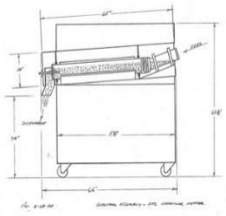
Radio Frequency Co.
INCORPORATED

Macrowave T.M.



RF Pasteurization

The wave of the future

RF Pasteurization – The wave of the future

John N Putnam – Radio Frequency Co, Inc

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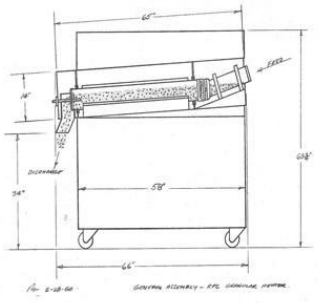
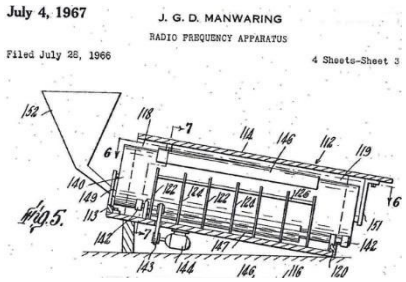
Introduction

Radio Frequency Heating and Drying Technology has been commercially utilized in the food industry since the 1960's.





The above 30 kW Macrowave™ Pasteurization System for granular food products was designed and patented by Radio Frequency Co.'s founder, Mr. Joshua G.D. Manwaring in 1966.

His design featured a rotary product feeding tube to prevent agglomeration and a closed loop temperature control system, both considered cutting-edge technology at that time.

RF Post Baking Dryers have also been widely commercialized in the USA and abroad, where this technology has increased the traditional conveyorized oven efficiency and throughput capacity by as much as 50%.

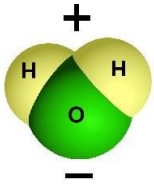
RF heating and drying improves shelf-life, eliminates checking and over-coloring, and minimizes water activity in both human and pet foods, enhancing quality and food safety.

With major food recalls beginning in 2009, and the resultant implementation of the Food Safety Modernization Act (FSMA), a **"New Wave"** of interest in pasteurization and disinfestation applications for this mature technology has developed.

Both human and pet food manufacturers are evaluating the safety of their supply chain and manufacturing processes, and in many instances where RF is a great fit, the implementation and commercialization continues. RF Pasteurization is particularly effective in the treatment of dry ingredients where pathogens can be dormant and more challenging to eradicate by other methods.

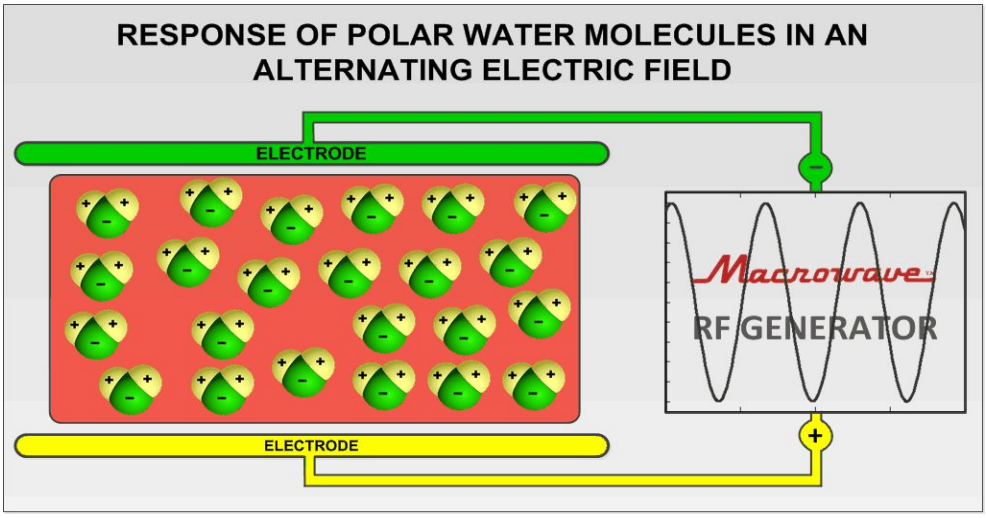
How Radio Frequency Heating Works

The unique structure of the polar water molecule, H_2O is the basis for the thermal response of water when subjected to an alternating RF energy field.



A water molecule is magnetically polar because there is an uneven distribution of electrons between the oxygen and hydrogen atoms.

In a Radio Frequency Heating System, the RF generator creates an alternating electric field between two electrodes, above and below the conveyor.



This alternating magnetic field causes the polar water molecules within the product to rapidly reorient themselves, creating friction, and in turn heat the product rapidly and uniformly throughout the entire thickness of the product whether it is in bags, or loose on a troughed conveyor.

The area of the machine where this occurs is referred to as the RF applicator.

Is Radio Frequency Heating Safe?

RF heating is a thermal process caused by a non-ionizing electromagnetic form of energy just like an FM radio transmitter.

The USDA does not view the RF thermal process as an added ingredient. Therefore an organic product treated with RF can carry the certified organic label.

Thermal Process

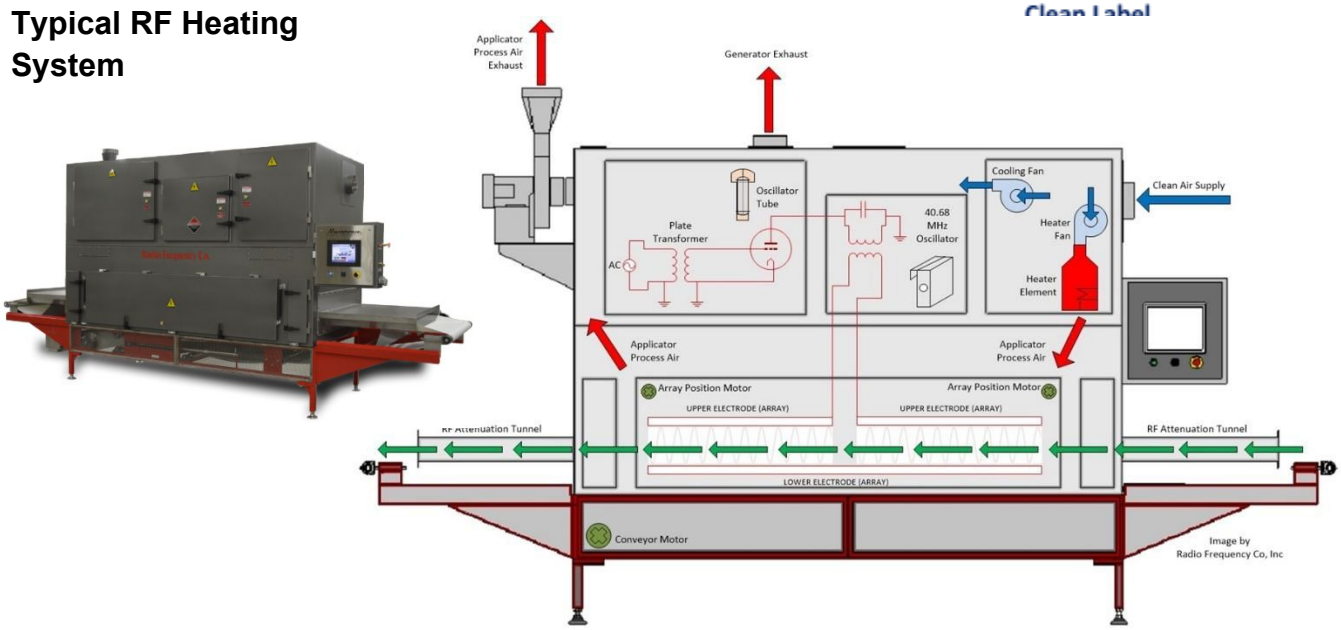
Additionally, the FDA does not view the RF thermal process as invalidating the application of “natural” on the label, unlike irradiation, which considered an additive, and therefore requires approval and special labeling.

is

Non-Additive

Clean Label

Typical RF Heating System



Frequencies Allowed

The FCC permits operating frequencies for dielectric heating as follows:

Microwave - 915 MHz and 2.45 GHz
RF - 13.56, 27.12 and **40.68 MHz**

Federal Communications Commission

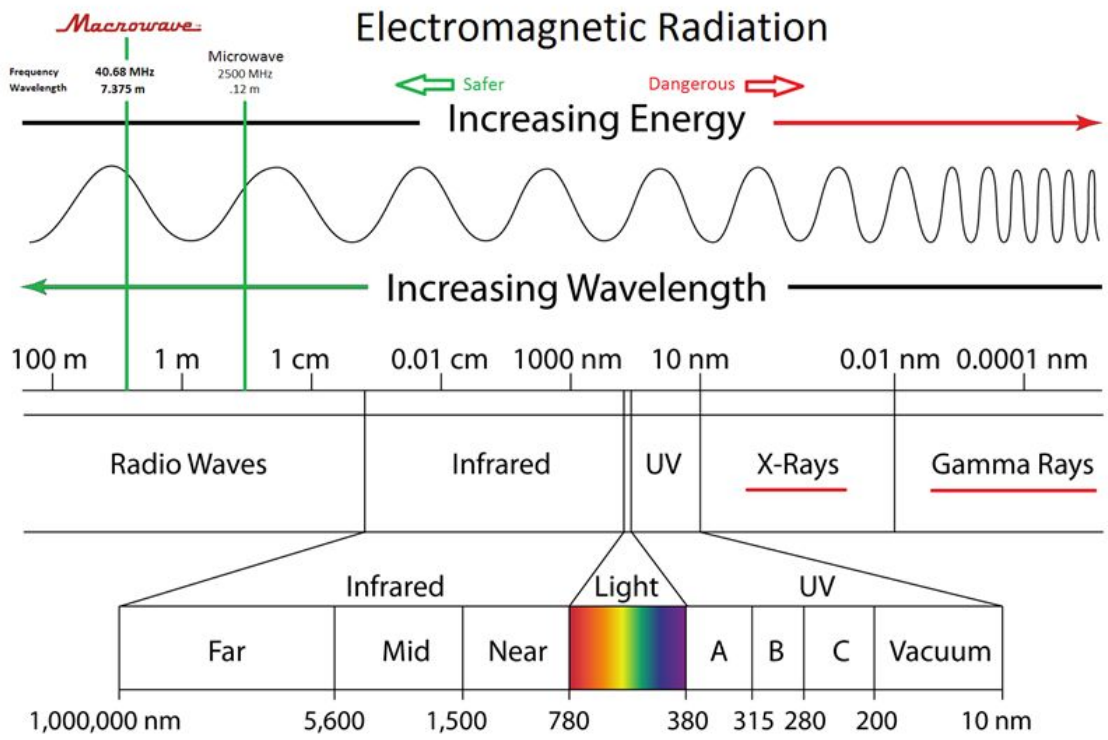
Why Use 40 MHz RF?

Microwave frequency wave lengths are very short. This is one reason for the difficulty heating food uniformly in your microwave at home. Because of microwaves' limited depth of penetration, as well as random scattering of the energy within the resonant cavity, the result is uneven heating and cold spots. These problems become increasingly difficult as you scale up to a commercial application, or attempt validation of the treatment process.

40.68 MHz RF (we'll refer to this as Macrowave™) frequency is a long wavelength, more uniformly controlled, and offers many advantages over microwaves.

These advantages include greater depth penetration, rapid volumetric heating, superior power control, and more processing versatility.

Additionally, Macrowave™ energy is a highly efficient "direct" form of heating. The technology is instant-on instant-off, using energy only during the treatment process. This results in lower operating costs.



RF Heating for Disinfestation

In the 1980s Macrowave™ Disinfestation Systems were introduced to the manufacturers of cigars and cigarettes for the control of tobacco beetles. Since that time, tobacco beetles, and other agricultural

insects, such as confused flour beetles, have been consistently eradicated by RF heating systems in all life stages, adult, pupae, larvae and eggs. Test data indicates that total mortality is achieved with RF heating at temperatures as low as 136°F

A sample lethality chart for disinfestation is below:

Improved Stem Temperature/Beetle Mortality Results - Continuous Mode Testing

Target Temp, F	Run	Avg. Actual Temp, F	Beetle Mortality	Overall Average Temp
160	1	157	100% A,P,L,E	
	2	179	100% A,P,L,E	
	3	166	100% A,P,L,E	167 F
	4	164	100% A,P,L,E	
150	5	139	100% A,P,L,E	
	6	151	100% A,P,L,E	
	7	153	100% A,P,L,E	148 F
	8	151	100% A,P,L,E	
140	9	140	100% A,P,L,E	
	10	142	100% A,P,L,E	
	11	141	100% A,P,L,E	136 F
	12	120	Mixed Mortality	

A=Adult, P=Pupae, L=Larvae, E=Eggs

RF Heating for Pasteurization

In March of 2006, Radio Frequency Co worked closely with the Almond Board of California to successfully develop a Macrowave™ Pasteurization System capable of providing a 5 log reduction for a particularly dangerous form of Salmonella, Enteritidis PT30. The final log reduction chart for the trials is shown below:

Figure 11: Trial III Log Reduction Results:

Sample	1A	1B	1C	2A	2B	2C	3A	3B	3C
Pasteurization Temperature (°F)	190	190	190	222	222	222	265	265	265
Log Reduction - TSA	6.11	6.11	6.11	>6	>6	>6	>6	6.11	>6
Log Reduction - XLD	>6	>6	>6	>6	>6	>6	>6	>6	>6

Systems for pasteurizing bagged foodstuffs have also been provided for products such as wheat, corn and rice flour, pea starch, various bean protein products, flax meal, nuts, spices, and other agricultural products, and prepared food items.

Thermal Pasteurization

The Key Success Factors for any Thermal Pasteurization Process are a combination of Temperature & Time. The higher the temperature the shorter the required kill time.

Microbial Kinetics

While an in-depth explanation of Microbial Kinetics is beyond the scope of this article, thermal pasteurization relies on microbial kinetics for lethality of microorganisms. Three key metrics impacting lethality are:

D value. The time required at a certain temperature to kill 90% of specific bacterial populations or reduce the bacterial load by one log under specified conditions.

Z value. The change in the temperature, in degrees Fahrenheit (F) or Celsius (C), required to

reduce the specific bacterial load by a factor of 10 or by one log.
Thermal Death Time (TDT). The shortest time needed to kill all bacteria or microorganisms in a product at a specific temperature and under defined conditions.

For RF Pasteurization to be successful, in addition to achieving the required temperature, the product being heated has to maintain the targeted temperature for a predetermined period, or “hold time”.

Achieving Hold Times with RF Pasteurization

There are three primary ways to achieve a proper hold time with RF pasteurization equipment:

1) **The applicator transition time needs to be sufficient.**

Meaning the speed of the conveyor moving the product through the RF applicator allows the product to be maintained at the proper temperature for a long enough time period.

Bagged RF Pasteurization System

2) **Utilize pallet heat retention.**

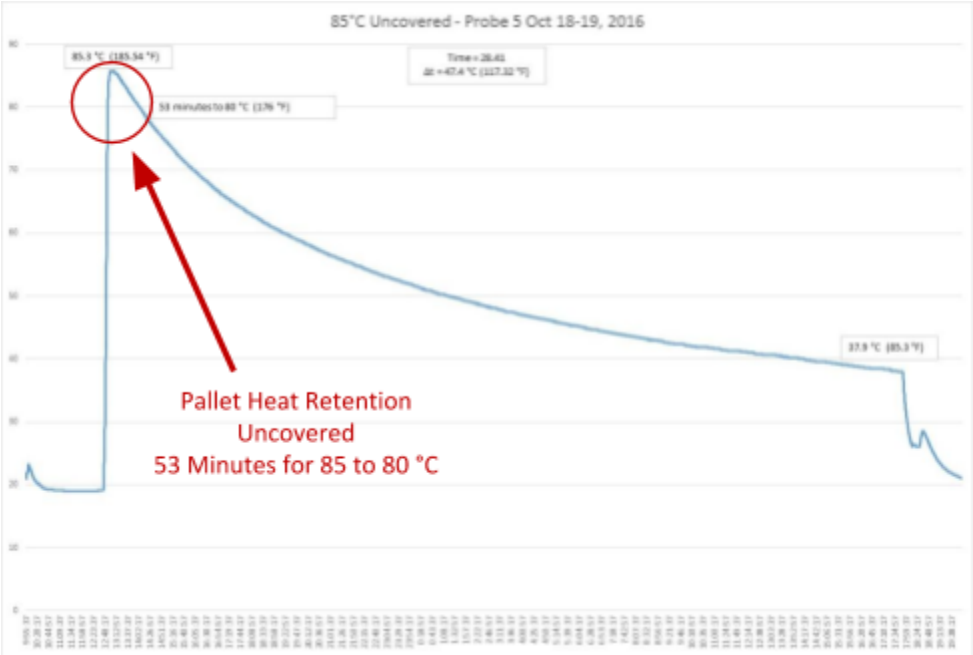
As a bagged product is removed from the RF pasteurization system and put onto pallets, a thermal mass is built up.

This thermal mass may be sufficient to keep the product at a temperature long enough to ensure lethality.

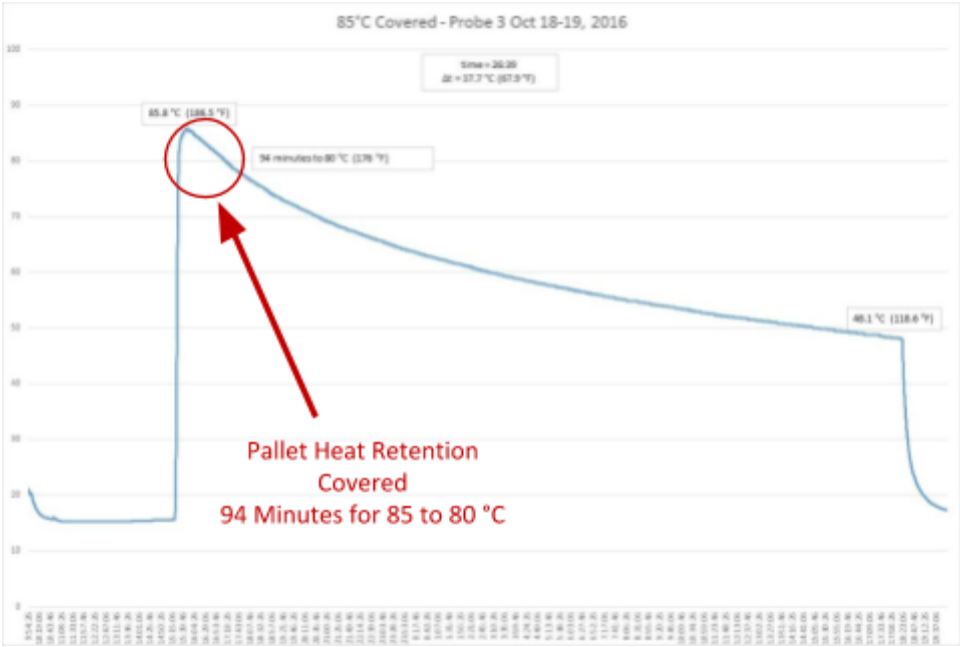
Stacking Hot Bags on a Pallet

Radio Frequency Co. has conducted palletized product thermal mass studies, and two examples are shown below.

The first shows that an uncovered pallet of 50 lb bags of flour maintains an average heat which dissipates only 5.3 °C (9.5 °F) over 53 minutes.



The second example illustrates that same pallet size, covered with a thermal blanket, holds the heat even more, with a similar drop in temperature taking an hour and a half!



3) Addition of a heat retention zone.

If pallet heat retention is not practical due to logistics or because the product being conveyed is a bulk, not bagged product, you can add a heat retention zone to the RF pasteurization system.

Primarily this strategy is used for loose product on a troughed conveyor where it may cool more rapidly than in packaging.

While the product is conveyed through the applicator it is brought up to the target temperature rapidly and uniformly. It then enters the heat retention zone which has circulating air, heated to the same temperature as the product. While the product is conveyed, no radiational cooling is allowed to occur; therefore the product is maintained at the target temperature, without overheating, for the required time period.

Key Benefits for utilizing RF Pasteurization for Dry Ingredients

Volumetric Heating means there is no temperature differential from the surface to center, and no prolonged soak time which could be damaging to protein functionality.

A Short Heating Cycle allows the product to maintain protein functionality, and other organoleptic and nutritional qualities.

A Rapid Temperature Rise reduces the ability for microbes to acclimate themselves to defend against high temperatures.

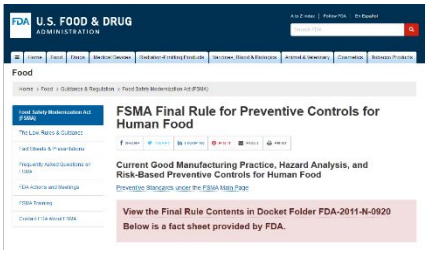
Sample RF Pasteurization Systems

400 kW capable of processing 25,000 lbs/hr

80 kW capable of processing 5,000 lbs/hr

40 kW capable of processing 2,500 lbs/hr

FSMA and Preventive Controls



Covered facilities must establish and implement a food safety system that includes an analysis of hazards and risk-based preventive controls. The rule sets requirements for a written food safety plan that includes:

Hazard Analysis
Preventive Controls
Oversight and Management of Preventive Controls

What is HACCP?

Hazard Analysis Critical Control Point or HACCP is a management system in which food safety is addressed through the analysis and control of biological, chemical, and physical hazards from raw material production, procurement and handling, to manufacturing, distribution and consumption of the finished product.

The HACCP system is used to comply with FSMA Hazard Analysis requirements.

Is RF Pasteurization a FSMA Preventive Control (Kill Step)?

The RF Pasteurization System can be implemented as a Preventative Control, and as a thermal process provides a Kill Step, which can be validated for compliance documentation.

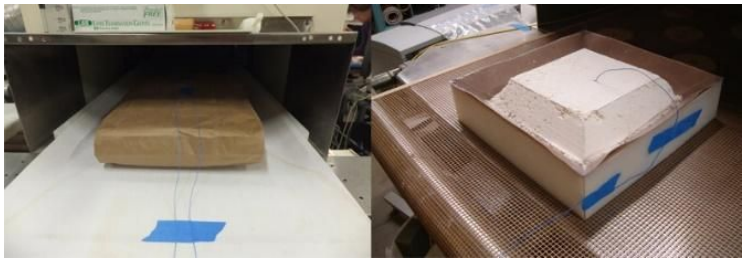
What is Kill Step Validation?

Quality Assurance & Food Safety

Kill-step validation is a preemptive scientific evaluation that provides documentary evidence that a particular process (e.g., cooking, frying, chemical treatment, extrusion, etc.) is capable of consistently delivering a product that meets predetermined specifications.

A successful validation study requires diverse expertise, detailed design, an experienced microbiologist, a statistician, and a keen eye for sources of process variability. (RF experience)

A simplified description of a RF Pasteurization System Validation usually consists of a client contracting with a laboratory (in-house or independent) to grow a surrogate for the targeted pathogen. A microbiologist inserts packets of the surrogate within the product itself, which is then heated to a target temperature by RF in a simulated production environment. The packets are then retrieved from the product and returned to the laboratory for analysis against a control sample.



The analysis is presented to the client, which if successful, demonstrates that when the product is processed within a given set of parameters, the log reduction (or APC/TCP) is expected to be within acceptable levels.

Is RF Pasteurization FSMA Oversite and Management Compatible?

The RF Pasteurization System, as a Critical Control Point, must be designed with Oversite and Management in mind.

Monitoring, Corrective Actions and Corrections, and Verification are components of the Oversite and Management system.

In most cases, each product will have its own treatment protocol. Accordingly, the treatment process parameters are recipe selectable from the Human/Machine Interface (HMI).

Monitoring:

All set-points and process variables that affect product temperatures and exposure time are monitored.

For example, in a bulk processing system with a heat retention zone, the product temperature is monitored at two critical locations.

1) After the RF heating to ensure the product achieved the target temperature

2) At the end of the heat retention zone to ensure the product remained at the target temperature for the entire heat retention time

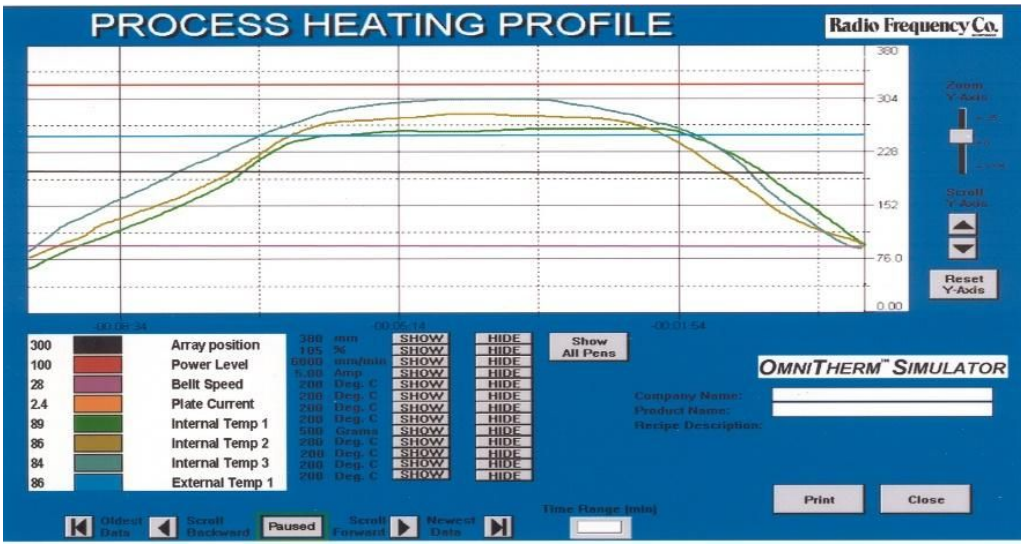
Corrective Action:

In the event of a process variable going out of specification, or a critical fault occurring, the event is recorded and the product stream is stopped or diverted to prevent it from entering commerce.

Verification:

All of these critical process set points and variables must also be archived with reference to the product code and lot numbers being processed to establish an audit trail. This data can be reviewed in the future to demonstrate the validated time/temperature profile, and other established criteria, was adhered to during processing and therefore the product was successfully pasteurized.

Screen Shot of Real Time Data Trending and Archiving



Does RF Pasteurization contribute to Brand Protection?

In 2016, after causing consumers' illness, a major manufacturer was forced to recall 45,000,000 pounds of retail flour. Their downstream commercial customers were impacted as well having used the potentially tainted flour as an ingredient.

The cost of notification, product recall efforts, potential liability, and preventative measures at numerous process points, is a huge expense, easily mounting into the millions of dollars. Repairing public relations is often an incalculable cost.

While RF Pasteurization Systems are primarily targeted at RTE and other high risk applications, RF Pasteurization contributes not only to Brand Protection, but to ***Business Protection***!

Conclusion

Radio Frequency is a proven technology that has been used in various industries for 70 years.

RF Post-Baking Drying has been widely used in the food industry for decades, and with uniform controllable heating profiles and proven performance, RF Pasteurization has also become fully commercialized.

It is a USDA Organic Thermal Process, FDA Clean Label, FSMA compatible as a Critical Control Point Kill Step, and is able to be validated to comply with FSMA regulations.

As such, it is no wonder that RF Pasteurization truly is the  of the future!