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Rev.	Description	Revision By	Date

Production Filename: 13500 (In Product Library)

Path to Working Files: DecaDoc\Application Notes\Master

Dimensions: 8.5 inch wide, 11 inch tall

Material: Paper, 92 Bright White or better, 75g/m² or heavier

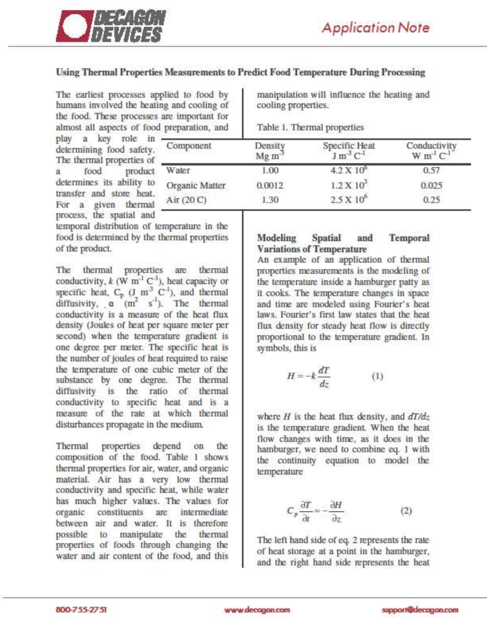
Colors: Color Print on White

Printer: HP Color LaserJet 8550-PS

Finish: None

Adhesive: None

Special Notes: Illustrations are Ref Only ** Not to Scale ** (Shown page 1 of 3)


DECAGON DEVICES — Application Note

Using Thermal Properties Measurements to Predict Food Temperature During Processing

The earliest processes applied to food by humans involved the heating and cooling of the food. These processes are important for almost all aspects of food preparation, and play a key role in determining food safety. The thermal properties of a food product determines its ability to transfer and store heat. For a given thermal process, the spatial and temporal distribution of temperature in the food is determined by the thermal properties of the product.

The thermal properties are thermal conductivity, k (W m^{-1} C^{-1}), heat capacity or specific heat, C_p (J m^{-3} C^{-1}), and thermal diffusivity, α (m^2 s^{-1}). The thermal conductivity is a measure of the heat flux density (Joules of heat per square meter per second) when the temperature gradient is one degree per meter. The specific heat is the number of joules of heat required to raise the temperature of one cubic meter of the substance by one degree. The thermal diffusivity is the ratio of thermal conductivity to specific heat and is a measure of the rate at which thermal disturbances propagate in the medium.

Thermal properties depend on the composition of the food. Table 1 shows thermal properties for air, water, and organic material. Air has a very low thermal conductivity and specific heat, while water has much higher values. The values for organic constituents are intermediate between air and water. It is therefore possible to manipulate the thermal properties of foods through changing the water and air content of the food, and this manipulation will influence the heating and cooling properties.

Table 1. Thermal properties

Component	Density Mg m^{-3}	Specific Heat J m^{-3} C^{-1}	Conductivity W m^{-1} C^{-1}
Water	1.00	4.2×10^6	0.57
Organic Matter	0.0012	1.2×10^3	0.025
Air (20 C)	1.30	2.5×10^6	0.25

Modeling Spatial and Temporal Variations of Temperature

An example of an application of thermal properties measurements is the modeling of the temperature inside a hamburger patty as it cooks. The temperature changes in space and time are modeled using Fourier's heat laws. Fourier's first law states that the heat flux density for steady heat flow is directly proportional to the temperature gradient. In symbols, this is

$$H = -k\frac{dT}{dz} \qquad (1)$$

where H is the heat flux density, and dT/dz is the temperature gradient. When the heat flow changes with time, as it does in the hamburger, we need to combine eq. 1 with the continuity equation to model the temperature

$$C_p\frac{\partial T}{\partial t} = -\frac{\partial H}{\partial z} \qquad (2)$$

The left hand side of eq. 2 represents the rate of heat storage at a point in the hamburger, and the right hand side represents the heat

800-755-2751 www.decagon.com support@decagon.com