HACCP - Cook CCP Validation made Easy!

Thru-process product temperature monitoring the accurate, efficient cost-effective solution.

Dr Steve Offley **Product Marketing Manager** **PhoenixTM**

Introduction

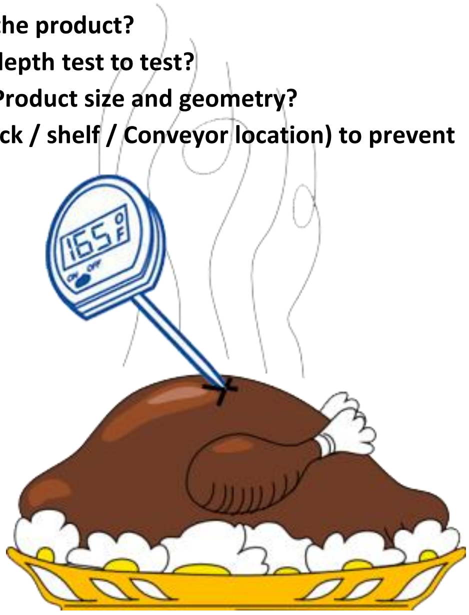
The fundamental priority of any food production operation is food safety. The following article discusses the important requirements of HACCP when applied specifically to ready-to-eat products such as cooked meats. The use of thru-process temperature monitoring techniques is shown to provide a means of satisfying all Cook / Chill CCP monitoring and validation needs. The technique is further demonstrated to allow optimisation of cook programs to optimise product quality, improve productivity and maximise yield.

HACCP Principles

HACCP which stands for 'Hazard Analysis Critical Control Point' is a systematic process to identifying potential risks in food production, that could cause a potential safety risk to the consumer and putting control measures in place to eliminate them. HACCP is comprised of 6 principles which must be applied to every food process as each may have very different hazards and monitoring demands. In the case of ready-to-eat cooked chicken a potential HACCP review may well look something like that shown in Table 1.

Day-to-day monitoring of the cook process (principle 4) in most cases is a simple case of sampling product post cook and manually checking with a handheld needle thermometer that the core temperature satisfies minimum requirements. Such monitoring must be done with care to ensure accuracy.

- **Is the thermometer accurately reading the coldest part of the product?**
- **Is the thermometer needle inserted accurately to desired depth test to test?**
- **Is the sample product representative of the whole batch? Product size and geometry?**
- **Is the product sample being taken randomly from cook (Rack / shelf / Conveyor location) to prevent positional bias?**
- **Is the data recording fully certified and traceable?**



Although a manual step, this check is relatively quick and efficient if done in a controlled scientific fashion. The manual testing is fine when the CCP limits are being achieved. Problems occur though when the CCP doesn't hit the critical core temperature of 74 °C /165.2 °F. The handheld thermometer will give you a simple PASS/FAIL indicator of SAFE/UNSAFE but in the event of a FAIL the data provides no indication of the root cause of the undercook.

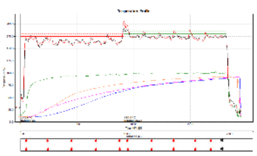
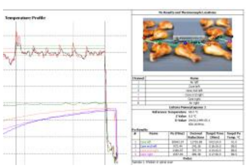
HACCP HAZARD PRINCIPLES – Ready- to-Eat Cooked Chicken	
	**Principle 1: HAZARD** **Product – Boneless Chicken Fillets** **Hazard Analysis – Food poisoning of consumers from Listeria monocytogenese**
	**Principle 2: Critical Control Point (CCP)** **Cooking of Processed Chicken to kill Listeria monocytogenes**
	**Principle 3: CCP – Critical Limits** **Achieve a minimum internal product cook temperature of 74 °C / 165.2 °F peak, 70 °C / 158 °F for minimum 2 mins or equivalent P_u = 2.0 mins**
	**Principle 4: Monitoring** **Validate that the cook program can achieve critical limits under worse case conditions. Oven Temperature Mapping. Check validation every 12 Months. Perform QA on each cook cycle (temperature monitoring each batch).**
	**Principle 5/6: Corrective Action & Verification** **Perform a temperature profile of cook process to identify potential root cause of undercook. Perform cook program adjustment or repair to faulty equipment. Repeat temperature validation to prove successful corrective action.**
	**Principle 7: Documentation** **Save annual process validation reports with batch QA reports for each process line and product type.**

Table 1. HACCP principles as applied to processing of ready-to-eat cooked chicken.

Faced with a failed cook CCP the hard work starts to identify the root cause of the problem. To help with root cause analysis / problem solving thru-process temperature profiling is an invaluable weapon in the food technologist's arsenal. With such technology temperature data can be collected through the complete cook process allowing CCP validation, process variations to be detected and location of critical technology failures.

The same technology is also ideal for the validation process for any new cook regime, new product, or annual process certification. Whether performing an oven survey "oven mapping to identify cold spots" or validating the cook under production conditions, the thru-process profiling solution gives you the accuracy, efficiency, and reliability you need to satisfy your HACCP demands.

Thru-process Temperature Profiling Technology

As its name suggests thru-process profiling is the method by which product and or process temperature is monitored throughout the complete cook / chill process. The data logger making the physical temperature measurement, with multiple thermocouples, travels safely with the product through the cook step. Protection from process conditions such as heat, steam, water, oil is provided by a suitably designed thermal barrier. Monitoring of continuous conveyorised linear and spiral ovens and semi-continuous or rotational batch cooks is feasible where the use of external recorders with trailing thermocouples is completely impractical.

Fig 1: PhoenixTM food thru-process temperature profiling system monitoring chicken cook in linear conveyorized oven.

Data logger

At the heart of the thru-process monitoring system is the PhoenixTM data logger. The PhoenixTM NT data logger range has been designed specifically for the challenges of monitoring food processing applications with an IP67 case design protecting from moisture. Type K or Type T data logger options allow accurate measurement of both cook and chill processes (Type T measurement range -200 °C to 400 °C (-238 to 752 °F)). The data logger itself can operate between -40 °C to 80 °C (-40 to 176 °F) with a data logger accuracy of ±0.3 °C (±0.54 °F) below +50 °C (+122 °F). Data logger and thermocouple correction factors can be further applied to the recorded data logger data to maximise measurement accuracy. Protected in a thermal barrier to suit the process the data logger temperature is kept below +80 °C (+176 °F) guaranteeing both accuracy and battery life of up to 1000 hours from the user replaceable 'AA' Alkaline batteries. Available in 6 or 10 channel variants cook processes can be monitored or validated in detail. Sampling rates down to 0.2 s ensure that temperature profiles are obtained with high resolution to capture in detail all the process temperature related features and maximise the accuracy of any lethality (Fo/Pu) analysis calculation.

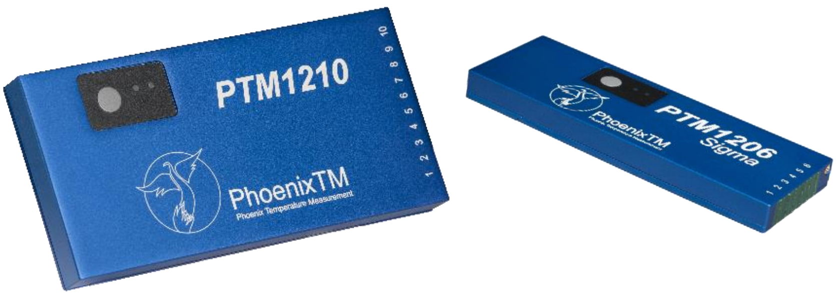


Fig 2: PhoenixTM NT (IP67) data loggers (PTM1210 – standard 10 channel) and (PTM1206 Sigma - compact 6 channel) designed specifically for monitoring cook chill process with accuracy and reliability.

Thermal Barriers

Obviously cooking comes in many different forms from steaming/ roasting to deep fat frying and technology can vary from a simple batch cook to a continuous conveyorized spiral cooker. Each has its own unique challenges when it comes to thru-process monitoring. For this reason, a single thermal barrier design is not enough. PhoenixTM offer a range of thermal barriers to suit the process type, duration and temperatures. Even if a standard thermal barrier can not meet the process requirements, PhoenixTM can often custom design a unique solution to suit. For longer duration processes, thermal protection is optimised through use of dual phase protection. The microporous insulation is complemented by an internal heat sink. The heat sink material phase changes at 58 °C (136.4 °F) keeping the data logger at a safe operating temperature for longer.

Fig 3: PhoenixTM TS24-064-1 thermal barrier - data logger in heat sink and thermocouple exit fitted with splash guard.

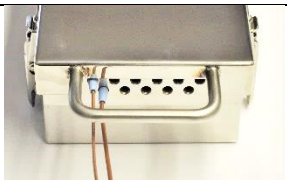
Barrier Model	Design	IP Rating	General Design Features	Application focus
TS14	 **TS14-040-1 (40 mm high)** **40 mins @ 200 °C / 392 °F**	**IP67**	**Front face plate design thermocouple bung seal** **Silicone o-ring face plate Seal.** **Low height clearance.** **Submersible in water / oil.**	**Fryer & linear/ spiral ovens** **Low height quick cook** **Steam Injection/ raining water or brine showers**
TS24	 **TS14-064-1 (64 mm high)** **2.5 hrs @ 200 °C / 392 °F**	**IP65**	**Barrier lid access to data logger.** **No thermocouple sealing.** **Probe exit splash guard** **Lid and base seal with integrated** **robust lid silicone gasket.** **Internal heat sink.**	**Dry bake/roast or low-pressure steam cook.** **(Batch/ DD RevoRack or linear/s piral ovens)** **Chillers/ freezers.** **Non submersible.**
TS44	 **TS44-120-1 (120 mm high)** **5 hrs @ 200 °C / 392 °F** **16 hrs @ 100 °C / 212 °F**	**IP67**	**Barrier lid access to data logger.** **Thermocouple bung sealing.** **Lid and base seal with integrated** **robust lid silicone gasket.** **Internal heat sinks.**	**Designed for long low temperature (<100 °C / 212 °F) cook with high levels of steam / water. Water or brine chill.** **Large joint/ ham stock cook.**

Table 2: PhoenixTM thermal barrier range developed to protect in a range of different cooking processes.

Thermocouples

Monitoring core temperatures of food products can be a challenge and getting it right or wrong can have a significant influence on the data collected and therefore any decisions or conclusions made. As part of any validation testing experimentation it is essential to identify the cold spot of the product to ensure that safe cook temperature is recorded from the worst-case scenario. Positioning the thermocouple sensor in the correct place repeatably in a protein-based product such as chicken generally requires the use of a needle thermocouple. The sensing point on a thermocouple often referred to as the 'hot junction' is located in the tip of the needle point.

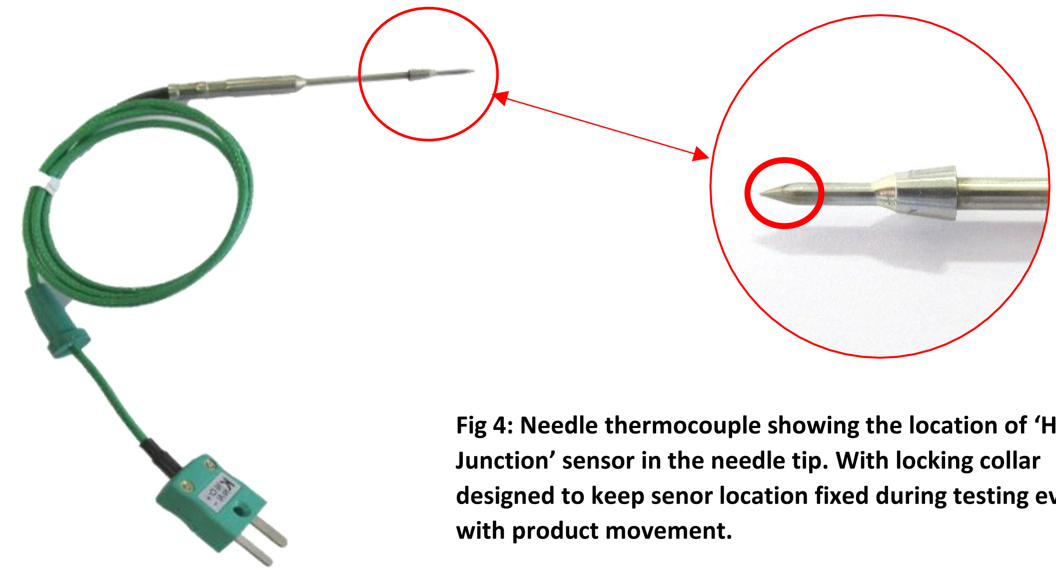


Fig 4: Needle thermocouple showing the location of 'Hot Junction' sensor in the needle tip. With locking collar designed to keep senor location fixed during testing even with product movement.

Selecting the correct tool for the job applies perfectly for thermocouple selection. Matching the needle length and size (OD) to the product being measured is important.

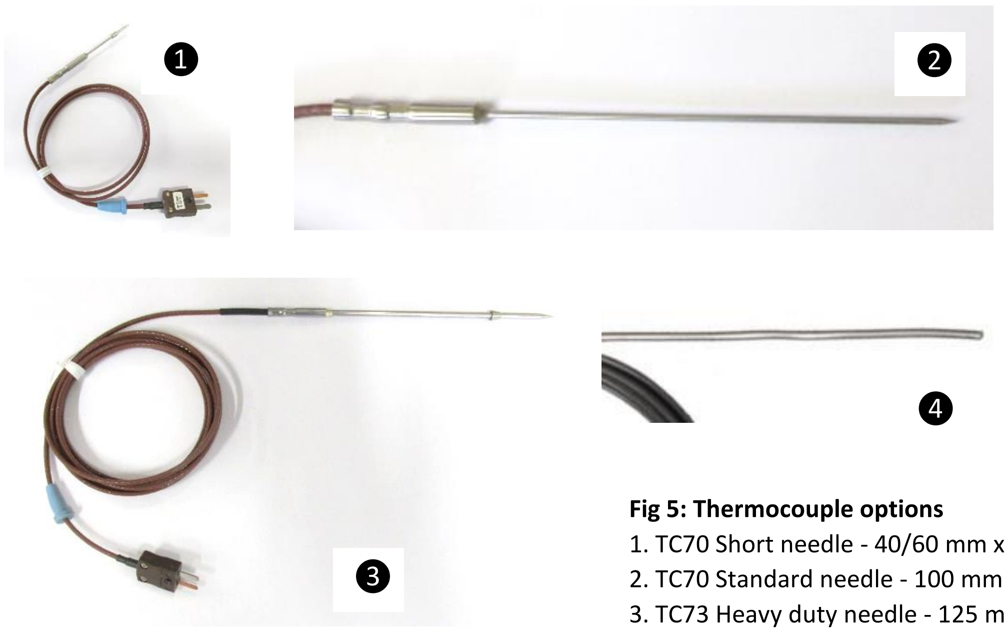


Fig 5: Thermocouple options
1. TC70 Short needle - 40/60 mm x 1.6 mm
2. TC70 Standard needle - 100 mm x 1.6 mm
3. TC73 Heavy duty needle - 125 mm x 3.2 mm
4. TC76 Mineral Insulated – No Needle x 1.6 mm

Needle thermocouples are supplied in most cases with PFA/PTFE cables which allow flexible routing of the cable through the process. Such cable is operational up to 265 °C / 509 °F, meeting the needs of most cook programs. Above 265 °C/509 °F the only food grade cable material option is a Stainless-Steel mineral insulated thermocouple (Fig 5.4). This thermocouple does not have a needle but the wire acts as if a needle. The theoretical accuracy of the thermocouple is governed by the type and classification. Type K thermocouple cables are provided with special limits or error ±1.1. °C / ±2.0 °F or 0.4% of reading. Type T are IEC EN 60584-2 class 1 therefore ±0.5. °C / ±0.9. °F (-40 to 125 °C / 257 °F). It is important to note though that the actual measurement accuracy is the combination of the data logger accuracy and thermocouple accuracy. The most accurate combination is a Type T thermocouple despite having a tighter measurement range.

Table 3: System measurement accuracy (data Logger + thermocouple)
(Measuring Chicken core temperature @ 70 °C /158 °F)

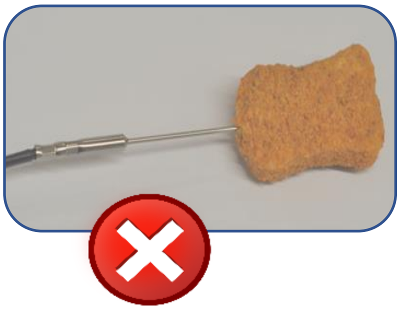
System Accuracy (Data logger + Thermocouple)			
	Data logger*	**Thermocouple**	**Measurement accuracy**
Type K	±0.3 °C (±0.54 °F)	±1.1 °C (±2.0 °F) or 0.4%	±1.4 °C (±2.5 °F)
Type T	±0.3 °C (±0.54 °F)	±0.5 °C ((±0.9 °F)	±0.8 °C (±1.4 °F)

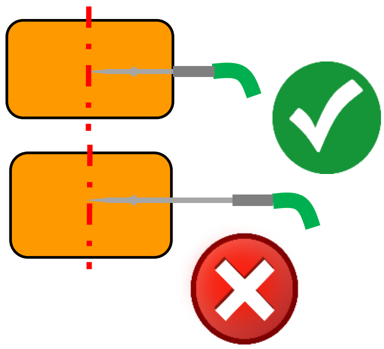
*** Operating to specification in the thermal barrier < 50 °C / 122 °F.**

Although accuracy of the instruments is fundamental to the quality of the data, as with any tools, they need to be used for the correct job and with an understanding of how they work. Inserting the thermocouple into the product to position the hot junction in the correct place needs to be done with care. As shown below setting up the thermocouples correctly first time prevents unexpected data, confusion, false positives or false negatives and possible need for repeat testing. The error associated with incorrect thermocouple insertion will be significantly higher than any theoretical instrumentation accuracy certification. Remember the thermocouple tip can only report the temperature of what it is in contact with.

Fig 6: Thermocouple usage - the technical challenge.

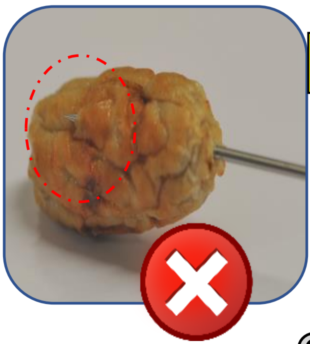
6. 1 Thermocouple size
Match needle length to product. Remember that a metal needle can conduct heat so can affect measurement temperature if influenced by oven temperature. Heat conducting down a needle will raise measurement temperature above true core temperature.

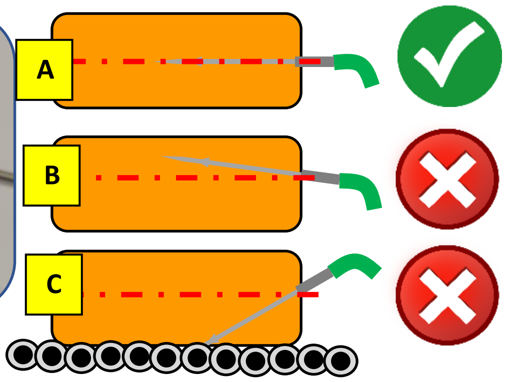




6. 2 Thermocouple position
Ensure that you insert the probe to reach true cold spot. A slight deviation from true will give a very different measurement. Make sure that probe insertion is not changed by movement or cooking process.

A. Good
B. Poor as measurement at surface not core
C. Poor as needle point measuring environment/mesh belt not product.





6. 3 Product size variation

Ensure that sample product(s) chosen for monitoring are representative of production. Pick the product form that will give slowest core heating rate. Products of identical mass can heat at different rates due to differences in surface area and product thickness through which heat needs to conduct.

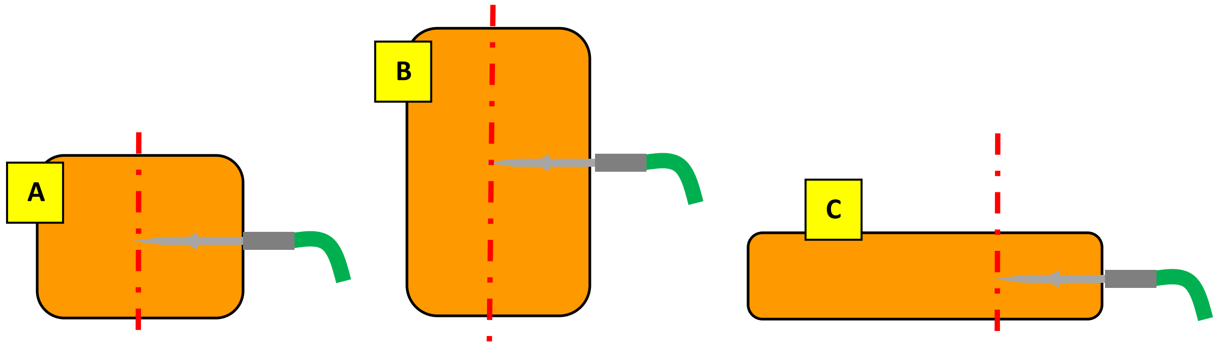
Side view of product sample all the same mass.

A Generic product sample

B Uniform product with long conductive path to core

C Thin product form with large top surface area

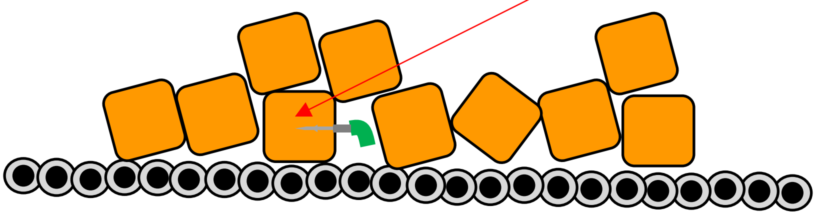
Core heating rate **C>>>A>>B**

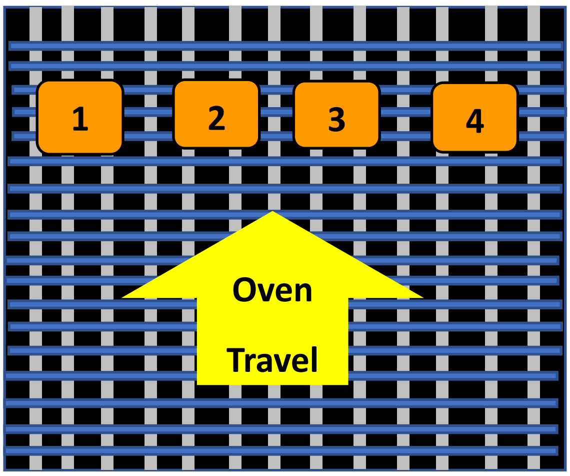


6.4 Product insulation problems

Be careful of possible 'clumping' issues. Layered product may create an insulation barrier to heat influencing cook rates. Check that you pick product that will experience least heat.

Product shielded (insulated) from direct heat so will heat slower than a surface product





6.5 Product placement in process (conveyorized oven)

Product placement needs to be across entire heating zone. Monitor extreme areas of the process. Ensure you obtain repeatability run to run. Product packing density (oven loading) should match production conditions.

Accurate Process Validation CCP analysis

Employing the thru-process temperature monitoring principle provides the food technologist with a complete temperature profile of the cook process from start to finish. This information is like the Cook DNA giving full details of the product and or process temperature which is invaluable to allowing validation of the Cook CCP as shown in Fig 7.

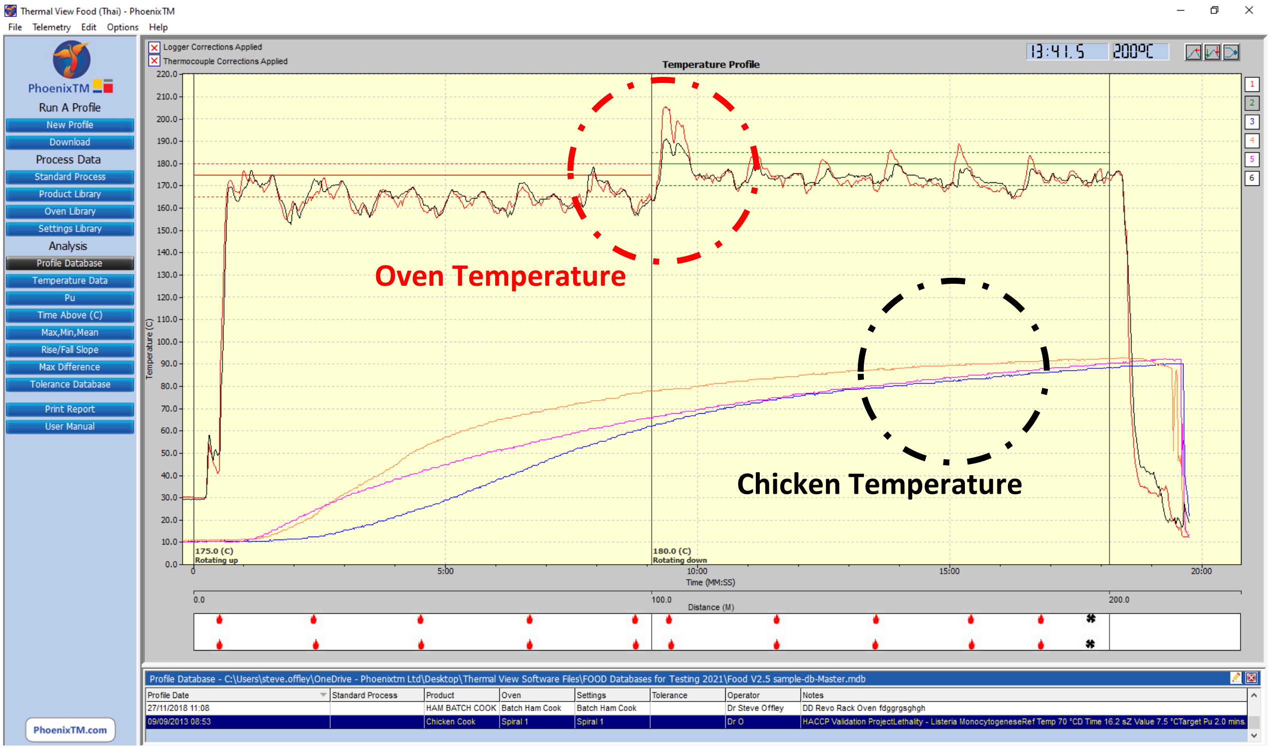


Fig 7: Thermal View Food Software showing a temperature profile for the cook program clearly showing both relationship between oven ambient temperature and product core temperature.

To satisfy HACCP principle 4 (monitoring and validation) the profiling system with 10 measurement channels allows a 9-point temperature uniformity survey to be performed to identify the behaviour of the cook technology and identify cold spots independently of the product. As shown below for a multi-shelf cook rack, thermocouples can be positioned over the oven chamber to identify temperature uniformity and highlight hot and cold spots.

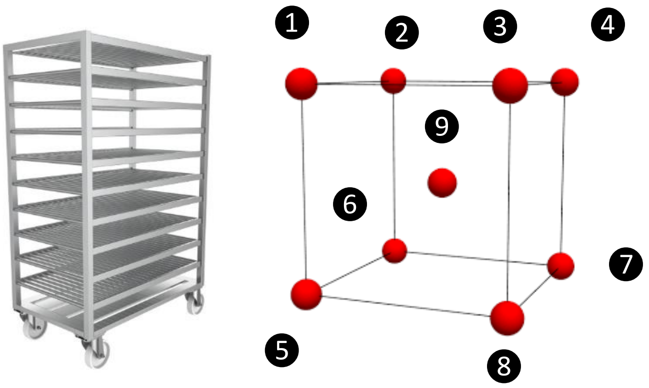


Fig 8: Thermal mapping of cook process. Thermocouples (1-9) positioned over the product rack to determine temperature uniformity (TUS) within the cook chamber and identify cold spots where product CCP is most challenging.

Having mapped the cook technology and identified the process cold spot it is necessary to further validate that the cook program is able to deliver the minimum safe cook CPP "core temperature" under worse case conditions. It is important to carefully design a validation experiment to factor in all aspects of the process that could negatively influence the product core reaching a safe temperature. This step incorporates both the cooking technology and the product under normal production conditions.

The following are a list of factors that need to be considered.

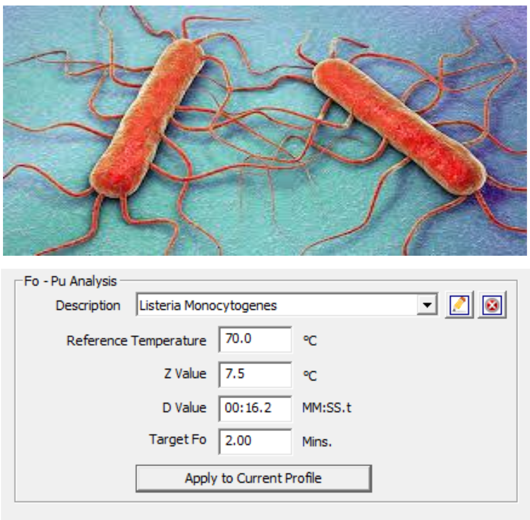
- Coldest position in the oven "cold spot" – Rack and shelf position in batch oven
- Lowest possible cook program temperature
- Lowest steam injection/ air velocity
- Shortest possible cook program time
- Heaviest loading in the oven – metal racking and product
- Largest individual product weight and size
- Most challenging product form to achieve heat penetration – chicken fillet vs drumstick?
- Coldest product start temperature – validation needs to match production (product chilled at 4 °C /39.2 °F?)
- Any process steps that could influence temperature – manual spot check on product cook mid program.

Accurate CCP analysis using lethality calculations (Fo/Pu)

For manual CCP monitoring on the production floor the handheld thermometer is only capable of proving that the chicken core temperature exceeds a safe limit such as 74 °C (164 °F) to kill harmful micro-organisms. From a temperature profile it is possible to accurately quantify product safety (pasteurisation) knowing both the temperature, and time at temperature, of the product.

Pasteurisation temperatures are typically < 121.1 °C and the cook time is governed by product type and additional preservation protocols (PH, water activity, salt levels, chilling etc). For ready-to-eat chicken the designated target micro-organism is normally Listeria monocytogenes. The pasteurisation conditions are nominally given as achieving the equivalence of a minimum core temperature of 70 °C / 158 °F for 2 mins.

The target cook of 70 °C/ 158 °F for 2 mins comes from scientific lethality kinetic studies into the effect of temperature/time combinations on microorganism population. The 2 mins is the time proven to reduce the population of microorganisms by 6 Log / 6 decimal reductions (1,000,000 to 1).
From such information it is possible to calculate from the temperature profile the Pasteurisation value referred as either Pu or Fo. The parameters for the Pu calculation are summarised below (Figure 9: Pu Analysis Parameter definition)



Reference Temperature (r) (°C/°F) = Target temperature to be achieved at the slowest heating point in the product
Process Time (mins) = Cook time at reference temperature to kill required number, log reductions of micro-organism.
Z (Z value) (°C/°F) = Killing Rate. Temperature change which results in a 10-fold decrease in D_t value (Decimal Reduction)
D_t (D value) (mins) = Time necessary to reduce micro-organism population by 90% (1 Log/ decimal reduction – 1,000,000 down to 100,000)

Fig 9: Pu analysis parameter definitions

The Pasteurisation Value (Pu) is the equivalent cook time for the temperature profile at the nominated reference cook temperature. Basically, the calculation converts each data point in the profile trace to an equivalent time at the reference temperature which is then summed. The Pu value (mins) is divided by the decimal reduction time to give the resulting number of log/decimal reductions in the micro-organism population. Many processors look for a minimum lethality of 6 log. For LMono the minimum target Pu is therefore 6 log x 16.2 s (D_t) = 1.62 mins which is rounded up to 2 mins hence the specification 70 °C / 158 °F for 2 mins.

In figure 10 below the Pu values have been calculated for a typical conveyorised oven chicken cook. The Pu values exceed the minimum 2.0 mins proving product safety. The high number of decimal reductions of >3000 (current zoom) may allow optimisation of this process to reduce cook time or temperature to improve productivity, yield, and quality without compromising safety (Decimal Reductions >> 6).

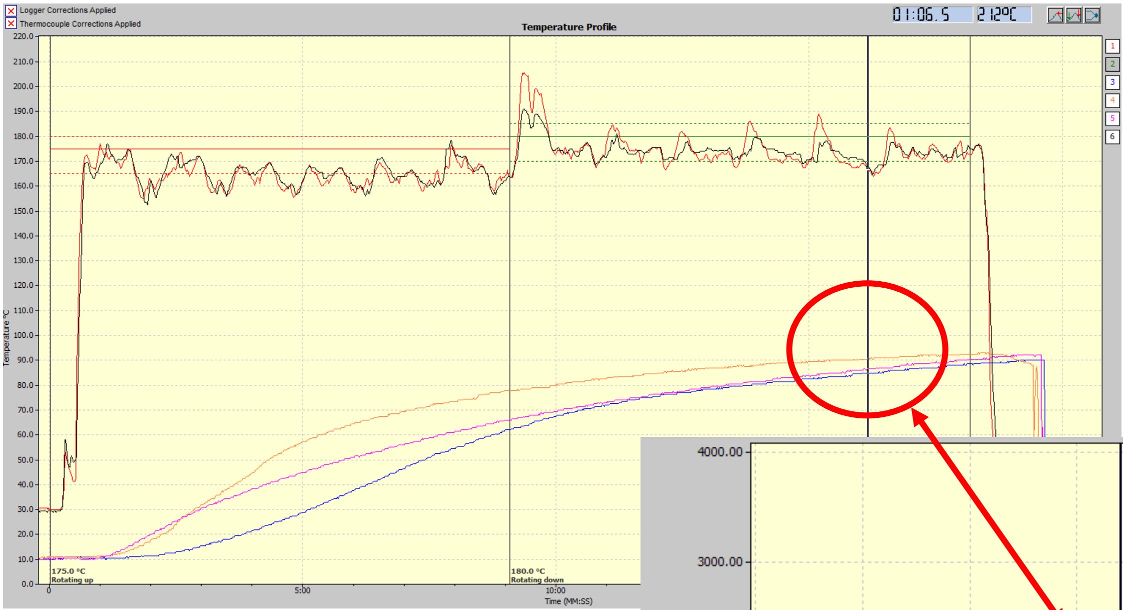


Fig 10: Tabulated and graphical Pu values and number of decimal reductions calculated for a typical conveyorised oven chicken cook. Adjustable cursor shows Pu at any point on the temperature profiles.

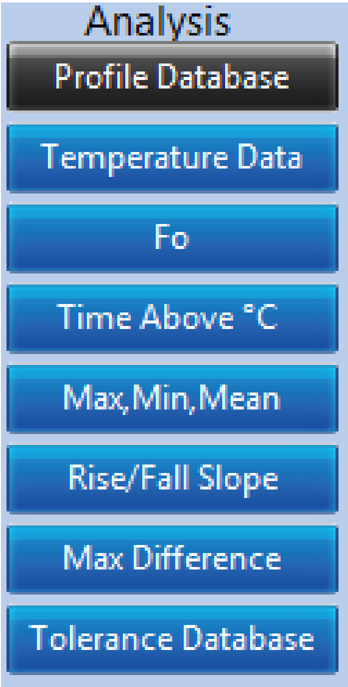
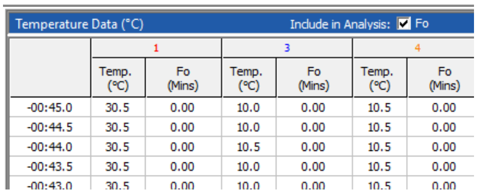
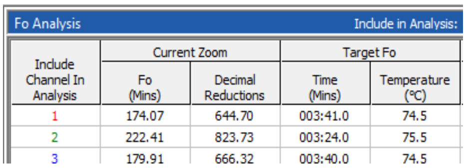
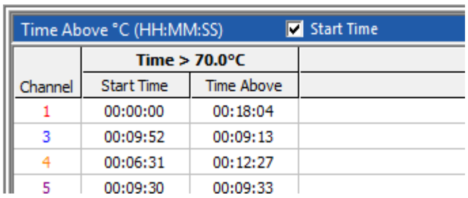
Pu Analysis — Include in Analysis: ☑ Decimal Reductions

Include Channel In Analysis	Current Zoom		Target Pu		At Cursor (00:17:09)		
	Pu (Mins)	Decimal Reductions	Time (Mins)	Temperature (°C)	Temperature (°C)	Pu (Mins)	Decimal Reductions
1							
3	1064.05	3940.93	011:18.0	73.5	86.5	273.48	1012.91
4	3884.25	14386.11	007:53.5	73.5	92.0	2005.38	7427.35
5	1830.14	6778.31	010:50.5	72.5	88.5	437.24	1619.41
6							

Converting profile data into meaningful information

The temperature profile as discussed before is the thermal fingerprint of the cook process. The raw data though needs to be interpreted to make sense of how the cook is performing and allow confident process decisions or changes to be made. To interpret the data PhoenixTM provide a range of analysis tools as detailed below in table 4.

<table>
<tr><th>Profile Analysis Tools</th><th>Analysis Tool Dialogue</th><th>Analysis Benefits</th></tr>
<tr><td rowspan="6">


</td>
<td>
</td>
<td>Temperature Data
Raw temperature data for each probe. Scroll across profile graph to see numerical values at any point on the graph.</td></tr>
<tr><td>
</td>
<td>F_o or P_u
Calculate accurate Pasteurisation values to confidently prove safe cook. (See previous section)</td></tr>
<tr><td>
</td>
<td>Time Above
Measure time above critical cook CCP temperature to prove basic lethality.

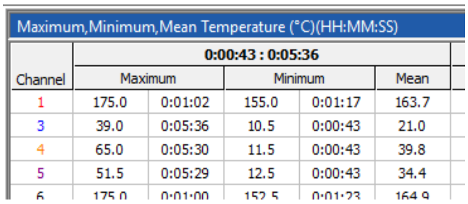
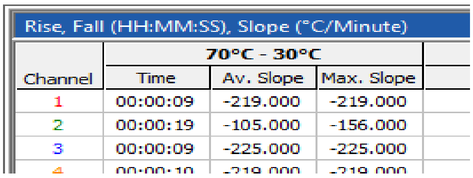
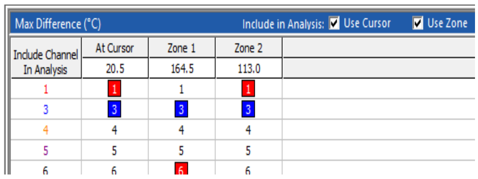
(Chicken – LMono
2 mins @ 70 °C / 158 °F)</td></tr>
<tr><td>
</td>
<td>Max, Min & Mean
Report max, min, and mean temperature for either oven zone or customized zoom Ideal for identifying cold spots.</td></tr>
<tr><td>
</td>
<td>Rise Fall Slope
Confirm that post cook cooling rates between target temperatures complies with regulations.</td></tr>
<tr><td>
</td>
<td>Max Difference
Determine temperature difference at any point on the profile graph or by oven zone. Efficiently check process temperature uniformity.</td></tr>
</table>

Table 4: Thermal View Food SW analysis tools and CCP validation benefits

HACCP Documentation

As defined in HACCP principle 7 it is essential that comprehensive validation records are archived for existing and new products / processes. The Thermal View Food software offers a range of comprehensive reporting tools to ensure that raw data and analysis results are complemented with information on how the validation was performed. Any CCP analysis needs to be made in context of process and test protocols.

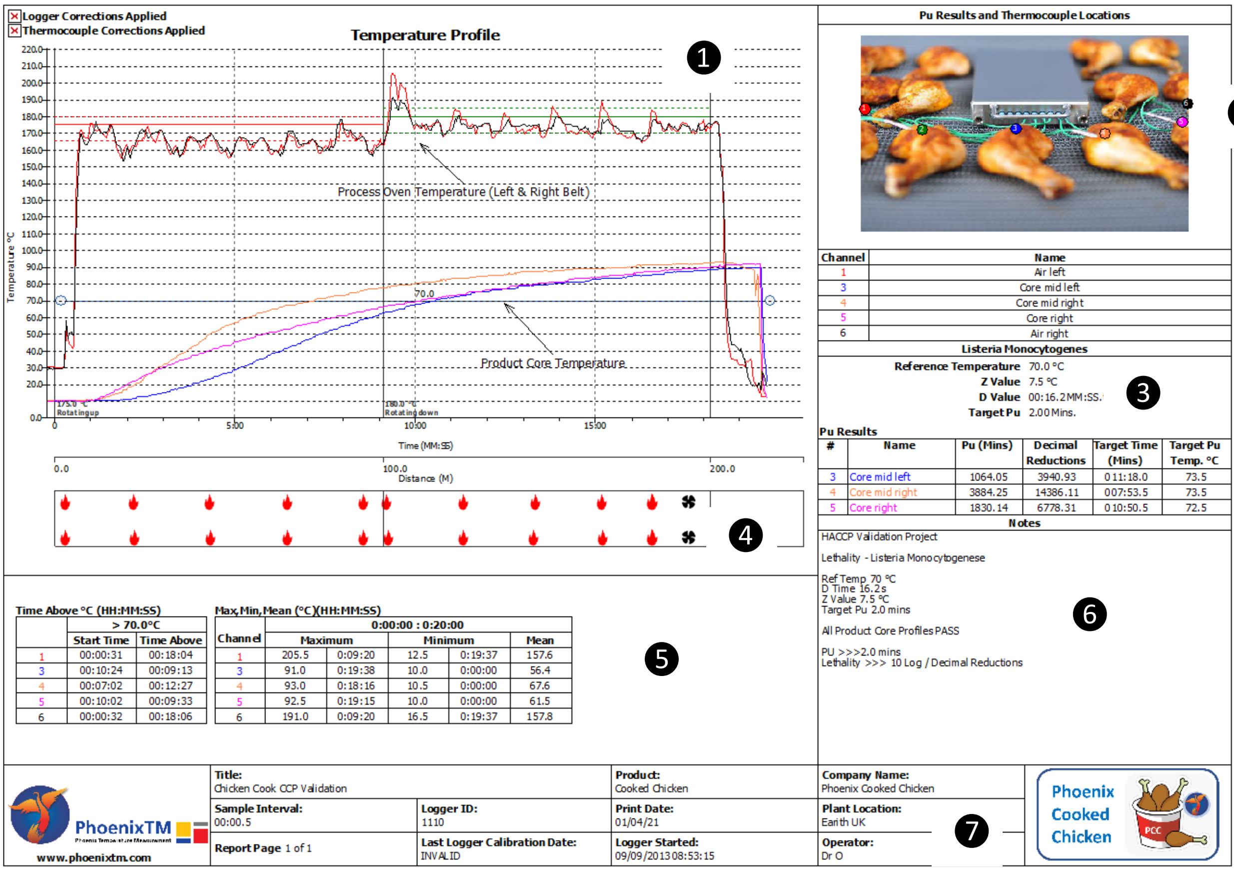


Fig 11: Thermal View Food software CCP validation report

1. Temperature profile graph showing process & product core temperature
2. Product library giving thermocouple placement detail (image and text)
3. Lethality calculation parameters and analysis results – Pu / Fo
4. Oven details showing profile against distance axis and oven features / set-points
5. Customised analysis results
6. Process notes – Documented test conditions & validation findings
7. CCP validation report traceability information

Summary

Thru-process temperature profiling is an accurate efficient method by which Cook CCP validation can be performed as part of any food processing HACCP protocol. The same technology can be used to allow informed process problem solving and optimisation to maximise product quality, yield, process productivity and efficiency.

Author

Dr Steve Offley [*Steve.Offley@phoenixtm.com*](mailto:Steve.Offley@phoenixtm.com)
Product Marketing Manager
PhoenixTM Ltd; Earith Cambridgeshire UK
[*www.phoenixtm.com*](http://www.phoenixtm.com)