TA Instruments

TAM AIR
ISOTHERMAL CALORIMETRY

TAM AIR

The best choice for isothermal calorimetry of chemical reactions and metabolic processes

High Sensitivity

Multi-Sample 3 or 8 Channel Option

Long-Term Temperature Stability

Lowest Baseline Drift

The TAM Air isothermal calorimetry system provides the sample flexibility and measurement sensitivity to accurately characterize heat flow in a wide variety of materials. The 8-channel calorimeters are widely recognized as the instrument of choice for cement hydration analyses using ASTM C1702 and C1679. The 3-channel calorimeters have the required sensitivity to detect low levels of metabolic activity required for applications such as soil remediation and food contamination analysis. Unmatched baseline stability and signal-to-noise performance makes the TAM Air the best choice for the analysis of medium to high heat-producing materials.

TAM AIR

A VERSATILE ISOTHERMAL CALORIMETER with HIGH PERFORMANCE & ROBUSTNESS

The TAM Air is a flexible, sensitive analytical platform that is an ideal tool for large-scale isothermal calorimetry experiments. Capable of measuring several samples simultaneously under isothermal conditions, the TAM Air with its air-based thermostat and easily interchangeable 8-channel standard volume or 3-channel large volume calorimeters, is especially well-suited for characterizing processes that evolve or consume heat over the course of days and weeks. The TAM Air offers high sensitivity and long-term temperature stability for detecting and characterizing heat production or consumption in a wide variety of sample types and sizes.

Applications include cement and concrete hydration, food spoilage, microbial activity, battery performance and more. Monitoring the thermal activity or heat flow of chemical, physical and biological processes provides information which cannot be generated with other techniques.

TAM Air Thermostat with 8-channel Calorimeter

TAM Air Thermostat with 3-channel Calorimeter

UNMATCHED

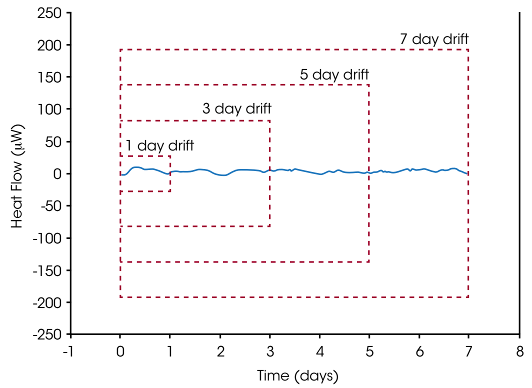
long-term temperature stability with

Easy Operation

The TAM Air is an internationally recognized microcalorimetry tool that combines unmatched long-term temperature stability and time-tested robust operation for measuring characteristic heat signatures in samples ranging from material science to metabolism of biologicals. The TAM Air thermostat can be configured to accommodate eight 20 mL samples or three 125 mL samples, each with an individual reference. The performance and reliability of the TAM Air thermostat, coupled with the easy-swap calorimeter blocks, creates a powerful analytical platform suitable for any laboratory.

TAM Air Feature and Benefits:

- Air regulated thermostat with high stability and low drift
- Eight-channel standard volume calorimeter block for up to 20 mL sample size to maximize sample throughput
- Three-channel large volume calorimeter block for up to 125 mL sample size for accommodating larger, complex and aggregate containing samples
- Compatible with new TAM accessory box for more specific measurements
- Satisfies ASTM C1679, ASTM C1702, and EN 196-11 for characterization of cement hydration
- Proven versatility for measuring both reaction kinetics and temperature dependence of these reactions
- Industry-proven reliability in the most challenging laboratory environments



Seven Day Baseline Drift Characteristics for a TAM Air with 3-channel Calorimeter. Red dashed lines represent the baseline drift specification limits.

Red arrows indicate direction of air flow within the thermostat. Air flows upward through a temperature regulating heat sink and then through inner chamber directly around the calorimeter block. It then flows downward through the outer space surrounding the inner chamber, in effect isolating the inner chamber from external thermal noise and ensuring greater long-term stability and lower thermal noise.

Precise Temperature Control and Industry-Proven Performance

The TAM Air is an air-based thermostat, utilizing a heat sink to conduct the heat away from the sample and effectively minimize outside temperature effects. The calorimeter channels are grouped in a single removable block. The thermostat uses circulating air and an advanced regulating system to keep the temperature stable within ±0.001 °C. The high accuracy and stability of the thermostat makes the calorimeter well-suited for heat flow measurements over extended periods of time, e.g. weeks.

TAM Air Thermostat Features and Benefits:

- Advanced thermoelectric elements for controlling the calorimeter environment
- Precision temperature control that enables stable long-term measurements, from days to weeks
- Wide temperature range for measurements: 5 °C to 90 °C
- Dry gas envelope for conducting experiments below room dew point
- Easy access to facilitate easy changing between the 8- and 3-channel calorimeter
- TAM Air Assistant software, widely recognized for its ease of use and data analysis

TAM Air 8-channel with admix ampoule

TAM AIR | TECHNOLOGY

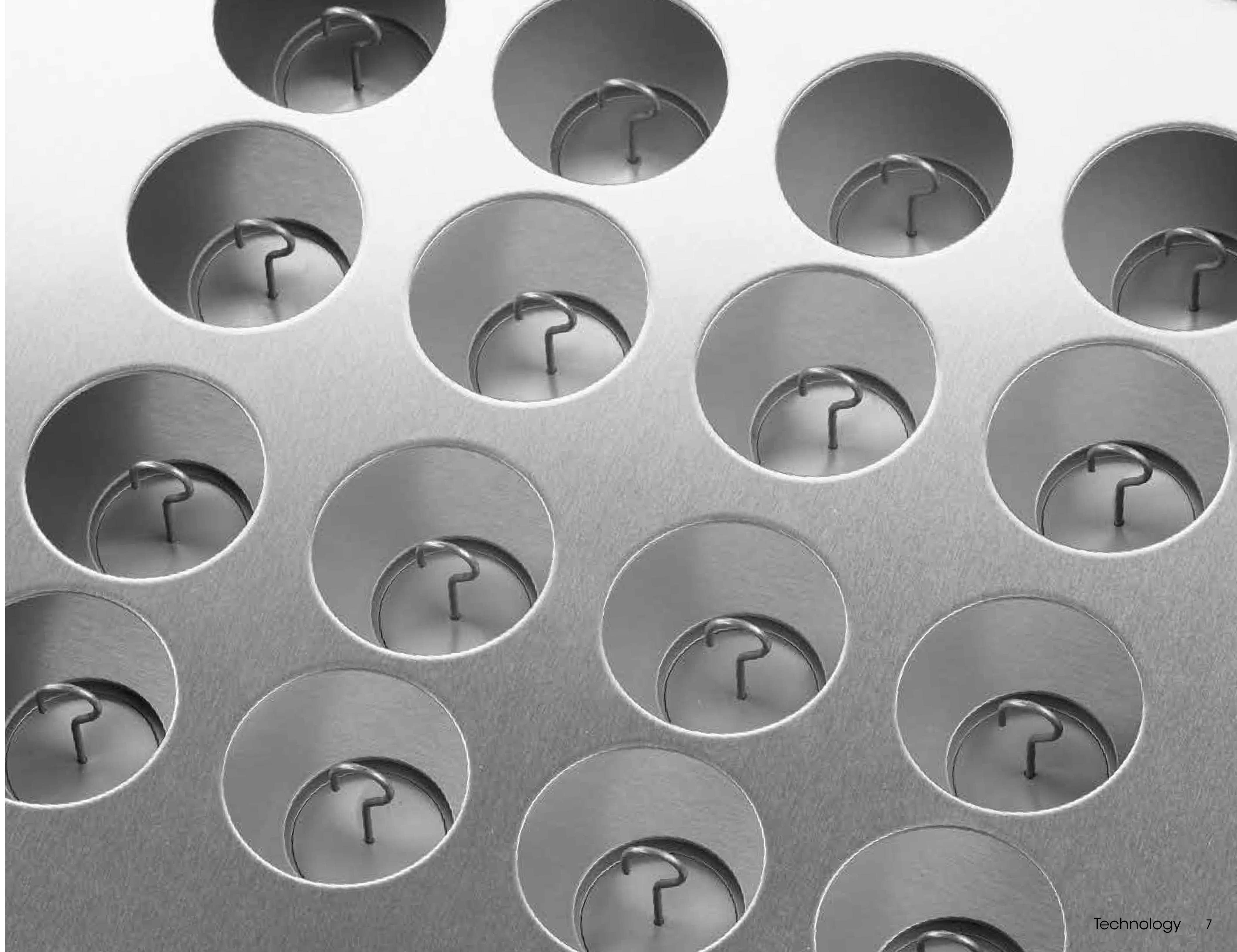
Versatile and Robust Calorimeter Performance

The TAM Air calorimeter block is available in two versions, both employing twin-type calorimeters. The 3-channel large volume calorimeter block has three twin-type calorimeters that can accommodate 3 samples of up to 125 mL volume. The 8-channel standard volume calorimeter can accommodate eight samples of up to 20 mL volume. In both calorimeter blocks, all the samples can be measured simultaneously and independently of each other. The only characteristic of each experiment in common is the thermostat temperature. The calorimeter blocks are interchangeable in the TAM Air thermostat and enable a high level of flexibility depending on the sample size and physical format.

TAM Air Calorimeter Features:

- Designed for accurate and reproducible measurements of heat produced or consumed by any process in the sample
- Temperature differences between sample and reference generates potential - Seebeck effect
- Voltage from sensor is proportional to the heat flow from the sample
- Continuous, real-time data collection
- Twin calorimeter design
    - Reduces baseline noise
    - Eliminates small thermostat fluctuations from data

20 mL calorimeter channel



MULTI-SAMPLE Capacity for **SIMULTANEOUS ANALYSIS**

8-Channel Standard Volume Calorimeter

The TAM Air 8-Channel Standard Volume Calorimeter consists of an eight-channel, twin-type calorimeter block and data acquisition system. The calorimeters are designed for 20 mL glass or plastic ampoules or the 20 mL Admix ampoules. This sample volume is ideal for measuring more homogeneous materials such as unfilled cement through its hydration process, foods, biological materials, and thermosets in curing.

8-Channel Calorimeter Features:

- Eight individual samples for maximum throughput
- Individual references for each sample for optimal signal resolution
- High baseline stability and low drift for the most accurate measurements
- Compatible with 20 mL disposable plastic or glass ampoules
- Easy configuration with 20 mL admix ampoules
- Industry-proven capability for analyzing cement hydration
- Compatible with TAM Accessory Box for simultaneous heat flow and optional user-configured probe measurements
- Complete, easy-to-use TAM Air Assistant software for data acquisition and analysis

TAM Air 8-channel

3-Channel Large Volume Calorimeter

The TAM Air 3-channel large volume calorimeter consists of a three-channel, twin-type calorimeter block and data acquisition system. The calorimeters are designed for 125 mL glass or stainless steel ampoules. This large volume calorimeter design is especially important for heterogeneous samples and those that contain large particles, such as concrete with aggregate and soil samples.

3-Channel Calorimeter Features:

- 3 individual samples with matching reference
- Low baseline noise and high baseline stability for the most accurate measurements
- Compatible with 125 mL glass or stainless steel ampoules
- Excellent capability for analyzing the hydration profile of concrete mixtures
- Complete, easy-to-use TAM Air Assistant software for data acquisition and analysis

3-Channel calorimeter block

Sample **FLEXIBILITY** with a choice of **AMPOULE CONFIGURATIONS**

Sample Handling System - Static Ampoules

The sample handling system for TAM Air includes static 20 mL and 125 mL ampoules, as well as the 20 mL Admix ampoules. The ampoules available for use in the 8-channel calorimeter block accommodate sample sizes up to 20 mL volumes. Both glass and plastic (HDPE) closed ampoules are available. These ampoules enable flexibility for sample management. The 3-channel large volume calorimeter block accommodates sample sizes of up to 125 mL. These 125 mL ampoules are available in both glass and stainless steel.

Ampoule & Fixture Features and Benefits:

- Choice of 20 mL plastic or glass ampoules for 8-channel calorimeter
- Choice of 125 mL glass or stainless steel ampoules for 3-channel calorimeter
- Choice of two types of 125 glass ampoules; the glass ampoule for wet samples has an o-ring seal to ensure no vapor escapes
- 20 mL admixture ampoule for *in situ* cement mixing capability
- Battery fixtures available for 18650, C- and D-sized batteries to be used in the large volume calorimeter

ADMIX AMPOULE

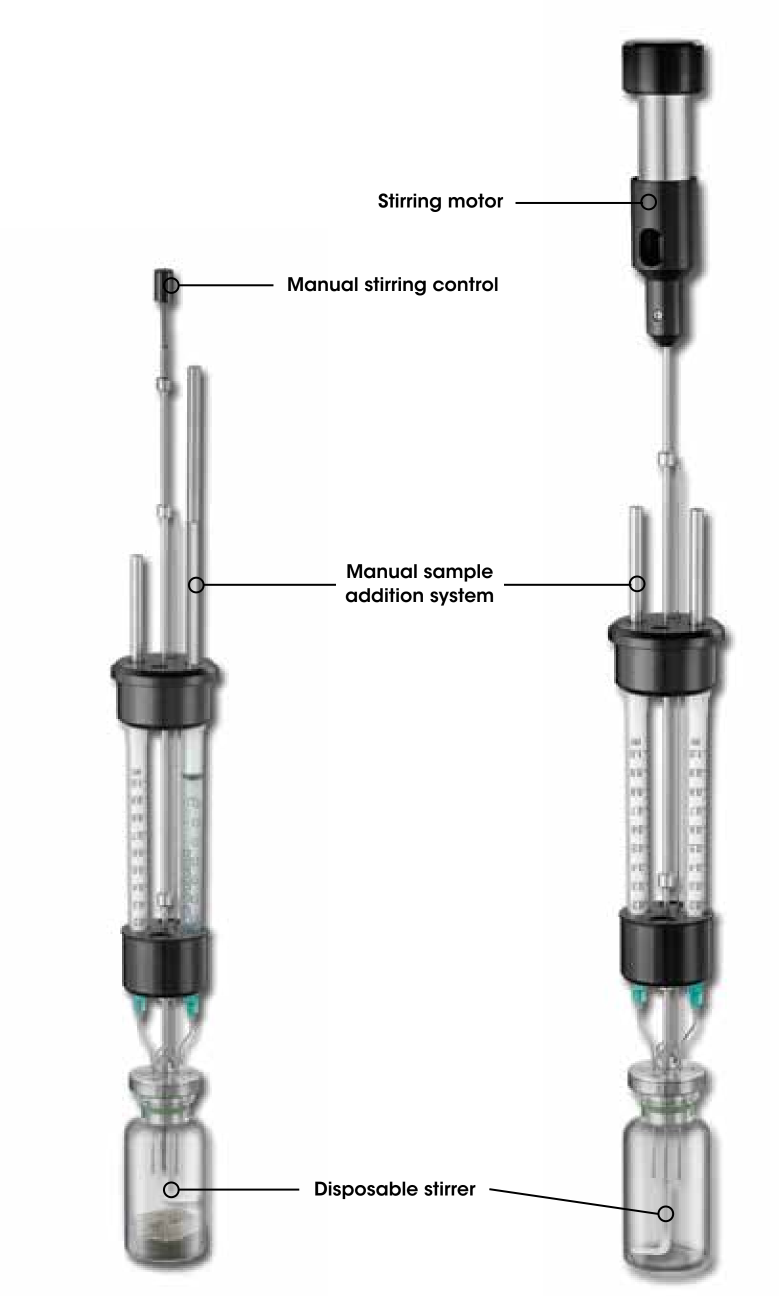
Sample Handling System – Admix Ampoule

The Admix ampoule is a 20 mL accessory available for the 8-channel standard volume calorimeter. It is used for initiating reactions inside the calorimeter, and can be used for monitoring a reaction from the initial injection. The Admix Ampoule can be configured with or without a motor for stirring. For samples such as mixtures of cement and water, manual stirring is recommended. For liquid systems, a motor may be used for stirring. The Admix Ampoule can only be used with 20 mL disposable glass ampoules.

Admix Ampoule Features and Benefits:

- *In situ* mixing gives information on the initial hydration reactions
- Disposable plastic stirrers for easy and quick experiment set-up and clean-up
- Possibility to inject up to 4 mL of liquid for optimization of each experiment
- Four individual syringes can be configured to deliver multiple components into a sample, sequentially or simultaneously
- Choice of manual or motorized stirring for measurement optimization

Admix Ampoule



Admix Ampoule with manual stirring

Admix Ampoule with stirring motor

Calorimetry is a non-specific technique as it measures everything that is occurring in the sample. To increase the specificity of a calorimetric measurement it is possible to add a probe to connect a chosen property to the heat flow signal. A user-configured probe can be connected to the Voltage In/Out module of the Accessory interface box to log the voltage measured simultaneously with the calorimetric data.

Features:

- Increased specificity of the measurement.
- Up to eight (8) identical or different accessories connected and controlled thru one accessory interface for measurement flexibility
- Can be configured with power for stirrer motors, and peristaltic pumps.
- Three-channel voltage I/O accessory card for applying or measuring voltage from user configurable probes (pH, O_2, etc.)
- Allows the measurement of the voltage of a battery under study

Accessory Interface Box Cards

INCREASED MEASUREMENT specificity with EXTERNAL PROBES

The Ultimate Choice for
CEMENT & CONCRETE
HYDRATION ANALYSIS

A powerful tool for the study of cement and concrete hydration processes

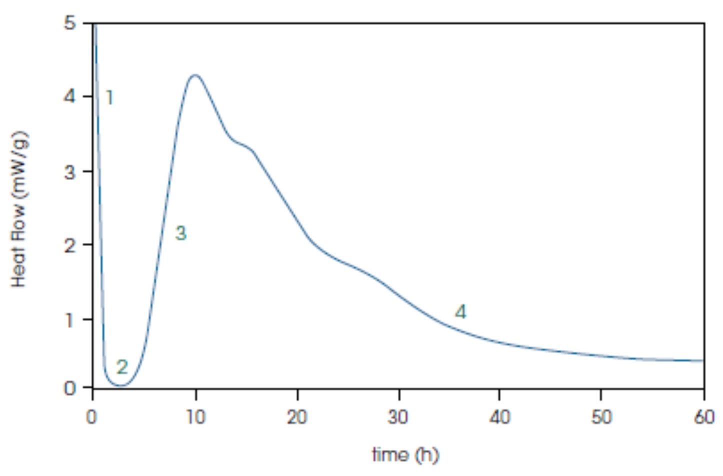
Isothermal calorimetry is an excellent tool to measure the total heat of hydration as well as to continuously follow the reaction rates in the different phases of the complex cement hydration process.

The heat flow profile from a hydrating cement or concrete sample is information-rich and can give insight and knowledge for:

- The development of new cements and admixtures
- Dosing and formulation optimization
- The impact of temperature on the hydration process
- The detection of any incompatibility of materials
- Production and quality control.

TAM Air features and benefits for the measurement of the hydration process:

- Application specific Cement Analysis software for acquisition and analysis
- Choice of two volumes, 20 and 125 mL, to allow measurements of either cement or concrete with optimal performance
- Availability of the admix ampoule for the study of the initial reaction directly when water is added to the cement
- High sensitivity and signal stability making it possible to follow the hydration process for weeks
- Multi-sample capacity for simultaneous analysis
- Conforms to the standards ASTM C1702 and ASTM C1679



Phase 1: Rapid Intial process - Dissolution of ions and initial hydration

Phase 2: Dormant period - Associated with a low heat evolution and slow dissolution of silicates

Phase 3: Acceleration period - Silicate hydration

Phase 4: Retardation period - Sulphate depletion and slowing down of the slicate hydration process

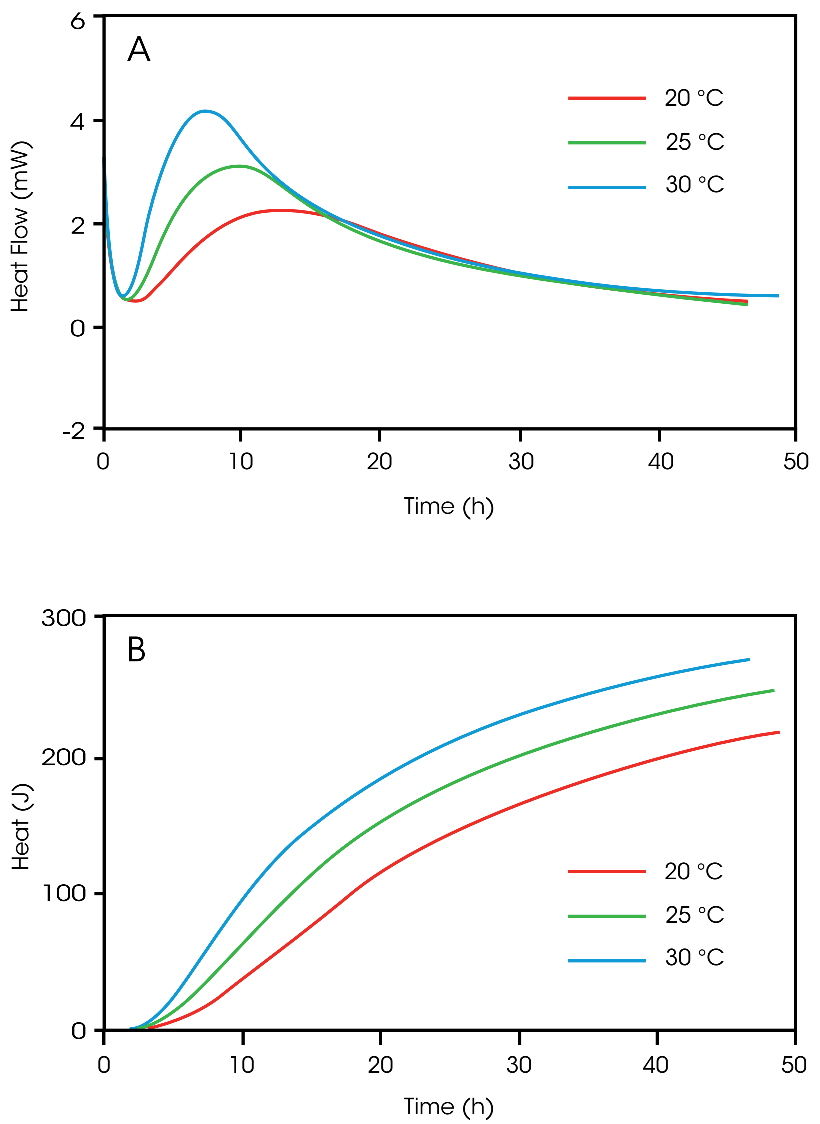
TAM AIR | CEMENT & CONCRETE - INFLUENCE OF TEMPERATURE

Complexity of Cement Hydration Process

The cement hydration process is temperature-dependent and mechanistically complex. Controlled studies at multiple temperatures provide setting profiles at each condition as well as insight into the multiple chemical reactions and their individual temperature dependencies.

When the TAM Air is used for studying the hydration process the temperature of the sample will be essentially constant (isothermal) during the measurement. This is an advantage of using heat flow calorimeters in contrast to adiabatic type of calorimeters. In a heat flow calorimeter the heat produced by the hydration process will be exchanged with the surroundings whereas it will be used to heat up the sample in an adiabatic type of calorimeter.

With the TAM Air a number of experiments can be performed at different temperatures and the influence of temperature determined. This can be done using different approaches. One way is to fit a rate equation to the hydration curve and determine an overall rate constant. The rate constant can be plotted as a function of temperature according to the Arrhenius equation. The slope of *ln(rate constant)* versus *1/T* gives the apparent Arrhenius energy.



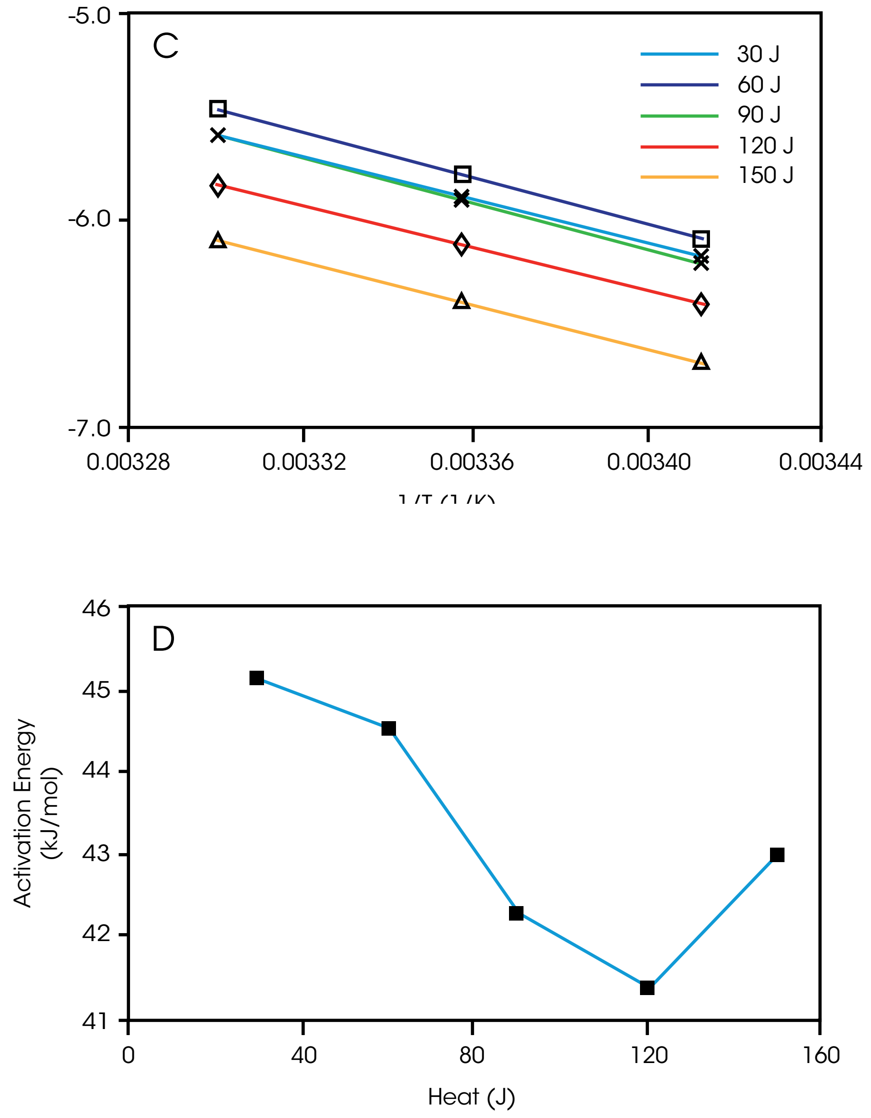
A more advanced approach is to determine the activation energy as a function of the extent of hydration

A. The directly measured output of a TAM Air measurement is heat flow over time and directly reflects the rate of reaction. This is shown for three temperatures of the same system.

B. The integral of this heat flow over time, the total heat, is a measure of the extent of the reaction.

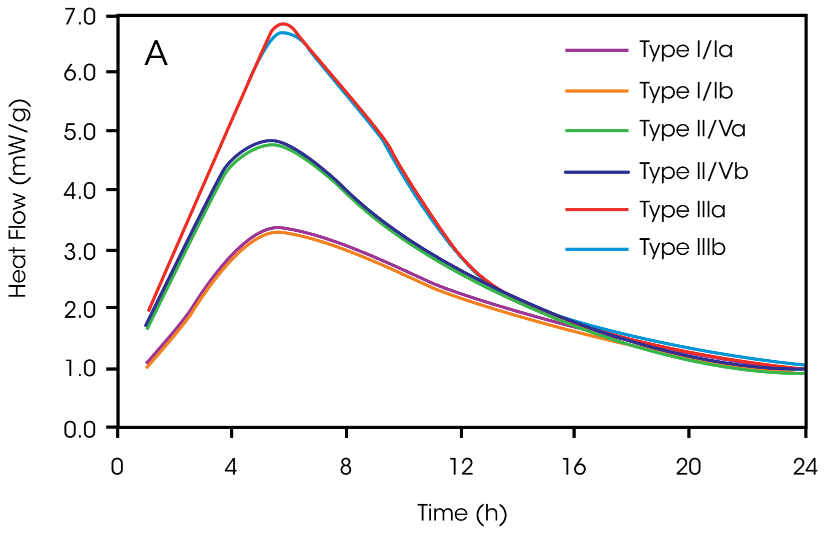
C. An Arrhenius plot of the reaction rate (heat flow) at several defined extents of reaction (total heat) allows for the calculation of the apparent activation energy at each stage of the process. A reaction with a single mechanism would show a constant activation energy throughout the process.

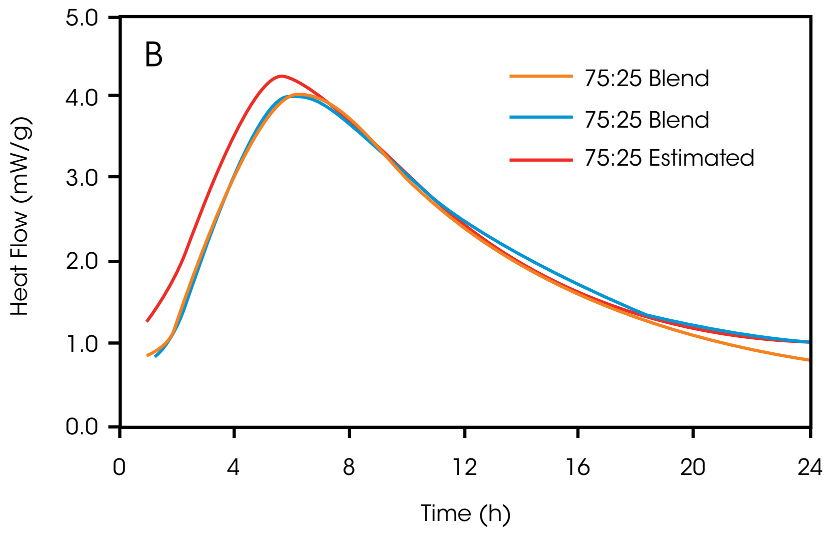
D. As shown in this figure the cement hydration process is complex, going through several sub processes realized by the multiple activation energies.



Cement/Concrete property engineering

Concretes are designed to fulfill specific engineering properties and many include a requirement for the 28-day compressive strength. Many ready-mix plants optimize this performance by changing the water/cement ratio, adding admixtures or changing cement paste content; however such changes will most likely also change transport properties and potentially durability of the concrete. Hence in some cases it would be desirable to adjust the 28-day strength without changing these parameters. There is a strong relationship between cement particle size distribution (PSD) and compressive strength. The example described here demonstrates it is possible to engineer properties of the concrete by the controlled blending of a fine and a coarse cement from the same clinker.

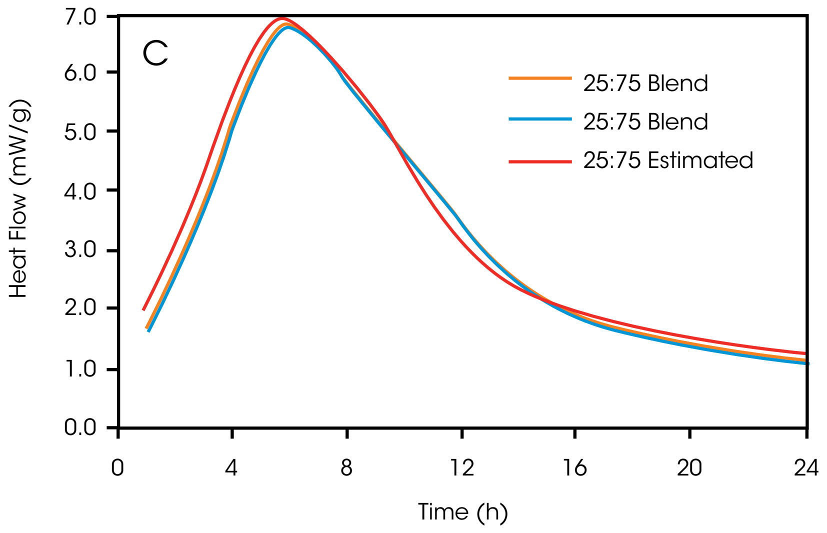


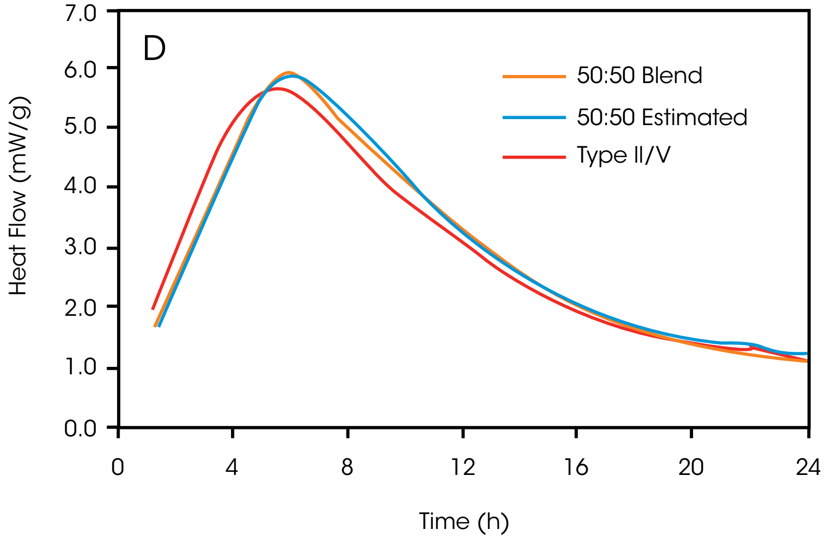


A. Duplicate hydration curves of three cements with different particle size distribution over 24 hours. In general, results for the two replicate specimens for each cement paste fall directly on top of one another. For the three cements, the heat release during the first 24 h increases with increasing cement fineness, as would be expected due to the increased surface area i.e. increased contact with water. Interestingly, for these cements based on a single clinker, the peak in heat release rate always occurs at about 6 h, while by 24 h, the heat release rate has diminished to a value close to 1 mW/g cement.

B. & C. Blended cements: The results imply that for the w/c = 0.4 cement pastes examined in this study, the particles are likely hydrating independently of one another during the first 24 h, such that the degree of hydration of blends of the fine and coarse cements can be quite accurately computed simply as a weighted average of their (measured) individual hydration rates.

D. The heat flow and calculated hydration for the 50:50 blend overlays with the Type II/V cement, which has a similar particle size distribution as the resulting blend.





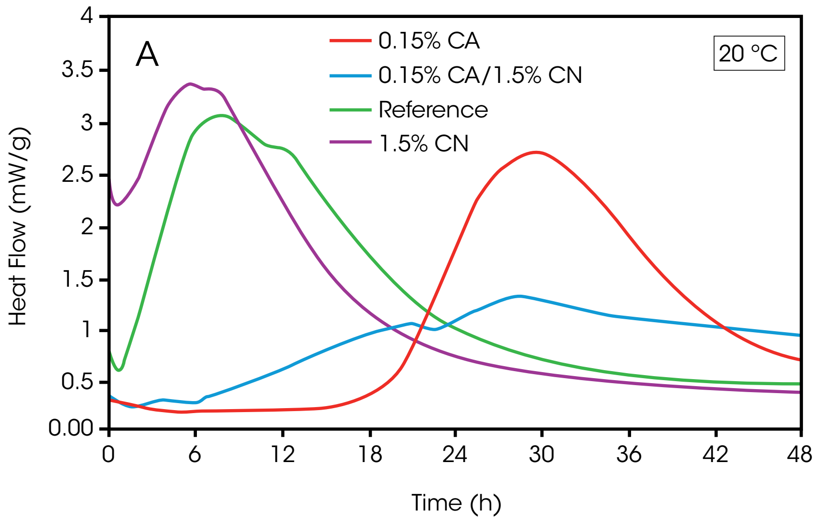
Optimizing admixture dosing

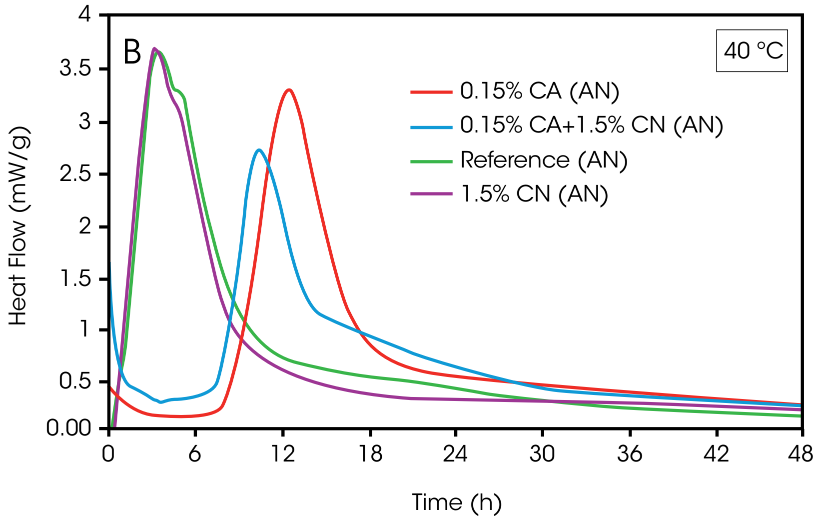
Isothermal calorimetry is an efficient technique to study the effect of an admixture or combinations of admixtures in cement or concrete. Hardening retarders are admixtures that will lower the rate of hydration by distributing the heat over time. A hardening retarder is used to lower the maximum temperature in a hydrating concrete construction to avoid thermal crack formation.

The example shows the synergistic effect of the combination of a minor amount of a strong setting retarder like an organic acid (0.1-0.3 %) with the setting accelerator calcium nitrate (1-3%).

A. The synergy of citric acid (CA) and calcium nitrate (CN) is clearly seen in the hydration profile, measured at 20 ˚C. CA is essentially a setting retarder relative to the reference, although the heat of hydration is slightly reduced and CN is clearly a setting accelerator. Together they behave as a hardening retarder.

B. The rate of hydration heat for the same mixtures at 40 °C shows that the function as hardening retarder is reduced at higher temperature. This data along with the cumulative heat data (not shown) indicate that the admixture combination may not function in the semi-adiabatic case of massive concrete.





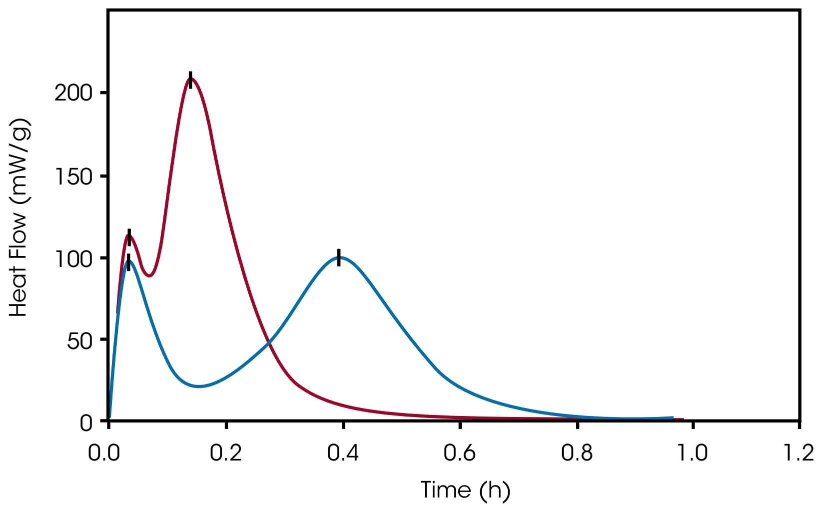
In situ addition and mixing with the admix ampoule

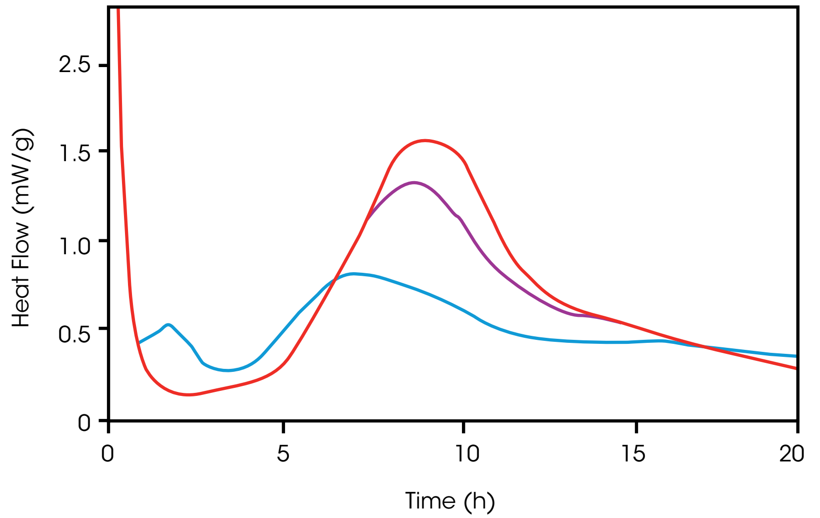
Identical samples of 2 g of calcium sulfate hemihydrate powder were mixed with a hydrating agent at a liquid to solid ratio of 1:2 using an admix ampoule in the TAM Air. The blue curve represents data for a sample hydrated with deionized water. The red curve is for a sample hydrated with a 5% sodium chloride solution. It is demonstrated that sodium chloride accelerates the calcium sulfate hydration reaction, but does not affect the initial reactions

Setting time of cement

The TAM Air calorimeter has been shown to be excellent for diagnosis of problems related to setting time and premature stiffening of cement. The blue curve in the figure to the right represents an industrial cement produced with too little soluble calcium sulfate. This cement suffers from early stiffening because of the aluminate reactions at 1–1.5 h hydration.

It also suffers from low early strength, because the aluminate hydrates formed retard the strength-giving silicate hydration indicated by the unusually small silicate peak at 5 -10 h. When 0.5% (purple curve) and 1.0% (red curve) of calcium sulfate hemi-hydrate was added to the cement the undesired early peak disappeared, and the strength-giving silicate peak regained its normal shape. The results indicate that premature stiffening is caused by a lack of soluble calcium sulfate.



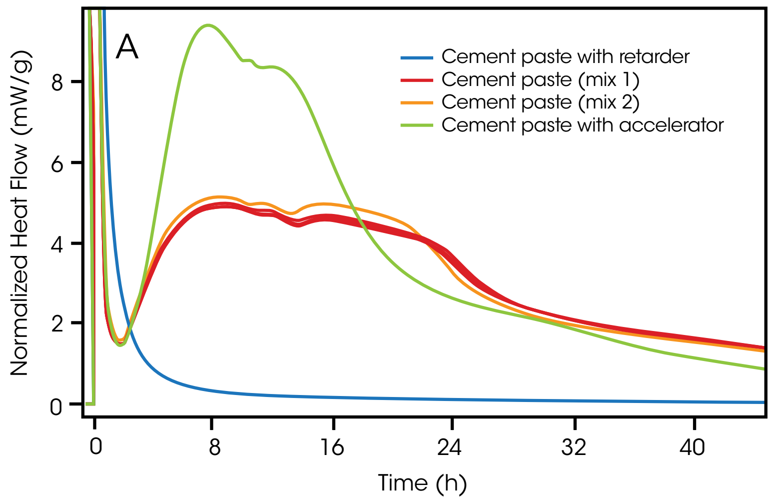


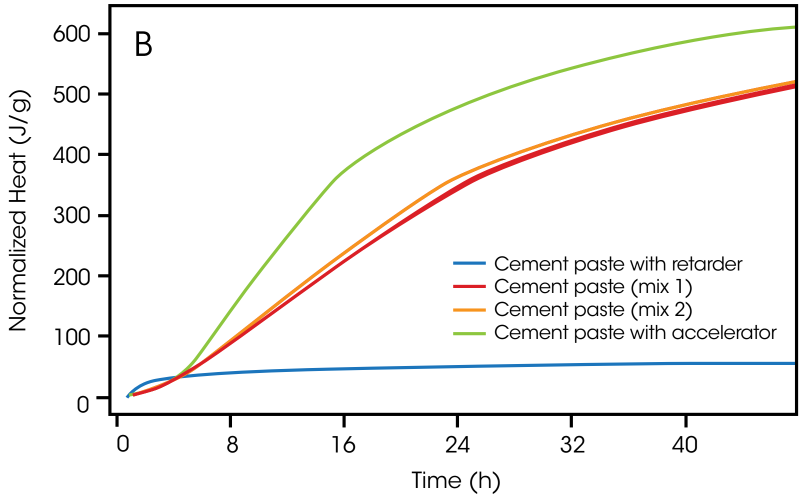
Cement Paste Variations

Cement paste is preferably tested in the 8-channel standard volume calorimeter and concrete in the 3-channel large volume calorimeter. Cement paste should be tested in smaller samples to keep the sample isothermal throughout the test. According to the ASTM C1702 the sample temperature should not exceed 1 °C difference to the test temperature; larger cement samples (> 6 g dry cement) that are hydrating fast might have a larger temperature rise. However, this example shows that a cement paste very well can be studied in a 3-channel large volume calorimeter, but the risk of possible temperature increase should be considered.

A. Three mixes of cement paste (w/c 0.45) were measured at 25 °C in the 3-channel large volume calorimeter. The paste is measured as a fresh specimen (red), an identical formula mixed and measured a week later (orange), with an admixture accelerator (green), and with a retarder (blue). The accelerator can be seen to accelerate the silicate reaction while the retarder accelerates the initial aluminate reaction but greatly retards the silicate reaction.

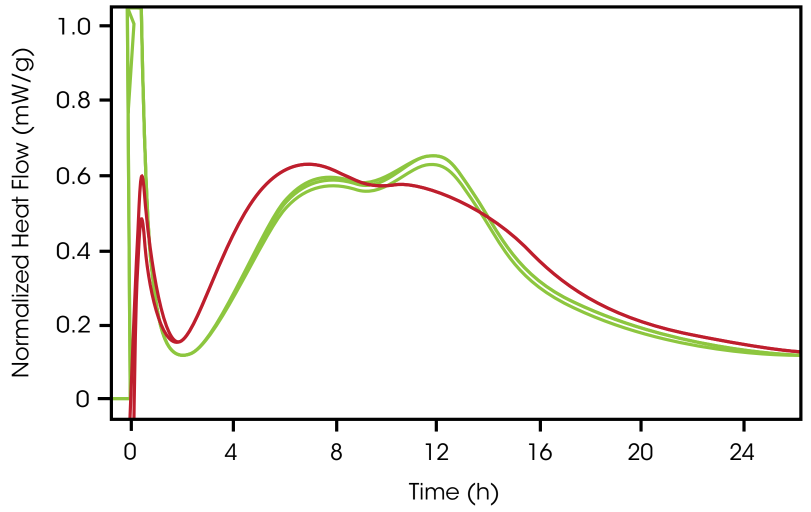
B. The total heat evolved is a measure of the overall extent of reaction. In this representation it is especially easy to see the initial acceleration of the aluminate reaction caused by the retarder, but the silicate reaction which drives setting is delayed beyond the time scale of this study.





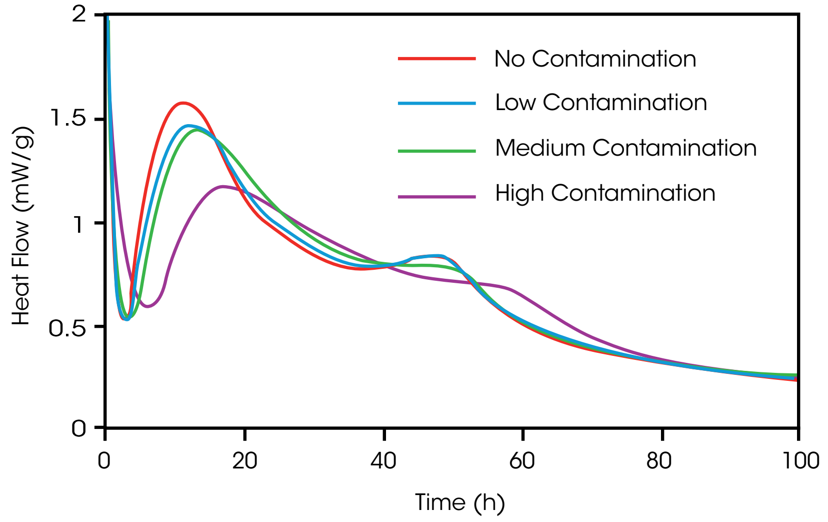
Hydration Process of Concrete

The hydration process of two different concrete (w/c 0.55) samples with (green curves) and without superplasticizer (red) were measured using the TAM Air 3-channel large volume calorimeter. The samples were prepared to contain 50 % small aggregates (0-8 mm) and 33 % large aggregates (8-16 mm). The concrete in this example is a shotcrete and the superplasticizer is used to first be able to pneumatically apply the concrete onto a surface and have it stick to this surface even if it is on a vertical wall or a roof. The high capacity of the 3-channel large volume calorimeter allows for these filled samples to be measured under their exact use conditions.



Cement Thermal Profiles with Contaminants

Cement setting thermal profiles can be influenced by contaminants. The graph shows the steady decrease in thermal power as the contamination of the cement mortar by a mixture of soil and sawdust increases (0; 0.9; 2.5 and 5.9% of w/c = 0.6 cement mortar).



Maximum Flexibility for FOOD ANALYSIS, MICROORGANISM DETECTION & ENERGY STORAGE CHARACTERIZATION

Calorimetry a universal technique

As almost all reactions and processes produce or consume heat and that is what calorimetry measures, any changing system can be studied in a TAM Air, chemical, physical as well biological.

TAM Air can be used as a:

- process monitor
- kinetic instrument
- analytical tool
- research instrument

For applications within:

- safety assessment
- stability and compatibility evaluations
- quality control

The TAM Air is especially suited for the study of chemical and biological activity in larger samples; samples that are either physically large, heterogeneous samples or samples that require a large headspace. Applications include but are not limited to:

Food science:

- Spoilage & shelf life
- Fermentation
- Metabolism

Environmental science:

- Biological activity in soil and sediment
- Effect of waste water treatments
- Soil or water remediation

Biology and microbiology:

- Germination
- Small animal metabolism
- Microorganism detection

Battery science:

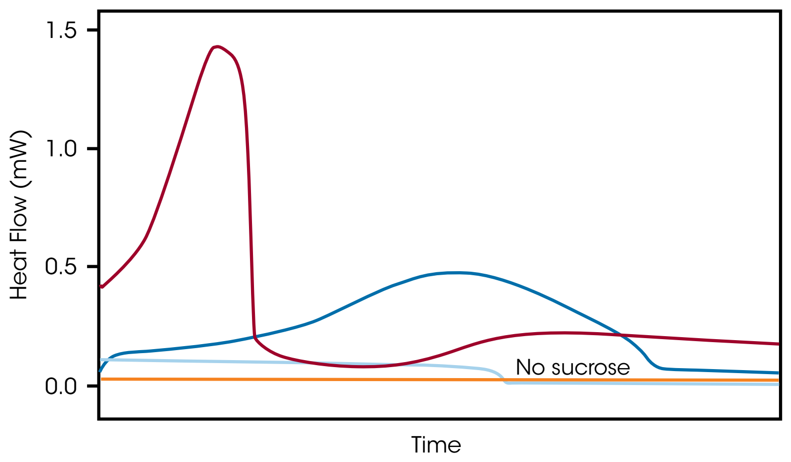
- Efficacy
- Charge-discharge cycling

Material Science:

- Curing reactions

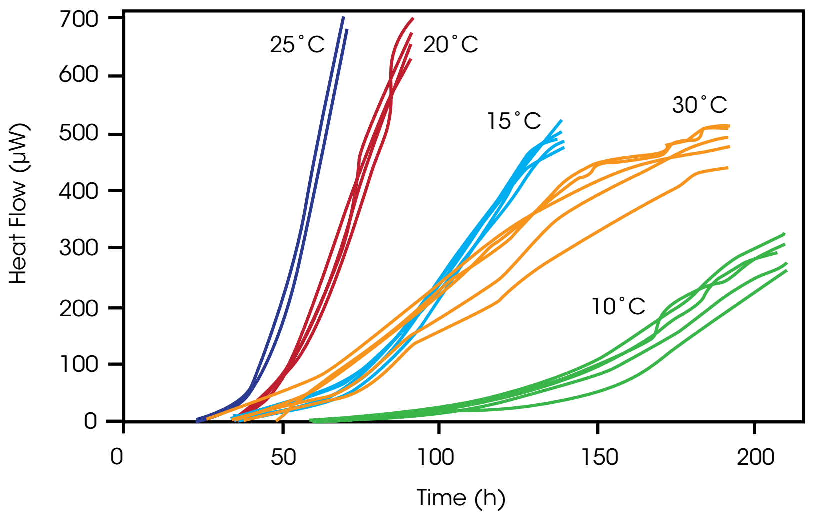
Soil

Isothermal calorimetry is a viable technique for determining the quality of soil through respiration measurements. Calorimetry provides a direct qualitative and quantitative assessment of soil condition and carbon cycling. In addition to heat measurements, simultaneous measurements of heat and CO_2 production increase understanding of soil processes. Well-designed control experiments allow separation of measured heat into different sources. Trends in calorimetric evaluation of soil have emerged that are consistent with soil conditions. This technique and the analysis methods applied to soil can also be applied to plants, insects, and other organisms. The example shows two different soils with and without sucrose addition



Fungal Growth

Calorimetric measurements can be a valuable addition to the measurement techniques for predictive microbiology. This example shows fungal growth based on the heat produced by Penicillium roqueforti growing on malt extract agar. At each temperature multiple inoculated specimens were measured. It is shown that the results at the five temperatures agree rather well with each other. The results could also be successfully fitted to different growth models.

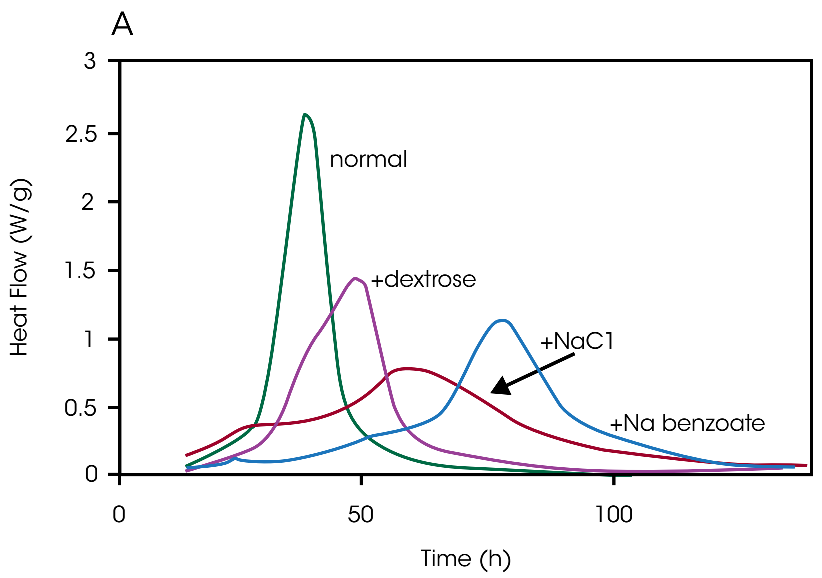


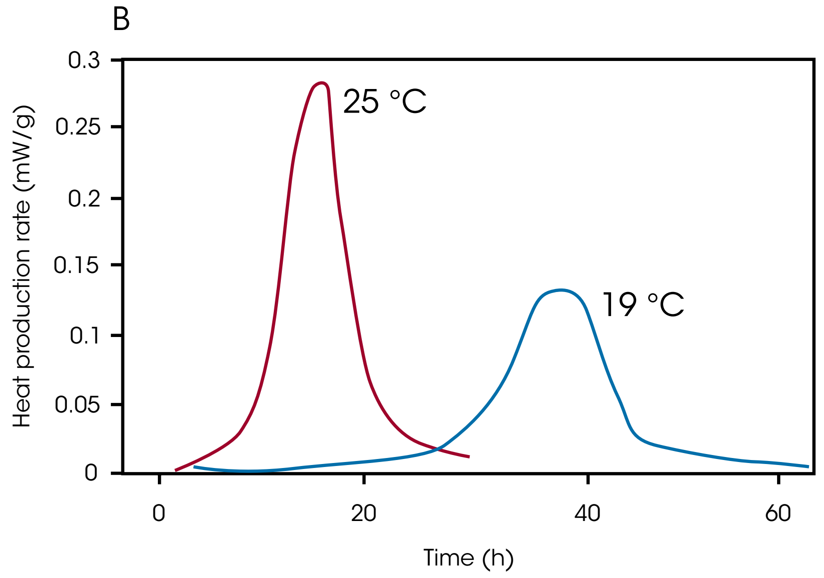
Fermentation

Isothermal microcalorimetry is a powerful tool in the study of microbial food spoilage. However, microorganisms not only spoil food, they can also be used to preserve it. There are many examples of foods which are made with the help of microorganisms, e.g.: beer, wine, pickled cucumbers, kimchi and some types of sausages. Also, there are fermented milk products, such as yogurt and the soft cheeses, such as camembert. Since all microbiological metabolism produces heat, isothermal microcalorimetry is a fast, easy and convenient method to study these processes.

A. The figure shows the heat produced during milk fermentation when different additives are included. The simultaneous direct measurements made on these samples revealed the effectiveness of each additive to either delay and/or reduce the heat flow from the samples over time and allowed the quick ranking of each additive as to its effectiveness in inhibiting the fermentation process.

B. Milk fermentation at 25 °C and 19 °C where it is shown that the fermentation process is faster at higher temperature.





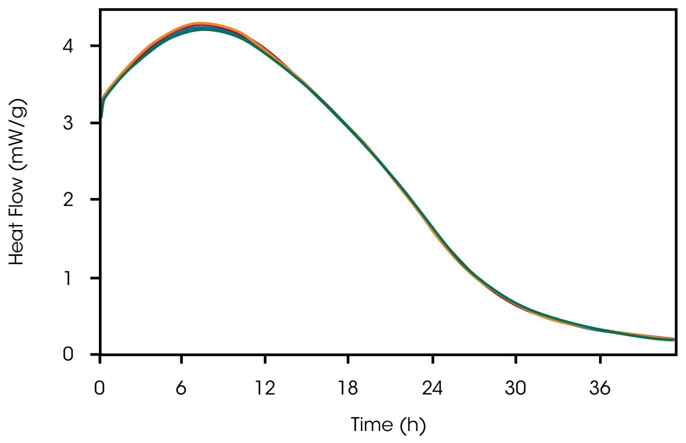
Epoxy Curing

Thermoset polymer precursors undergo irreversible chemical reactions to form cross-linked or cured materials. A common example of a thermoset polymer system is a two-part epoxy. The cross-linking reaction is an exothermic process and an isothermal microcalorimeter can be used to measure the heat evolved by this reaction at a given temperature. Cross-linking or curing of an epoxy can depend on many variables such as chemistry, temperature and sample mass.

A. Four samples of epoxy curing measured at 25 °C

B. Sample measured at 5 different temperatures. Time to peak is shorter and reaction rate is faster at higher temperatures

C. Arrhenius plot. Arrhenius kinetic analysis is used to calculate the activation energy and rate constant of a reaction. Using the labeled points (in plot B) for kinetic analysis involves the assumption that the percent total enthalpy or conversion at this point is the same at each temperature. For more quantitative values of activation energy and rate constant it would be recommended to use curve deconvolution to more accurately calculate the time elapsed to reach the identical percent conversion.



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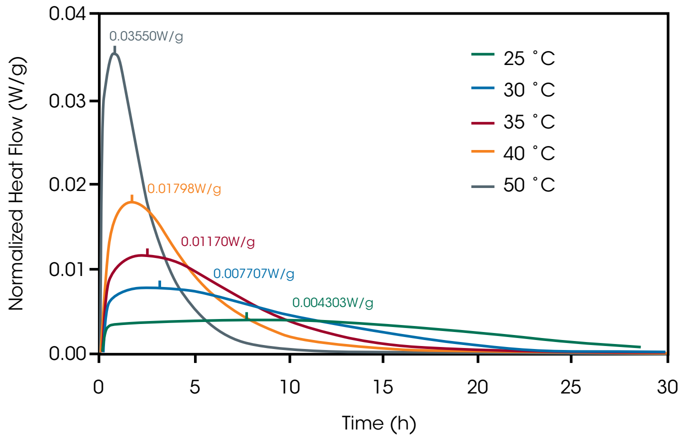
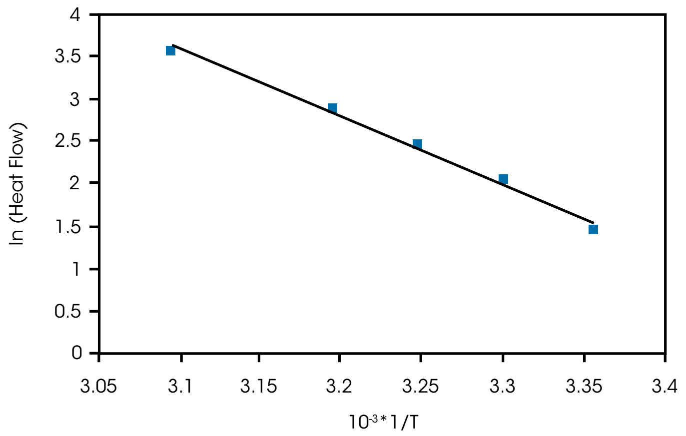


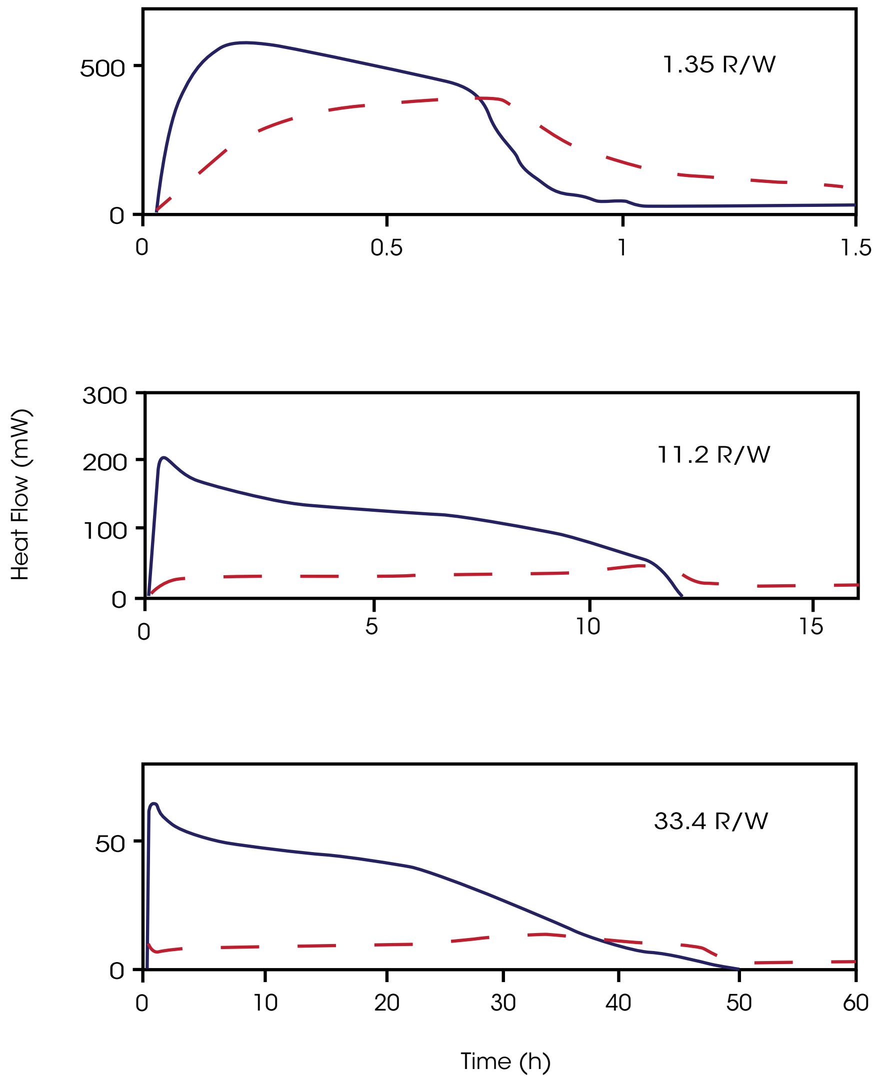
B



C

Battery Testing

The properties of batteries during discharge with three different resistance loads are shown. Single channels in the TAM Air were loaded with 1.5 V alkaline batteries, size AAA. Three resistors of different values were placed in an adjacent channel for connection to the batteries. The solid line represents the useful energy in the battery which is the heat production measured in the resistor, while the dotted line is the heat production from the battery itself, i.e. the internal losses. The batteries were fully discharged during the course of the evaluation in the TAM Air. The lowest resistances cause a rapid drain of the battery (e.g. as in a flashlight) whereas the highest resistances cause a very low rate of discharge (e.g. as in an alarm clock).



TAM AIR | PERFORMANCE SPECIFICATIONS

	3-Channel Large Volume Calorimeter	8-Channel Standard Volume Calorimeter
Thermostat Specifications		
Calorimeter Positions	3	8
Operating Temperature Range	5 °C to 90 °C	5 °C to 90 °C
Thermostat Type	Air	Air
Thermostat Stability	± 0.001 °C	± 0.001 °C
Temperature Accuracy	± 0.15 °C	± 0.15 °C
Maximum Sample Size	125 mL	20 mL
Calorimeter Specifications		
Limit of Detection	8 µW	2 µW
Short-Term Noise	< 8 µW	< 1 µW
Enthalpy Precision	0.3%	0.1%
Baseline over 24 hours		
Drift	< 55 µW*	< 5 µW*
StandardDeviation	< 10 µW	< 2 µW
Error	< 34 µW	< 6 µW

* Baseline drift specification is based on a 24-hour room temperature cycle and can be extended to be valid for multiple days and up to several weeks

ASTM C1679-14 Standard Practice for Measuring Hydration Kinetics of Hydraulic Cementitious Mixtures Using Isothermal Calorimetry
ASTM C1702-15b Standard Test Method for Measurement of Heat of Hydration of Hydraulic Cementitious Materials Using Isothermal Conduction Calorimetry
Bentz, D.P. Blending Different Fineness Cements to Engineer the Properties of Cement-Based Materials. Mag. Concrete Res.
D. Rodríguez, A.U. Daniels, J.L. Urrusti, D. Wirz, O. Braissant. Evaluation of a low-cost calorimetric approach for rapid detection of tuberculosis and other mycobacteria in culture. Journal of Applied Microbiology 111, 2011
Herrmann, A., Coucheney, E., Naoise, N. "Isothermal Microcalorimetry Provides New Insight into Terrestrial Carbon Cycling" Environmental Science & Technology. 2014, 48: 4344-4352
Harris, J., Ritz, K., Coucheney, E., Grice, S., Lerch, T., Pawlett, M., Herrmann, A. "The thermodynamic efficiency of soil microbial communities subject to long-term stress is lower than those under conventional input regimes" Soil Biology & Biochemistry. 2012, 47:149-157.
Justness, H., Wuyts, F. and D. Van Gemert. Hardening Retarders for Massive Concrete. Thesis. Catholic University of Leuven. 2007.
Lars Wadsö and Yujing Li. A test of models for fungal growth based on metabolic heat rate masurements. 2000.
Lars Wadsö Milk Fermentation Studied by Isothermal Calorimetry Thermometric AN 314-04
Lars Wadsö. Investigations into Dry Cell Battery Discharge Rates using TAM Air. 2000. TA Instruments, AN 314-03.
MA002 The use of Isothermal Microcalorimetry to Characterize the Cure Kinetics of a Thermoset Epoxy Material
MA005 Wetting and Hydration of a Mortar Mix Measured by Isothermal Microcalorimetry
MA006 Early Hydration and Wetting of a Calcium Sulfate Hemihydrate Measured by Isothermal Microcalorimetry
MCAPN-2012-04 Following Anaerobic Digestion of Pretreated Algae by Calorimetry
MCAPN-2015-1 Hot Holobionts! Using Calorimetry to Characterize These Relationships
MCAPN-2011-03 Food Spoilage and Heat Generation

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