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1. Our Value Proposition

Our patented catalytic heating technology totally eclipses all other methods of personal portable heating. Competing technologies are much less powerful, heavier, more cumbersome, less safe, less controllable and less portable.

Coolfire® heating technology is a unique, proprietary embodiment of flame-free catalytic heat energy that is free from noxious emissions and safe enough to be used in unattended situations and close quarters.

While there are many ways that our technology might be used, we have developed prototypes of a portable travel mug that are basically the "ideal" coffee, tea, soups etc. travel mug. Our mug version improves the user experience with high energy efficiency, high power and precise temperature control by using the intelligent self-starting capability featured in Coolfire®. It can repeatedly heat or boil liquids and keep itself hot for days. Most importantly, it can be manufactured at an attractive cost.

2. Coolfire® Technology is a Unique Type of Catalytic Heating

Before Coolfire® technology, no catalytic combustion was completely enclosed. All have been open to the atmosphere. Learning how to enclose such a reaction while providing enough oxygen to adequately burn the fuel was the challenge that needed a solution.

We solved that. Cliff Welles, founder of CNW, has been working in the catalytic field for more than 20 years and changed all that. As a result, CNW has been granted patents covering our technology.

What does this change? Why is this a big deal? Let's go over some of the advantages:

The Advantages of Catalytic Heating in General:

- A catalytic reaction allows the combustion to take place ONLY on the surface where the catalyst is placed. By placing that catalyst in the appropriate spot, (on the surface that you want heated), the designer can direct the heat to occur where it makes the most design sense unlike a flame-based design where the physics of flame orientation severely limits this option. This property of catalytic heat can be applied so as to increase the heating efficiency.

- A catalytic reaction can be started much more easily than one without a catalyst involved, allowing ignition without flame or other high energy sources (e.g. spark).

- A catalytic reaction can be run at a much lower temperature than flame based reactions, significantly increasing the safety profile.

- A catalytic reaction is largely orientation insensitive. Unlike flame based heating, a catalytically heated travel mug can be designed to function just as well lying on its side as it would when operated in the standard resting position (.i.e.vertical).

Added Coolfire® advantages

- An enclosed reaction is safe. That is, there is NO way for a flame to get out of the reaction chamber. No fire can be started even by someone not using the device correctly.

- This allows catalytic heating to move from industrial to consumer products!

- An enclosed catalytic reaction not only does not have a flame but also goes a step further by completely isolating the user, as well as, the products internal structure from exposure to the hot reaction zone. This allows for a much more compact and lightweight design. By allowing better control of where the heat energy is directed, Coolfire® makes new product applications possible.
- An enclosed reaction can be better monitored and controlled. If the reaction were not enclosed, then some of the O2 would be coming from the outside the fuel-air stream (i.e. air diffusing in from the surrounding atmosphere). This makes it harder to control the reaction precisely to insure best combustion. In an enclosed reaction, all of the fuel AND O2 can be premixed in exact amounts to obtain the most favorable combustion state. With Coolfire® technology, our enclosed reactions have virtually NO pollutants exhausted!

- With the use of sensors, it is easy to ascertain the temperature, and thus with a simple control unit, to automatically adjust the fuel-air flow rate and ratio in order to maintain the temperature at any particular level.

- An enclosed reaction is windproof thus less affected by outside conditions.

Thus, with a Coolfire® technology device, one can burn any appropriate fuel (see section 6) in perfect safety.

Such a device can be entirely controlled by digital logic, with real-time temperature also displayed digitally. In many ways, such a device is more like a small microwave than a stovetop.

Like a microwave, where most people feel very safe, Coolfire® operational simplicity and ultra-safe profile engenders a similar spirit. It could be operated in a car, on a boat, in an office, on a hiking trail, by most anyone that can push a button. The temperature can be set to whatever the user wants, and the temperature once achieved will stay at exactly that temperature for as long as you want or potentially set a pattern of temperatures much like an InstantPot®.

3. Coolfire® vs Alternatives - Introduction

Portable heat-generating methods generally fall into two broad classifications; (1) exothermic chemical reactions and (2) electrical resistance heating. Applications utilizing exothermic chemical reactions can be further classified as (a) open flame heating and (b) catalytic heating.

Catalytic heating, in a variety of forms, has been utilized for some time. Until now, the lack of innovation in this technology has prevented it from reaching its full potential. In fact, the conventional approach to catalytic heating has many of the same issues as flame-based heating.

By comparison, portable electrical resistance heating products have lagged far behind combustion-based heating technologies (both flame and catalytic). Although modern battery technology is excellent for a wide variety of product applications, it currently lacks certain critical properties needed to successfully address personal portable heating applications. For example they are severely hampered by the very low energy density, compared to chemical energy storage. Batteries in general, including top performing lithium based chemistries, also bring a host of other performance limiting issues (self-discharge, weight, max power delivery, cost, etc.). Because of this, portable electric heating products have been relegated to a very small part of the marketplace and are unable to meet many of the basic user requirements demanded of the larger market.

The following comparison between Coolfire® catalytic heating technology and battery powered heating, illustrates why battery technologies are not likely to successfully address these shortcomings in the foreseeable future.

4. Coolfire® vs Batteries - Point by Point: Why Batteries Can’t Do It.

The use of electrical power to generate heat in consumer products has been in use since the beginning of the electrical distribution grid. The engineering principles underlying this form of heat generation are well established and understood. When the electrical power is obtained from the grid, there is generally little design challenge required to obtain a satisfactory product design.

In contrast, when the electrical power is obtained from a battery, the design challenge needed to obtain satisfactory product characteristics can become extreme. Sometimes the desired product attributes are simply unattainable with the current battery technology.

We will briefly explore some of these challenges and indicate why meeting these challenges using battery power is very unlikely to occur in the near future (5 to 10 years).

For portable heating applications, the battery attributes that are most important in achieving an acceptable product design are:

- Energy Density
- Power Density
- Maximum recommended charge and discharge rate
- Number of Charge/Discharge cycles before battery wears-out
- Cost

ENERGY DENSITY

When battery energy density is compared to liquefied petroleum-based fuels, it becomes readily apparent that liquefied petroleum is many times (~ 100x) more than the very best commercially available battery energy sources.

The battery industry has expended a great deal of effort toward increasing the energy density of batteries, especially with Lithium based chemistries. Figure 1 shows the energy density for several different battery chemistries currently in production.

The effort to increase battery energy density has been driven to a large extent by the needs of the EV market. Lithium battery energy density has been increasing slowly over the years, averaging around 5% per year. There are often reports appearing in the engineering journals that suggest that a large increase (i.e. 2X) in energy density is about to happen. Indeed, bench test results for some new designs do support this prediction but the technology never makes it into production because of other issues.

The reason for this is that successful battery production requires that a large number of critical performance and cost parameters be achieved, not just energy density. Dramatically increasing energy density often results in one or more of the other critical battery performance parameters deviating well beyond the acceptable range.

One possible exception (It has as yet to be demonstrated) is the lithium solid-state battery. It has a theoretical energy density improvement of about 2X. Several reputable companies have committed to introducing a prototype EV powered by solid-state lithium batteries before 2025. It is not anticipated that the energy density will increase by the theoretical maximum of 2X, but even if it did, the fuel cartridges that power the Coolfire® catalytic heat products will have about 50x more energy density, at a cost that is many times less.

The practical impact this has on product attributes for small portable heating products can be seen by comparing the CoolFire® catalytically heated travel mug to two battery heated travel mugs, Ember and Cauldron Frye Mobile.

Ember attempted to apply battery power to a travel mug beverage heater while at the same time bounding the size and weight to be within typical travel mug parameters (8” tall with a tapered diameter of 2.8” at the bottom and 3.12” at the beverage cup mouth and a weight of 16 oz.)
.
Because of current battery technical constraints, the result was that the Ember travel mug does not have sufficient battery energy density to bring a beverage from room temperature to boiling even though the beverage volume is only 12 fl oz. Because of this limitation, it is advertised as a device that maintains an already heated beverage (presumably from a barista) at between 120°F and 140° F for two to three hours. In other words, with current battery technology, it was not possible to store sufficient electrical energy within an acceptable package size to achieve even minimal functionality for an all-purpose cooking, warming, and temperature-maintaining portable travel mug. Even if the energy density were doubled, this would not solve the problem as illustrated in the Cauldron battery-driven travel mug.

The Cauldron travel mug attempts to overcome the performance limitations of the Ember product. It can take a 16 fl. oz. beverage from room temperature to boiling one or two times before a full re-charge of the battery is required. Cauldron’s average time to reach boiling from room temperature is 18 minutes.

To achieve this feat, Cauldron substantially increased its package size and weight. Its height dimension is 50% greater than Ember and its weight is at an astonishing 37 oz (2.3lbs) vs Coolfire’s 14 oz.. Most of the extra weight gain comes from increasing the number of batteries (i.e. increasing the total stored energy available).

As will be explained in the next two sections, Cauldron’s long period of time to boil is NOT because of the energy density limitation of batteries but due to more fundamental limitations that affect all battery heated products.

By comparison, the 16 fl. oz. CoolFire® travel mug has a package size (similar to the Ember travel mug) 8” tall with a tapered diameter of 2.8” at the bottom and 3.75” at the beverage cup mouth with a weight of 14 oz. CoolFire® can perform 12 boiling events with one small 4fl.oz. gas cartridge that fits unobtrusively within the body of the mug.

POWER DENSITY

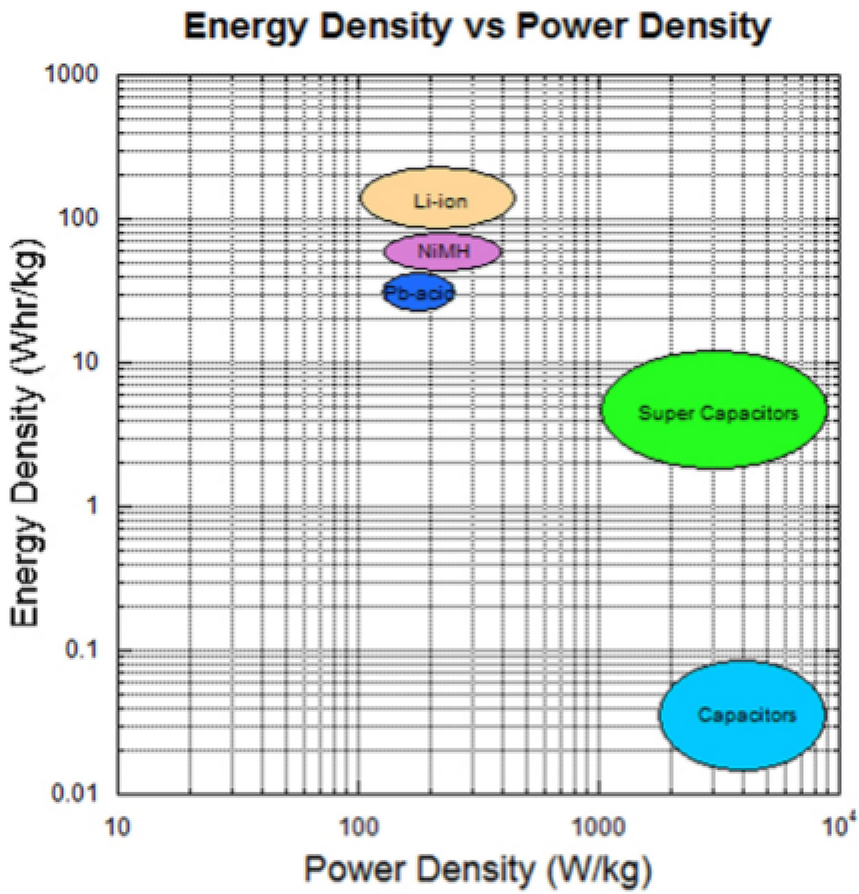
Because of the ubiquity of electric vehicle technology, Power Density (unlike energy density) is not a parameter that is frequently discussed in trade magazines. This is because energy density relates directly to miles available between vehicle charging.

Nevertheless, for certain portable electric heating applications, Power density can be a more important parameter. This is particularly true for electrically heated travel mugs.

Power (e.g. watts) is the rate at which energy is extracted from the battery. A battery may have a lot of stored energy but if it cannot be extracted at a sufficient rate, it can severely limit its applications. Power density refers to either how compact (volumetric power density) or how heavy (gravimetric power density) a battery will be for a given energy extraction rate (i.e. watts). If you cannot heat the beverage to a given temperature at a reasonable rate, having high energy density doesn't really help and becomes almost irrelevant. In other words, doubling the energy density has no effect on the time it takes to reach boiling.

This is especially relevant when evaluating potential future battery technologies, such as solid-state batteries, which are projected to have higher energy density than current lithium-ion batteries. This is because they are anticipated to have relatively low power density (e.g. at the low end of current lithium-ion batteries) as shown in figure 1.

Power density limits for batteries are a result of several factors such as internal battery resistance, as well as, potential physical changes that may occur at the anode and cathode which could permanently change its performance. In addition, how well the battery can dissipate internal heat will also affect limits to power density.. Figure 1 is a Ragone plot showing both the energy and power densities for several electrical energy storage devices including Lithium-ion batteries. One useful way to use this chart is to pick any point within the bounds of a particular battery chemistry and note both the energy density and power density. The ratio of Energy density to Power density is the time (in hours) that the battery can operate before being completely discharged.



Gravimetric Energy Density versus Power Density
For a Variety of Stored Energy Sources
Figure 1

Achieving the highest theoretical power density may require adding a cooling method which can be either passive (convective and conductive) or active (forced air or liquid). This adds additional weight and/or volume. Active cooling is usually reserved for large applications like electric vehicles. For smaller applications like the battery-driven travel mug, active cooling is not practical which means the actual power density available may be much less than the theoretical.

By comparison, the power density of air/fuel fed catalytic combustion processes are limited only by the air/fuel feed rate which is virtually unlimited (although, from a practical perspective, at some point, very high catalytic power densities may require a redesign of the product to address safety issues). Thus, even a very small fuel cartridge is capable of delivering heat power at levels far beyond a battery of similar size and weight.

In summary, for certain applications, like the heated travel mug or small portable stoves, power density is just as important, if not more so, than energy density and current technology road maps regarding future battery improvements in the next 10 years do not show batteries as a viable energy source to replace or compete with compressed liquid fuel sources in these applications. With the advent of 2nd generation renewable fuel sources, it is believed that the Coolfire® fuel/air driven catalytic heating approach will remain the top contender.

In addition to battery issues of energy and power density, another potential impediment that battery-driven energy sources must contend with is the very nature of electrical power transfer from the battery to the load (i.e. heating coil). A fundamental theorem in electrical engineering (i.e. Maximum Power Transfer Theorem) adds an additional complication to extracting energy from batteries.

ELECTRICAL LOSSES AND INEFFICIENCIES

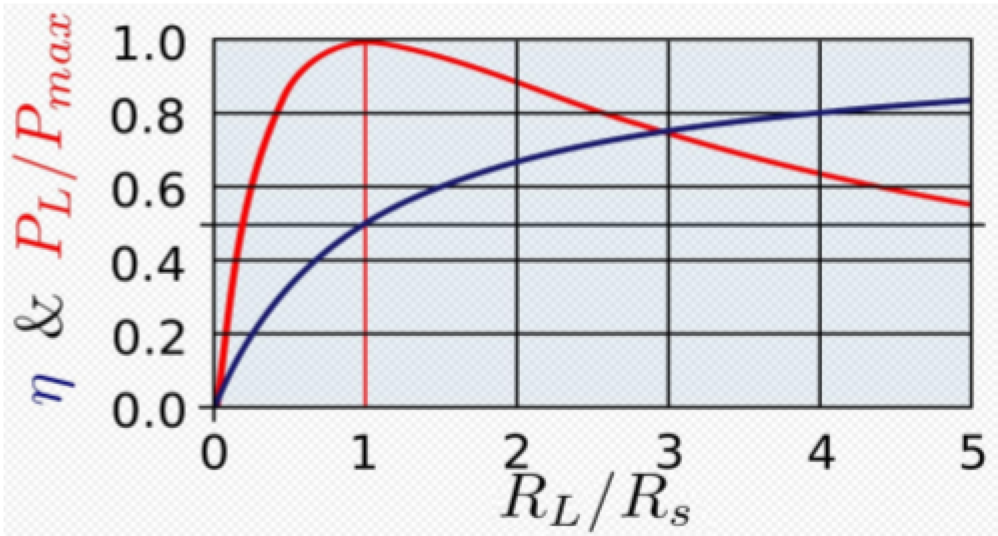
By way of a simplified design example, let's say it is desired to heat a 16 fl. oz. volume of beverage from room temperature to boiling in 10 minutes and compare battery and catalytic combustion approaches. A simple calculation shows, assuming no heat loss, that a 16 fl. oz. volume of fluid (water) must receive heat energy at a rate of about 261 watts to reach boiling (100C) from room temperature (i.e. 21C) in 10 minutes.

From figure 1 it is possible to deduce that by pushing the limits of lithium-ion technology, it might be possible to access a power density of 400 W/kg with a maximum run time of 18 minutes before discharging the battery. However, not all of the power can be delivered to the heating coil resistance.

The maximum amount of electrical power that can be delivered to a load (e.g. heating coil) is determined by the Maximum Power Transfer Theorem. The theorem states that maximum power is transferred (red curve in figure 2) to the heating coil when the coil's electrical resistance (RL) is equal to the internal resistance of the battery (RS). The blue curve in figure 2 shows the battery efficiency. It indicates that the efficiency of the power transfer is 50%. This means that half the power is being lost in the internal resistance of the battery. If the circuit was allowed to operate this way, then for the example given above, the battery would need to deliver a total power of 522 watts. Under this scenario, the battery would weigh at least 1.3 Kg (2.8 pounds) and have a total stored energy capacity of 195Wh (i.e. 150Wh/Kg from Ragone plot multiplied by 1.3Kg).).

In this case, the battery has to dissipate 261 watts. This can be a very difficult challenge. The very limited space and weight constraints make active cooling impractical and passive cooling (convective & conductive) is not likely to be sufficient.

The only practical approach would be to operate the system at higher efficiencies. Figure 2 illustrates that this moves the operating point further to the right on the blue curve. The trade-off, is of course, that the maximum possible power transfer into the heating coil must be reduced substantially below what is theoretically possible. For instance, if the designer chooses a point on the power transfer curve that is 80% efficient (80% of energy from battery is converted to heat a beverage and the rest is wasted.) the maximum possible power from the battery is reduced to about 64% of the battery's maximum power density.



Red curve shows power delivered to load (R_L) as a percentage of maximum possible. Blue curve shows battery efficiency.

Figure 2

The volume occupied by the batteries can be estimated by examining figure 3. The graph shows that the highest volumetric energy density available in current lithium-ion battery chemistries is about 370Wh/Liter. This provides an estimate that the battery pack will occupy about ½ liter of space.
It can be concluded that even setting modest performance requirements (i.e. 10 minutes to boil 16fl.oz.), the battery's weight and volume are exceeding acceptable levels for a handheld travel mug.

Driving the heater coil for 10 minutes (time to reach boiling from room temperature) will cause 87Wh of energy to be expended during the 10 minute period. This gives the battery the ability to cycle 2.24 times before a recharge is required. In reality it will be less than 2.24 cycles because the power transfer operating point (fig. 2) will probably be between 50% and 80%.efficiency (see below).

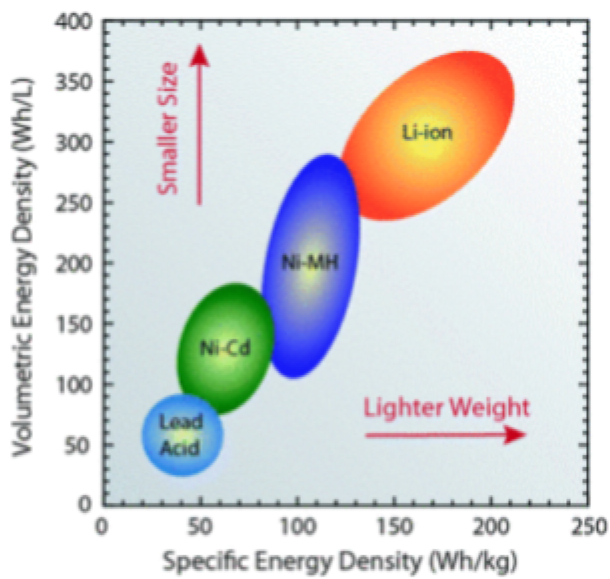
To achieve 9 heat cycles on one charge would require 4 times as much battery or 5.2 Kg (11.4 pounds) and occupy a volume of at least 2 liters of volume which is very far from a practical solution for this type of application.

In practice, it is usually desirable to have the system operating at efficiencies higher than the 50%. This is achieved by increasing the load resistance (heating coil) well above the battery's internal resistance as shown in figure 2 above. Doing this, of course, the percent of total power available to the load is reduced. Generally, the designer requires a specific minimum power transfer without regard for whether one is extracting the maximum power available from the batteries. To achieve this, the number of batteries can be increased in such a way that the net power transferred to the load is increased to the required amount, regardless of the operating point (figure 2).

The disadvantage is that the total number of battery cells must increase well beyond what a casual examination of the battery's (maximum theoretical) power density might indicate as being sufficient. This makes a bad situation (i.e. weight and package size) even worse.

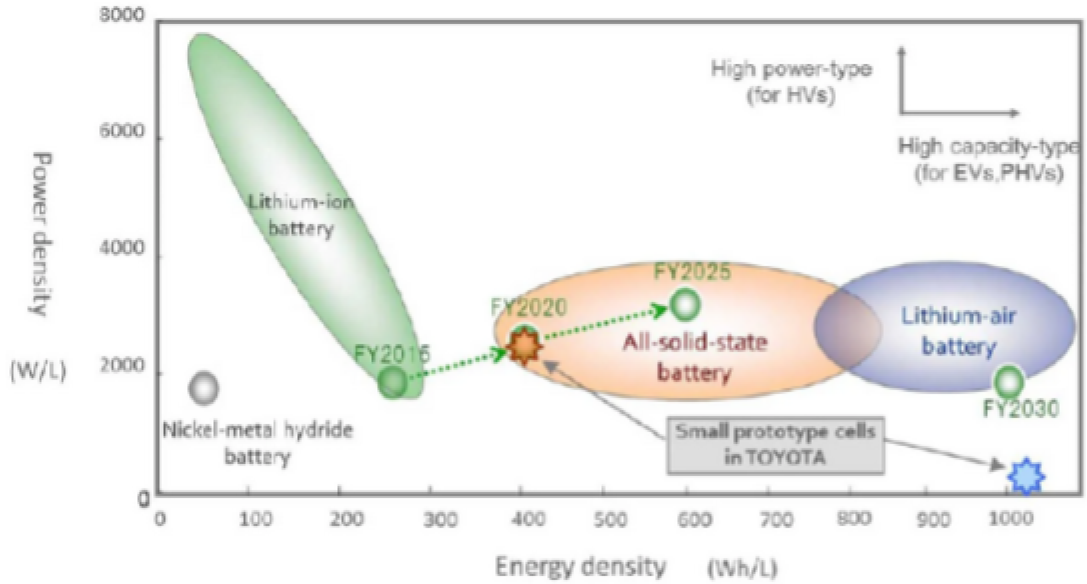
For an application like electric vehicles, this is an acceptable trade-off because weight and volume increases are more acceptable and high efficiency in EV applications is essential for good mileage.

Contrast this to Coolfire® technology, where a very small (about 4 fl. oz.) and lightweight (3.3oz) fuel cartridge can produce 12 boiling events. Additionally, Coolfire® power densities are not limited by any fundamental properties of the technology as they are in batteries. This means boiling times faster than 10 minutes are obtainable and at a very low fuel cost.



Energy densities for different battery chemistries

Figure 3



Volumetric Energy Density versus Power Density
Projected by Toyota
Figure 4

5. Coolfire® vs Open-Flame - Point by Point

Fundamentals:

FLAME BASED HEATING:

In order for heat to be generated by a flame-based process, the fuel molecules and oxygen molecules in the air must collide with sufficient kinetic energy (molecular speed) to overcome an energy barrier that normally keeps the molecules from reacting (i.e. exothermic reaction product) and releasing heat. The high energy barrier requires a high flame temperature (> 1000°C) to sustain the reaction, as well as, to start it (match, spark, etc).

CATALYTICALLY BASED HEATING:

Coolfire® technology employs a catalyst within the reaction zone to produce a flame-free, low temperature (< 260°C) heat reaction. The basic principle of operation is that the catalyst lowers the energy barrier between the fuel molecules and the oxygen molecules so that they may combine at a much lower temperature. The catalyst is not consumed in the reaction. Instead, it acts as a kind of "broker" to ensure that the molecules combine at a much lower temperature than normally would be required. It then proceeds to perform this function in a continuous manner as new, unreacted fuel and oxygen, enter the reaction zone. Although catalytic heating is not a new concept, the Coolfire® approach is a unique and patented method of optimizing catalytic heating for a wide variety of portable heating applications including beverage and food heating applications. In stark contrast, conventional catalytic heating has many of the same problems and limitations as flame-based heating.

Startup, Control, and Emissions:

FLAME BASED HEATING:

The kinetic energy required to start the reaction is generally supplied in the form of a high energy mechanism (match, spark, etc) or process of some sort to produce a temperature above the autoignition point. Automated starting of flame-based products depend on spark-based mechanisms. Portable products, that utilize a spark starting approach, universally depend on a manually switched piezoelectric component. Piezoelectric starters are prone to damage and tend to have high failure rates, are cumbersome to operate (high starting force manually applied), and relatively noisy. Once started, the heat power is controlled by manually adjusting a flow valve (e.g. needle valve).

When a high temperature flame contacts a much cooler cooking utensil surface, an unsteady boundary layer is formed at the surface. The gases within the boundary layer transfer their heat energy to the cooking utensil causing some of the fuel/air mixture within this layer to drop below a critical temperature. This can prevent some of the fuel/air mixture constituents within the flame from completing combustion. Consequently, incomplete combustion products often form which include the toxic emission of carbon monoxide.

CATALYTICALLY BASED HEATING:

Coolfire® technology does not require a flame or spark to start the reaction. Instead, a micro-miniature, electrically driven (joule heating) resistance coil is embedded within the catalytic media and raises the local temperature to a point (well below the autoignition point) where the reaction begins. The reaction then spreads rapidly throughout the reaction chamber, allowing completion of the heat-generating fuel/air reaction without noxious by-products (i.e. no CO or NO_x). Unlike portable open flame products, the starting process for Coolfire® catalytic technology is completely automated, noise-free, and requires a very low energy draw (0.5 W-sec) per start. Heat power is controlled by built-in sensors and a set of microcontroller algorithms.

Combustion Stability:

FLAME BASED HEATING:

Naked flames can only be sustained by a careful balance between flame propagation speed (which is determined by fuel type and fuel/air ratios) and the rate at which the raw fuel/air feed enters the reaction zone. Because of the need to balance these and other parameters within a narrow range of settings, flames may be thought of as essentially borderline stable. This tendency toward instability (i.e. flame out condition) also makes them susceptible to being extinguished by wind currents that interrupt this balancing act.

In addition, flame-based products have other restraints, such as being sensitive to the physical orientation of the product (i.e. the flame is always vertical), so it is necessary to provide (a reasonable degree) of product leveling to ensure proper heat transfer and optimum performance. Another limiting factor for flame-based products is that fuel/air mixtures must be within a relatively narrow operating range. If the mixture is too lean or too rich, flame ignition becomes unreliable.

CATALYTICALLY BASED HEATING:

Coolfire® catalytic technology avoids most of the limitations of flame-based heat sources. The reaction cannot be extinguished by wind effects and is not susceptible to flame lift-off or flash-back effects. Moreover, our patented catalytically driven combustion technique runs at temperatures below the ignition point of most materials encountered in daily life. In addition, it operates over a very wide range of fuel/air ratios not achievable with flame combustion. It is also not dependent on product orientation, which makes it safe and convenient to operate while walking, hiking, or traveling in a vehicle. Because of this and other properties, Coolfire® accommodates a much wider design space resulting in more desirable product attributes.

Fire Safety and Heat Transfer:

FLAME BASED HEATING:

Because of their high temperature, (typically above 1000 °C) and the lack of a flame isolating envelope, flame-based portable heaters present a serious fire hazard if knocked over or placed too close to flammable material. The lack of a flame isolating envelope also contributes to safety issues during the starting process. For instance, inexperienced or inattentive users, who inadvertently let the unignited fuel/air mixture build up too much before manually igniting the flame, may see a sudden and unexpected back flash that propagates out of the air vents, exposing the user to potential harm.

The high temperatures common in flame-based heating tends to cause a high degree of local turbulence as a result of flame zone buoyancy. The turbulence can adversely affect heat transfer, limiting overall efficiency.

CATALYTICALLY BASED HEATING:

Coolfire® catalytic technology produces a reaction that runs at an average temperature of about 260°C, which is well below flame-based heat sources. The Coolfire® catalytic heat-generating technology is completely enclosed within a porous, open-cell, metal foam structure. The resulting effect is that the boundary layer at the cooking utensil surface is laminar. This allows a

more uniform heat transfer to occur which increases overall efficiency and eliminates local hot spots.
In addition, the metal foam, in which the catalytic reaction is maintained, has geometric properties that cause it to behave as a flame arrestor, further limiting the potential for any kind of flame formation or propagation.

6. Coolfire® and Fuels: Maximizing Value

For a variety of practical reasons, the energy sources for exothermic chemical reactions (flame and catalytic) have been generally limited to fuels that liquefy under moderate pressures while operating in a narrow range of ambient temperatures. These include propane, n-butane, and iso-butane. Fuels that are not stored in the liquid phase suffer from very low volumetric energy density (i.e. stored energy per unit volume of fuel).

Because portable heat generating applications benefit from having a lightweight fuel container, the fuels or fuel mixtures (n-butane, isobutane, propane) used in practice are chosen such that the saturation vapor pressures (liquefying pressure) fall within a DOT (Department of Transportation) specified range.

Coolfire® technology has been carefully designed to take advantage of a very special fuel source known as DME. To understand what makes DME so special and the very best choice for a liquid phase fuel canister requires a more careful look at the details.

A bit of chemistry may be necessary to explain. Basically, to have a reaction where something successfully burns, you need three components: fuel, heat, and O2. Fuel is supplied by the canister. An ignition source starts the process and then heat is released by the reaction. Oxygen is usually supplied by the environment. An open flame like a candle is a good example of this.

Air is made up of lots of gases, but the one we are interested in is Oxygen. The percentage of oxygen in the open air is approximately 21%. But at altitude, while the percentage doesn't change, the amount of O2 decreases significantly. About 2/3 of the amount of O2 that is available at sea level is available at 10,000 feet. Different fuels require different amounts of O2 to burn. For example, for the gas fuels that that are currently sold in small, lightweight canister format are:

- Propane requires 25/1 air to fuel ratio for complete combustion.
- Isobutane requires 31/1
- DME requires 15/1

We have successfully devised methods to completely and efficiently combust these common fuels (n-butane, iso-butane, propane). However, the results have shown us that there is such a huge advantage to DME, that use of any other fuel would result in a more complex system design, which in turn substantially increases product cost.

Stoves don't work as well at altitude, as it is considerably harder to find enough O2 to make them burn efficiently. But "flame combustion" stoves don't burn that efficiently in the first place. There have been considerable discussion and testing of stoves in the last 10 years concerning their inability to burn fuel completely, resulting in unacceptable amounts of CO, and unburned fuel.

Tests done by Roger Caffins, published in BackPacking Light, showed that the average backpacking stove produced about 250 ppm of CO during operation. It is true, that a few of the stoves tested better under very specific operating conditions (20ppm). Nevertheless, some medical literature has suggested long term low level exposure is potentially harmful to the user.. It is worth noting that two of the most popular stoves tested, were actually far worse.

These tests were done at sea level. IF the tests were done at altitude, the results would be worse still. The sampling method used placed the stove into a specially constructed box intended to simulate a particular environment. Our results were obtained by direct sampling at the stove exhaust outlets which results in a more sensitive indicator. Testing thus, the rates we obtained on such open flame stoves were more than double what Roger found.

CNW does not consider these rates to be acceptable. Coolfire® technology is NOT open flame burning. It is our aim to burn a fuel cleanly and completely, both for health reasons and because complete burning is obviously more efficient.

All open flame devices use an orifice driven Venturi device to supply the majority of the air to the combustion.They are rated according to their ability to entrain air with the fuel gas. It turns out that one of the parameters that has a major effect on the entrainment ratio is the flow resistance (i.e. pressure drop) that occurs downstream of the venturi.

To completely burn the fuel gas from canisters currently being sold (Butane or butane/propane mix), the venturi device must have an entrainment ratio of at least 31. Unfortunately most stove burner pressure drops are such as to make it difficult to achieve this ratio, resulting in incomplete combustion. Even if the 31/1 ratio could be achieved at sea level, it would fall short at higher altitudes.

While theoretically possible to make a venturi that might reach 30/1, the evidence shows that current burner designs must rely on extra air that is supplied from the outside air surrounding the burner flame (secondary air). Because secondary air does not always mix thoroughly with the primary fuel/air stream, the results are often incomplete combustion products.

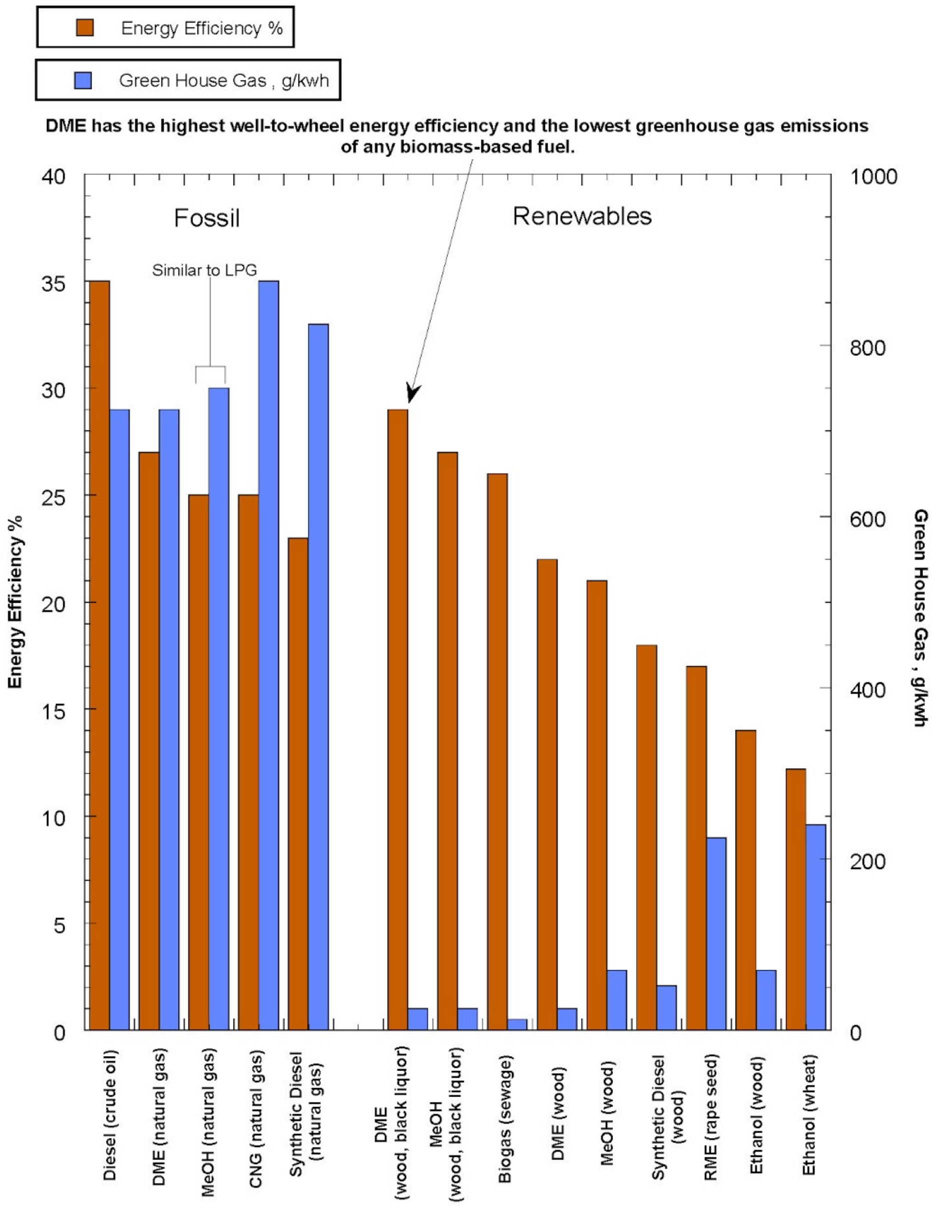
Using pure propane would improve the situation (i.e. 25/1 ratio) but other factors can still interfere with the combustion process. For instance, it is common to see soot forming on the bottom of pots, which is a good indicator of incomplete burning. Additionally, pure propane is rarely used in portable devices because its higher vapor pressure requires a stronger walled and much heavier cartridge.

For Natural gas, it would be quite good. No additional air would be needed. However, Natural gas is not practical in a canister format as the pressure required to obtain reasonable energy densities (i.e. liquefying the gas) would result in very thick walls.

DME, it turns out, is a great candidate, as it does not require additional O2 beyond what is easily produced by a Venturi.

Coolfire® technology is NOT open flame technology. There IS NO flame. The combustion process is totally internal and completely encloses the catalytic process. NO secondary air is required with DME. If we use isobutane as a fuel with our technology, boost air must be provided using a more expensive Coolfire® design. Consistent long term testing of Coolfire® technology has shown that our devices burn extremely efficiently and that the amount of unburned fuel and CO is undetectable using 1ppm resolution measurement tools.

Coolfire® catalytic heating technology is designed to take maximum advantage of a unique, renewable form of fuel gas (DME).It can be sourced as a second generation biofuel and is considered to be carbon neutral. It also has the lowest greenhouse gas contribution of any biomass-based fuel and the highest “well-to-wheel” energy efficiency. It functions much better in cold conditions than other canister fuels and because it is oxygenated, it maintains complete combustion over a wide range of altitudes. Thus DME is the fuel that is indisputably best for catalytic devices. Cartridge fillers are also very familiar with DME.



7. Consumer Products

The device we have been working on first is a very portable beverage mug. But a camp stove is also possible, as well as using the technology for heating food in a temporary setting such as a chafing dish. (No electric wires to hide or trip over, perfect heat control, no smell of sterno, and

MUCH safer.) Additionally, there have been inquiries from very different fields...in engines or devices where combustion control is desirable for instance.

We are seeking to license our patents but the CNW team has experience in product development, engineering, and sourcing of both components and finished products. We are available on a consulting basis to supplement your team where needed.

8. Coolfire® Technology Summary

- FIRE SAFETY - Coolfire® catalytic heating provides a level of safety far beyond any previous fuel-based heating technology. Low average temperature (<260°C) and the fact that there is no actual flame generated and that the microscopic heat-generating sites (catalytic particles) are surrounded by open-cell metal foam which acts as a natural flame arrestor means that it cannot induce a fire under any conceivable condition encountered by a user.

- An additional layer of protection is provided by multiple temperature sensors distributed strategically throughout the unit in order to shut-off the reaction if operating parameters exceed nominal settings.

- IMMUNE TO WIND EFFECTS – Unlike flame-based products, Coolfire® catalytic heating is a completely enclosed heat reaction process, isolating the heating mechanism from the effects of wind and air turbulence. This is a consequence of both the flameless nature of catalytic combustion and the unique geometry of the Coolfire® design.

- OPTIMIZED USER EXPERIENCE BY PRECISE SYSTEM & PROCESS REGULATION – The Coolfire® catalytic heating approach is designed to be amenable to microcontroller operation. The heat-producing reaction may be rapidly turned on and off without user interaction using preprogrammed user scenarios. This allows exact temperature control of the beverage or food item being heated. An integrated web of temperature sensors located throughout the product provides the microcontroller continuous system and process status. The rapid and easy ignition or quenching of the catalytic heat reaction affords a high level of precise temperature control and operational flexibility in order to optimize user experience.

- RELIABLE “EASY START” IGNITION MECHANISM -The reaction starting mechanism (ignitor) is entirely automated and utilizes a pulsed joule heating coil. This type of ignitor provides a highly reliable starting process with extremely low failure rates (millions of start cycles) and lends itself to being easily embedded into microcontroller-based operating systems. By comparison, most portable flame-based devices that have starters, require the user to manually actuate a snap-action piezoelectric device in order to generate a spark. Piezoelectric starters are not always reliable in igniting the fuel/air mixture and tend to have a short operational lifetime (typically on the order of a few thousand starts) because of the fragility of the piezoelectric material.

- <u>NO</u> DETECTABLE TOXIC EMISSIONS

Typical Carbon Monoxide Emissions from Canister Stoves				
STOVE	CO PPM (method 1)* (sea level)	CO PPM (method 2)** (sea level)	COMMENTS (highest values were selected from each run)	each run)
Brunton Raptor	286		Upright canister stove	
Coleman Fyrestorm	30		Upright canister stove	
Coleman F1 Ultralight	154		Upright canister stove	
Jetboil GCS	90		Upright canister stove	
Jetboil Minimo	N.A.	1100	Upright canister stove	
Kovea Expedition	12		Remote canister	
Kovea Moonwalker	50		Remote canister	
MSR WindPro	85		Remote & liquid feed canister	ter
MSR Pocket Rocket	220	3000	Upright canister stove	
MSR Reactor	300		Upright canister stove	
Optimus Crux	300		Upright canister stove	
Optimus Stella +	136		Remote canister	
Primus Gravity MF	100		Remote & liquid feed canister	ter
Primus EtaPower EF	13		Upright canister stove	
Primus Micron Ti 2.5	90		Upright canister stove	
Snow Peak GST 100	21		Upright canister stove	
Snow Peak GS200D	260		Remote canister	
Vargo Jet Ti	30		Upright canister stove	

* Method 1: CO values are established by operating the stove inside a containment vessel (e.g. box) designed to allow air to enter at the bottom and exhaust to exit through a chimney where measurements are obtained. This method, because of the dilution with outside air, gives CO values substantially less than method 2 (e.g. by a factor of 5 or 10). Measurements obtained by Roger Caffin/Backpacking Light.
** Method 2: CO values are obtained by direct sampling of emissions exiting the stove exhaust vents. Measurements obtained by CNW Global

Measurements performed by Roger Caffin for "backpacking Light" included examining the changes in CO emissions that occur when altering a variety of operational parameters. These include; high and low power settings, small and large pot sizes, the distance between pot bottom and burner head, wind, horizontal flames versus vertical flames.

These results suggest that CO generation in flame-based products derives largely from the dynamical nature of flames. In other words, the physical properties of the flame chamber (i.e. geometry, size, and materials that define the volume between the burner and the item to be heated, such as a pot or frying pan) and the parameters that affect the fuel/air reaction (e.g. air/fuel feed rate, surface temperature of the item to be heated, wind effects and altitude) is not fixed and can be altered by small changes in its physical environment. Because of this, it can be difficult to predict with certainty a set value for CO emissions from a particular product design.

In contrast to flame-based heat, CoolFire® catalytic combustion does NOT produce any measurable (< 1ppm) quantities of CO after start-up is completed, regardless of wind, power level, orientation, or altitude (i.e. up to 12,000ft.)

9. History and Background

A catalyst, as many people know, is basically something that, when involved in a reaction, allows the reaction to take place at a lower temperature or pressure than it would otherwise be able to. Furthermore, the catalyst itself does not enter the reaction. It does not change itself; it just facilitates the reaction.

There has been study of catalysts for several hundred years. Originally and for well over 100 years, the most common use of catalysts was in catalytic heaters and in mantles of lanterns. Of course, nowadays, folks generally think of catalytic converters in cars. The concept is the same. Gases that won't burn in the engine, for whatever reason, were ejected out the tailpipe until the additions of catalytic converters. The converter uses a catalyst, (usually something like platinum) to allow the unburned gases that are passing through it to combine with O2 and burn, thus venting less unburned gas to the atmosphere.

Catalysts HAVE been used in heating devices, but all such devices in the past HAVE been open to the outside air, so not totally enclosed combustion. Think of it like this: a thousand years ago, civilization had candles, and fires, all of which were very useful, but then the internal combustion engine was invented. Now real work could be performed using combustion. I think we all can admit that this was a huge discovery, whether you want to admit it was a boon to mankind or not.

Catalytic combustion heating technology, for the most part, has remained essentially an open air catalytic process. No catalytic combustion had been completely enclosed-until Coolfire® technology was developed.

Cliff Welles, the founder of CNW, has been working in the catalytic field for more than 20 years. No one could figure out how to enclose a catalytic reaction while providing enough oxygen to adequately burn the fuel. We've changed all that!

[intro to Paul]