicker the mixture. The dissolved method makes a thicker mix because you really can't get a better and more thoroughly mixed propellant no matter how fine they are ground in the dry heat method.

You may find various people claiming to have come up with the method of using the dissolved method first but it would be like claiming to be the first person to think of mixing up a cake using a liquid as one or more of the ingredients. All you have to do is be in a kitchen and the idea is so obvious as to be ridiculous not to use water. If you took high school chemistry, you will also be very familiar with dissolving chemicals in water to mix them and then driving off the water.

Jimmy Yawn came up with a variation of this and has been using his method for many years. You can see his method on his website at http://www.jamesyawn.com/rcandy/index.htm. His method is more novel in his use of corn syrup and a kitchen oven to bake the liquid. More recently, he has gone to the more common method of using a skillet or deep fryer.

Sorbitol -- dissolved and heated method. Using sorbitol with this requires special methods and if done improperly will result in a propellant that retains water and will never cure properly nor burn properly. 500 grams of sorbitol propellant will take over an hour to "cook" compared to 20 to 40 minutes for sucrose. Scott Fintel uses 500 ml of water, 50 ml of distilled white vinegar for pH balancing, 325 grams KNO3 and 175 grams of sorbitol. He starts at 300 F and as it thickens, turns it down to 250 F, and finally to 200 F to finish it. The grains can then be cast and after casting should be put in a desiccator for a couple days to remove any residual moisture.

Heating Methods

A variety of method have been used to heat caramel candy propellant. The concept of dissolving in water first is more important than the method of heating. The main thing to consider when heating propellant is that you don't want exposure it to a high temperature source or a flame so a kitchen stove is not the best method. It is easy to spill a little propellant and it will readily ignite on a kitchen burner. It also can splatter during one phase of the preparation driving off the water. You don't want an entire batch catching fire because there is no way to put it out. It just has to finish burning and then the job is to put out what it caught on fire. This is not even a remote option. You must use safety procedures the prevents ANY possibility of this happening.

Directly on a Burner

This is the least desirable method. If this is the way it is going to be done, it must be done outside away from all burnable material and using protective clothing and a face shield (if you are smart). You must use a **double boiler**.

Double Boiler (on a stove top)

A double boiler means that you have one pan that heats oil (any kitchen oil like corn oil, safflower, etc.) or wax (paraffin which is what candle wax is) and another pan that sits down inside the first pan. The second must have a lip that extends over the lip of the first pan so that it cannot go all the way down inside but is held up off the bottom of the first. Many sets of kitchen pans include pans that can be used this way. See additional details under the deep fryer section.

Kitchen Oven

Jimmy Yawns original "recrystalized" propellant was done using a kitchen oven for the last step. He dissolves his ingredients, heats them up to boiling, then pours them into pie pans and puts them into the oven to finish. It takes a lot longer and I see no advantage in using an oven with a standard recipe for caramel candy propellant.

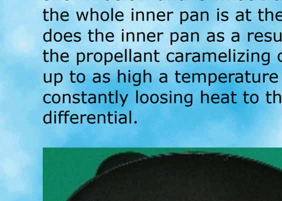
Toaster Oven

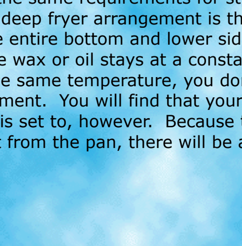
A Toaster Oven is even a worse choice. Because of its small size, the temperature variation in it makes it very unreliable. I tried using one and all I managed to do was burn it. You don't have access to stir it and stirring is very important.

Electric Skillet or Wok (thermostatically controlled)

This is the second best choice. A used electric skillet or wok can often be found very cheap at yard sales, estate sales, or thrift stores. They actually aren't that expensive new. The advantage is that they have a thermostat and you can control the temperature... sort of. Why "sort of?" Any thermostatically controlled kitchen heating device (fry pan, wok, deep fryer, etc.) control the heating element by just turning it off or on. The thermostat probe is in contact with a portion of the bottom of the pan and is actuated by the temperature of the metal in that vicinity. The actual heating element is embedded into the bottom of the pan and when the thermostat turns it on, it heats up. The portion of the pan directly above the heating element gets hot. That heat has to move out through the rest of the pan so it will be a lot higher temperature at the element than it is at the thermostat probe location. So what you have is a ring that alternately gets much hotter, then the rest of the pan, and then cools in a cycling process. The actual variation of temperature of the different areas of the pan is considerable. Constant stirring of either the dry heat or dissolved heating method is absolutely critical and even then, you will end up caramelizing some of the mixture. In the early heating stages of the dissolved heating method, it isn't important because the liquid will distribute the heat but as the water is driven off, constant stirring is required.

Trying to use an electric skillet or wok in a double boiler arrangement is not practical. You'll slop the oil or wax all over.





Deep Fryer (thermostatically controlled)

This is the best method. I use a double boiler arrangement with a deep pan that sits down inside the deep fryer. I found a Presto deep fryer at Kmart that was inexpensive and has worked excellently. Any double boiler arrangement is a little more complex and a little more trouble because of the extra heating fluid and extra pan, though, so using an electric frying pan with constant stirring in the last stages may still be the most practical method.

Double Boiler (with a deep fryer)

The deep fryer has a similar heating arrangement as an electric fryer but has the advantage of being deep and readily adaptable to a deep fryer configuration. It can be used without the deep fryer arrangement in the same way as the electric fry pan above and has the same requirements for stirring and the same handicaps, plus being deeper. The advantage of the deep fryer arrangement is that the wax or oil (wax is shown below and is what I use) is in contact with the entire bottom and lower sides of the inner pan and so the whole inner pan is at the same temperature. The wax or oil stays at a constant temperature and so does the inner pan as a result. Because it is all at the same temperature, you don't have the problem with the propellant caramelizing or scorching over the element. You will find that your propellant will not heat up to as high a temperature as what the thermostat is set to, however. Because the propellant is constantly loosing heat to the air as it is getting heat from the pan, there will be a small temperature differential.