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CEMENT CALORIMETERS

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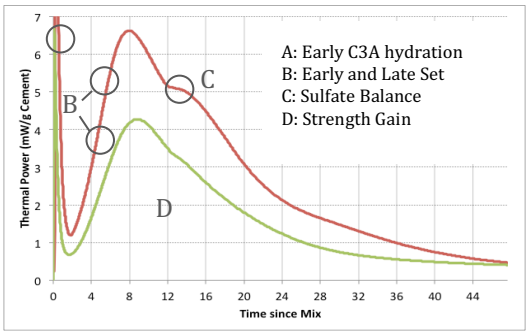
About Calorimetry

Calorimetry measures the heat generated from a chemical reaction. For building materials scientists and cement and concrete professionals, calorimetry is a useful tool to study the properties of cementitious materials. The heat outflow measured by a calorimeter tracks the hydration reactions of cement, which gives visibility into the behavior of concrete or mortar in a way that a simple set time or compressive strength test could not.

The timing and shape of the temperature curve obtained through calorimetry is an indicator of relative performance of cementitious mixes, and of potential adverse interactions among materials used in the mix.
In adiabatic calorimetry, concrete samples are in a perfectly insulated environment, simulating hydration at the core of a mass concrete application.



In an isothermal calorimeter, the outside temperature is maintained constant to simulate different curing temperatures. The tight temperature control further allows for excellent repeatability.

The Calmetrix team has decades of real life experience with calorimeters used at concrete production sites and in research laboratories. We not only understand calorimetry, but also have a deep knowledge of cement chemistry and a genuine understanding of the industry.

Who are Calmetrix's customers?

Industry and Academia trust our products. Examples of customers can be found on the map below.

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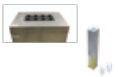
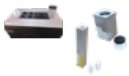
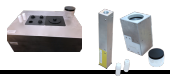
CALMETRIX CEMENT AND CONCRETE CALORIMETERS

APPLICATIONS TABLE

	I-Cal 2000 HPC	I-Cal 4000 HPC	I-Cal 8000 HPC	I-Cal Ultra	I-Cal Flex	F-Cal
						
Type of calorimeter	Isothermal	Isothermal	Isothermal	Isothermal	Isothermal	Semi-adiabatic
Sample type						
Number of test channels / vial size	2 / 125 ml	4 / 125 ml	8 / 125 ml	up to 8 / 20 ml	up to 8 / 20 ml up to 2 / 450 ml	8 / 0.6 l
Cement paste	✓	✓	✓	✓	✓	✓
Mortar	✓	✓	✓		✓	✓
Concrete					✓	✓
Internal (in-situ) mixing capability (optional)	✓	✓	✓	✓	✓	
High effciency mixing	✓	✓	✓	✓	✓	
Software modules for data analysis						
Reporting and Export into Excel, Matlab, etc.	✓	✓	✓	✓	✓	✓
Set time estimation	✓	✓	✓	✓	✓	✓
Compressive Strength estination	✓	✓	✓	✓	✓	✓
Sulfate Optimization	✓	✓	✓	✓	✓	
Heat of Hydration testing	✓	✓	✓	✓	✓	
Cement plant Process Control	✓	✓	✓	✓	✓	
Activation Energy	✓	✓	✓	✓	✓	
Standards and norms						
ASTM C1679 (Isothermal Calorimetry)	✓	✓	✓	✓	✓	
ASTM C1702 (Heat of hydration testing)	✓	✓	✓	✓	✓	
ASTM C563 (Sulfate Optimization)		✓	✓	✓	✓	
ASTM C1897 / RILEM R3	✓	✓	✓	✓	✓	
ASTM C1753 (Semi-adiabatic calorimetry)						✓
EN 196-11	✓	✓	✓	✓	✓	
Examples of Applications (partial list)						
Mix Design Optimization	✓	✓	✓	✓	✓	✓
Detect Cement - admixture interaction	✓	✓	✓	✓	✓	✓
Characterization of fly ash, slag, etc.	✓	✓	✓	✓	✓	✓
Optimal admixture dosage and addition time	✓	✓	✓	✓	✓	✓
Compare different sources of materails (QC)	✓	✓	✓	✓	✓	✓
Sulfate optimization	✓	✓	✓	✓	✓	
Pozzolanic reactivity testing	✓	✓	✓	✓	✓	
High temperature studies (> 70 °C)				✓	✓	
Low Temperature studies (< 5 °C)				✓	✓	
Compressive strength estimation	up to 7 days	up to 7 days	up to 7 days	any curing age	any curing age	48 hours
Setting Time estimation	✓	✓	✓	✓	✓	✓
High Volume Fly ash mix testing	✓	✓	✓	✓	✓	✓
Shotcrete testing	✓	✓	✓	✓	✓	✓
Field testing (portable equipment)						✓
Determination of activation energy	✓	✓	✓	✓	✓	
Admixture formulation	✓	✓	✓	✓	✓	
Sensitivity tests on temperature variations	✓	✓	✓	✓	✓	

CALMETRIX ISOTHERMAL CALORIMETERS

DETAILED SPECIFICATIONS

	I-Cal Flex	I-Cal Ultra	I-Cal 8000 HPC	I-Cal 4000 HPC	I-Cal 2000 HPC
					
General Design					
Number of active sample cells					
For 20 ml vials	1 to 8 (flexible)	1 to 8 (flexible)	n/a	n/a	n/a
For 125 ml vials	n/a	n/a	8	4	2
For 450 ml vials	1 - 2 (flexibe)	n/a	n/a	n/a	n/a
Sample Type					
Cement Paste	✓	✓	✓	✓	✓
Mortar	✓		✓	✓	✓
Concrete	✓				
Sample vials					
Reusable			✓	✓	✓
Anti-cross talk design	✓	✓		✓	✓
internal Mixing					
Internal in situ Mixer (accessory)	✓	✓	✓	✓	✓
Advanced Mixing Technology for full mixing	✓	✓	✓	✓	✓
Normative compliance					
ASTM Compliance					
ASTM C1679 - isothermal calorimetry	✓	✓	✓	✓	✓
ASTM C1702 - heat of hydration	✓	✓	✓	✓	✓
ASTM C563 - sulfate optimization	✓	✓	✓	✓	✓
ASTM C1897 / RILEM R3 - pozzolanic reactivity	✓	✓	✓	✓	✓
Software Functionalities					
I-Cal AE - Activation Energy	✓	✓	✓	✓	✓
I-Cal Set - Setting Time Estimation	✓	✓	✓	✓	✓
I-Cal Strength - Compressive Strength Estimation	✓	✓	✓	✓	✓
I-Cal HOH - ASTM C1702 Heat of Hydration	✓	✓	✓	✓	✓
I-Cal QC - Cement Manufacturing Quality Control	✓	✓	✓	✓	✓
I-Cal SO3 - Sulfate Optimization	✓	✓	✓	✓	✓
Performance Specifications					
Temperature range	2 °C to 90 °C	4 °C to 90 °C	5 °C to 70 °C	5 °C to 70 °C	5 °C to 70 °C
Thermostat Type	Air	Air	Air	Air	Air
Temperature Stability	+/- 0.001 °C	+/- 0.005 °C	+/- 0.02 °C	+/- 0.02 °C	+/- 0.02 °C
Limit of detectability	2 µW	2 µW	5 µW	5 µW	5 µW
Precision	+/- 2 µW	+/- 2 µW	+/-100 µW	+/- 60 µW	+/- 40 µW
Short term noise	< +/- 2 µW	< +/- 2 µW	< +/- 10 µW	< +/- 10 µW	< +/- 10 µW
Baseline over 24 hours					
Drift	< 5 µW	< 5 µW	< 80 µW	< 60 µW	< 20 µW
Deviation	< +/- 1 µW	< +/- 1 µW	< +/- 50 µW	< +/- 50 µW	< +/- 25 µW
Baseline over 72 hours (ASTM C1702)					
Drift	< +/- 0.01 µW/g/h	< +/- 0.01 µW/g/h	< +/- 0.1 µW/g/h	< +/- 0.05 µW/g/h	< +/- 0.01 µW/g/h
Deviation	<+/- 0.1 µW/g	<+/- 0.1 µW/g	<+/- 4 µW/g	<+/- 2 µW/g	<+/- 0.5 µW/g

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I-CAL ULTRA

CALMETRIX I-CAL ULTRA FOR ADVANCED TESTING OF CEMENT

Background: Isothermal Calorimetry in cement testing.

Isothermal calorimetry measures the heat generated by a cementitious binder in a tightly controlled temperature environment. The thermal power is used as a continuous measurement of the rate of reaction, which itself is a determining factor for engineering properties such as workability, set and early strength development. Calorimetry is widely used to perform research and development of new materials and processes in the cement industry.

I-Cal Ultra for advanced precision testing of cement and pozzolanic materials.

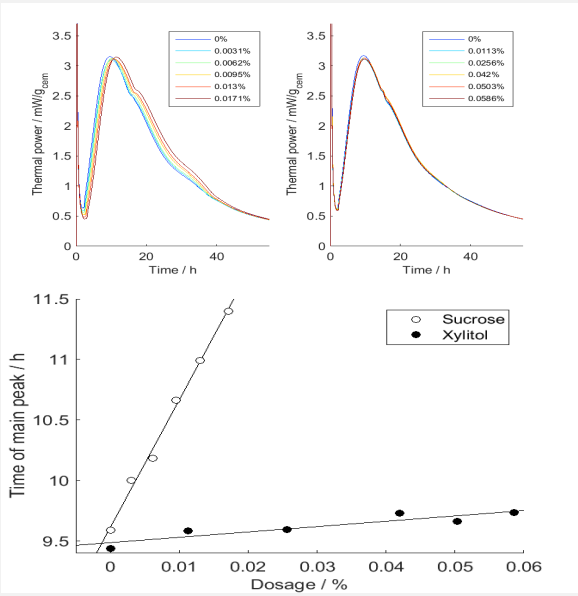
The I-Cal Ultra is an advanced Isothermal Calorimeter for up to 8 sample channels of differential measurement with variable references. Fully compliant with ASTM C1679, ASTM C563, ASTM C1702 and EN 196-11, it is designed to be ideally suited for measurements that require a high level of precision or very long term testing. The I-Cal Ultra can carry up to eight individual plug-and-play calorimeters. Users can choose the number of calorimeter cells they want to install, between one and eight channels. Each calorimeter can be taken out or plugged back into the thermostated chamber individually at the user's discretion. The I-Cal Ultra is the only isothermal calorimeter where each sample cell is completely isolated from the others, thereby completely eliminating any cross talk and resulting in unparalleled precision and stability. The admixture testing vial and advanced mixing accessory is the only true mixer in the market. It ensures cement paste is mixed completely when competitor mixers frequently fail to mix properly, for example at the 0.4 w/c ratio mandated by EN 196-11.

Advanced mixing in I-Cal Ultra

Left: conventional mixer. Incomplete dispersion, poor mixing.

Right: Calmetrix advanced mixer. High dispersion and good mixing

Example: comparative effect of two retarders
(Applicable Instruments: I-Cal Ultra)



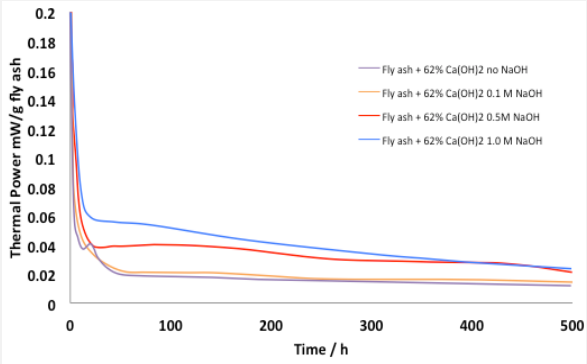
This example shows how to quantify the effect of xylitol and sucrose on the delay of the alite reaction in a Portland-limestone cement paste. In this experiment, each sample contained 2 g of Portland limestone cement, showing the excellent signal-to-noise ratio obtained in the I-Cal Ultra with small samples. The measurements were carried out simultaneously in six of the eight calorimeters, and no cross-talk was observed, as the calorimeters are physically separated by a wide air gap.

The effect of retardation can be seen in the shift of the main peak of reaction as both the sucrose (left graph) and xylitol (right graph) were added in increasingly larger dosages. The dosage increment was 0.0031% for the sucrose and 0.0113% for the xylitol. The near perfect resolution of the Thermal Power curves with these small dosage increments highlights the excellent precision of the instrument.

By plotting the retardation (time of main peak) as a function of dosage, it can be seen that the response to dosage increments for both components is linear, although the sucrose has a stronger retarding effect than the xylitol, by a factor of 25.

Data generated by the I-Cal Ultra is retrieved and analyzed with Calmetrix's state-of-the art CalCommander 2.0 software. Featuring a new design for use with touchscreen computers and an emphasis on user friendliness CalCommander 2.0 offers cement scientists a series of tools for easy determination of setting times, compressive strength, activation energy, sulfate optimization and heat of hydration testing in exact conformance with ASTM C1702. Users can also easily create customized reports and export data into their own analytical software tools.

Example: long-term reactivity testing
(Applicable Instruments: I-Cal Ultra)



Supplementary materials such as fly ash typically react slowly with calcium hydroxide generated by the hydration of clinker. One can measure the reactivity of supplements directly by using a simulated Portland Cement environment consisting of a mixture of calcium and alkali hydroxide, as would be found in a Portland Cement after several days of hydration.
The graph on the left shows a comparative reactivity test for a low calcium fly ash sourced form a power plant in India. The results show that for this fly ash, the effect of an increase in sodium hydroxide concentration is quite substantial, which is possibly attributable to a relatively high content of amorphous material.
I-Cal Ultra is a powerful tool for long term studies of materials like seen here, that exhibit a low heat of reaction.

Applications and uses.

I-Cal Ultra is an advanced precision calorimeter that is particularly suitable for all applications that require a very high degree of precision or long term testing. The I-Cal Ultra's main uses are found in R&D and Investigative work on the properties of clinker phases, cement, pozzolanic materials, and other hydraulic binders or specialty materials, such as:

- testing of individual clinker, or synthetic clinker
- evaluation of pozzolanic reactivity over extended periods of time
- resolution of sulfate imbalance issues
- determination of the exact heat of hydration of cement (e.g. ASTM C1702)
- complex sensitivity testing on variations in admixture or other material content
- precise assessment of activation energy in geopolymers or other alkali activated systems

Typical users of I-Cal Ultra are laboratories for advanced research of cement and other hydraulic materials among Cement Producers, Universities, and Specialty Chemicals companies.

Specifications.

Specifications			
Operating Voltage	110 - 240 VAC - 50/60Hz	**Precision**	+/- 2 µW
Number of test channels	1- 8 (user defined)	**Baseline (24 hours)**	
Sample vial size	20 ml	**Drift**	< 5 µW
Operating Temperature Range	4 °C to 90 °C	**Deviation**	< +/- 1 µW
Temperature Stability	+/- 0.005 °C	**Error**	< +/- 10 µW
Temperature Accuracy	+/- 0.4 °C	**Dimensions**	L20"xW16"xH44" (50 cm x 40 cm x 108 cm)
Detection Limit	2 µW	**Weight**	75 lbs (34 kg)

Note: Performance data measured at 23°C. I-Cal Ultra is an instrument suited for high precision testing in an advanced research laboratory setting. Optimal performance and conformance with specifications is achieved when placed in a climate-controlled room according to standard research laboratory conditions.

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I-CAL FLEX

CALMETRIX I-CAL FLEX FOR ADVANCED TESTING OF CEMENT

Background: Isothermal Calorimetry in cement testing.

Isothermal calorimetry measures the heat generated by a cementitious binder in a tightly controlled temperature environment. The thermal power is used as a continuous measurement of the rate of reaction, which itself is a determining factor for engineering properties such as workability, set and early strength development. Calorimetry is widely used to perform research and development of new materials and processes in the cement industry.

I-Cal Flex for advanced precision testing of cement and pozzolanic materials.

The I-Cal Flex is an advanced Isothermal Calorimeter for up to 8 sample channels of differential measurement with variable references. It is designed to be ideally suited for measurements that require a high level of precision or very long-term testing. The I-Cal Flex can carry up to eight individual plug-and-play calorimeters using glass or HDPE vials. Users can choose the number of calorimeter cells they want to install, between one and eight channels. Each calorimeter can be taken out or plugged back into the thermostated chamber individually at the user's discretion, and is calibrated using its own embedded electrical calibration heater. The I-Cal Flex is the only isothermal calorimeter where each sample cell is completely isolated from the others, thereby completely eliminating any cross talk and resulting in unparalleled precision and stability. The high precision thermostat spans a temperature range from 2 °C to 90 °C, with a stability of +/- 0.001 °C over an indefinite time period, thereby extending the potential of very long-term testing over periods of several weeks or months. The I-Cal Flex's baseline drift and noise levels are the best in its category among any cement calorimeters. Optional accessories are available for internal mixing and injection of water and admixtures. Naturally, the I-Cal Flex is fully compliant with ASTM C1679, ASTM C1702, ASTM C563, ASTM C1897, RILEM R3 and EN196-11.

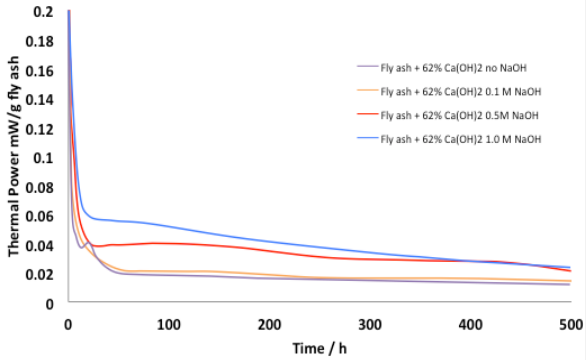
20 ml cells
User can insert between 1 and 8 calorimeters for 20 ml glass or HDPE vials

450 ml / 125 ml cells
User can insert 1 or 2 calorimeters for 450 ml vials or other customizable options (e.g. up to 4 calorimeters for 125 ml vials, etc.)

Mix of 20 ml and l 450 ml cells
One calorimeter for 450 ml vials and between one and four calorimeters for 20 ml vials

I-Cal Flex is connected via USB connection to a Windows PC that is delivered jointly with the calorimeter. Data generated by the I-Cal Flex is retrieved and analyzed with Calmetrix's state-of-the art CalCommander 2.0 software, which can be used in multitasking mode for data analysis even while collecting data for a new experiment. Featuring a new design for use with touchscreen computers and an emphasis on user friendliness CalCommander 2.0 offers cement scientists a series of tools for easy determination of setting times, compressive strength, activation energy, sulfate optimization and heat of hydration testing. Users can also easily create customized reports and export data into their own analytical software tools.

Example: long-term reactivity testing
(Applicable Instruments: I-Cal Flex)



Supplementary materials such as fly ash typically react slowly with calcium hydroxide generated by the hydration of clinker. One can measure the reactivity of supplements directly by using a simulated Portland Cement environment consisting of a mixture of calcium and alkali hydroxide, as would be found in a Portland Cement after several days of hydration.
The graph on the left shows a comparative reactivity test for a low calcium fly ash sourced form a power plant in India. The results show that for this fly ash, the effect of an increase in sodium hydroxide concentration is quite substantial, which is possibly attributable to a relatively high content of amorphous material.
I-Cal Flex is a powerful tool for long term studies of materials like seen here, that exhibit a low heat of reaction.

Superior performance with true internal mixing.

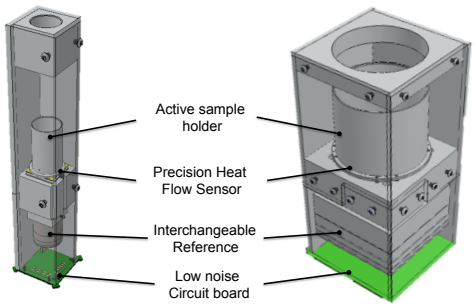
Advanced mixing in I-Cal Ultra

Most internal mixer alternatives in the market frequently fail to mix properly, for example at the 0.4 w/c ratio mandated by EN 196-11. The I-Cal Flex 20 ml admixture testing vial and advanced mixing accessory is the only true mixer in the market. Motor and manually controlled with adjustable speed, it uses a unique and patent pending vibrating mechanism to ensure that sample materials are properly dispersed and mixed completely. In this picture, one can see comparative results of a cement paste mix at 0.4 water/cement ratio. The vial on the left side a conventional mixer, with incomplete dispersion and poor mixing. The vial on the right shows the Calmetrix I-Cal Flex advanced mixer, with high dispersion and superior mixing.

Specifications.

The I-Cal Flex has the highest performance of all microcalorimeters in its class. With individual calorimeter cells that are completely isolated from each other, cross-talk is non-existent. A high precision thermostat, with tightly controlled air flow and optimized design of calorimeters gives the I-Cal Flex a baseline that is ten times more stable than that of its closest competitor, and a precision of +/- 2 µW.

20 ml calorimeter cell **450 ml calorimeter cell**



Specifications	
Operating Voltage	110 - 240 VAC - 50/60Hz
Sample size	'Up to 20 ml / up to 450 ml
Operating Temperature Range	2 °C to 90 °C
Temperature Stability	+/- 0.001 °C
Temperature Accuracy	+/- 0.15 °C
Detection Limit	2 µW
Dynamic range	500 mW (adjustable)
Precision*	+/- 2 µW
Accuracy of Enthalpy measurement*	0.1%
Number of test channels	1- 8 (user defined)
Baseline* (24 hours)	
Drift	< 5 µW
Short-term noise	< +/- 1 µW
Dimensions	L20"xW16"xH44" (50 cm x 40 cm x 108 cm)
Weight	75 lbs (34 kg)

* as measured in 20 ml calorimeter at 23 °C. I-Cal Flex is an instrument suited for high precision testing in an advanced research laboratory setting. Optimal performance and conformance with specifications is achieved when placed in a climate-controlled room according to standard research laboratory conditions.

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I-CAL 8000 HPC

CALMETRIX I-CAL 8000 HPC FOR CEMENT AND CONCRETE SCIENCE

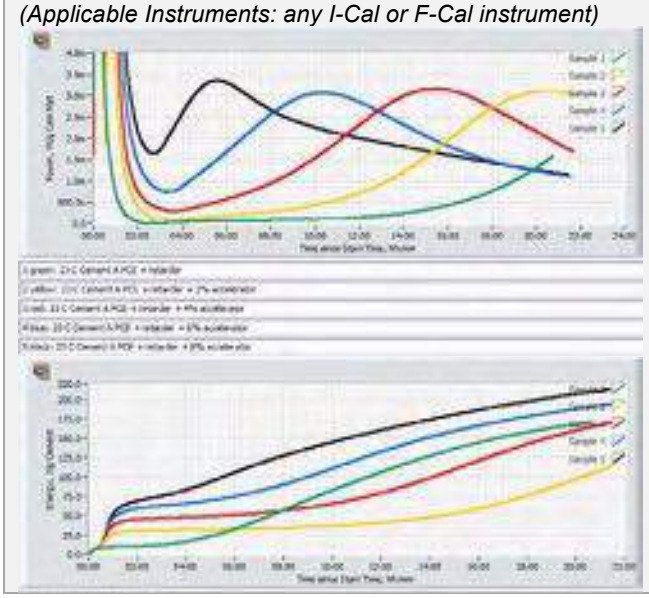
Background: Isothermal Calorimetry in cement and concrete testing.

Isothermal calorimetry measures the heat generated by a cementitious binder as an indicator for the rate of reaction. Since the rate of reaction is very important for engineering properties such as workability, set and early strength development, calorimetry is widely used to develop new binders and mixes, for quality control and to study the effect of different chemical admixtures and binder compositions on performance.

I-Cal 8000 HPC High Precision Calorimeter for Cement / Concrete Professionals.

The I-Cal 8000 HPC is an 8-channel Isothermal Calorimeter that can be used to test cement paste, mortar or **even real concrete**. Testing on real concrete is particularly important to detect unwanted interactions between complex admixture molecules and binders. A thermal hydration curve is plotted as the ambient temperature around the sample is kept constant. The temperature is easily set via software interface with a feedback loop to ensure optimal control, while precision sensors measure the heat flow generated by the cementitious binders reacting in concrete during the first days. I-Cal 8000 HPC complies with ASTM C1679 and ASTM C1702, and is recommended for both short and long term heat of hydration measurements.

Example of use: efficiency of shotcrete accelerator
(Applicable Instruments: any I-Cal or F-Cal instrument)



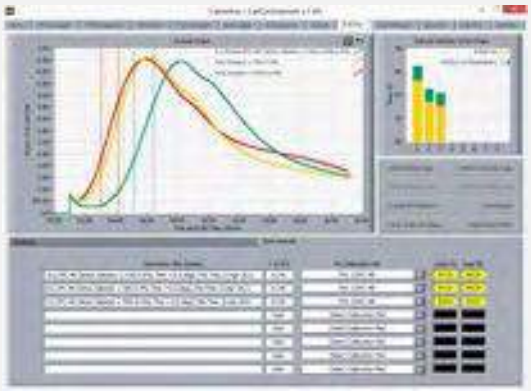
Shotcrete accelerators work through accelerated formation of calcium aluminate sulfate hydrates. The reactivity of the aluminate and sulfate phases in the binder used is of particular importance, both of which are visible in isothermal calorimetry, making it an excellent tool for optimizing admixtures for shotcrete as well as for the selection of binders for shotcrete.

This example shows the hydration performance of a cementitious binder in presence of a dispersant, a retarder (green curve) and four increasing dosages of a shotcrete accelerator (yellow to black). The initial exotherm measured immediately after dosing of the accelerator (first two hours on top graph) correlates primarily to set, while the main cement hydration peak occurring after the accelerator exotherm correlates to strength development.

The relative impact of the accelerator on strength development is most easily visualized by plotting the integrated power – Heat of hydration (bottom graph).

Data generated by I-Cal is retrieved and analyzed with Calmetrix's state-of-the art CalCommander software, which combines ease of use and a suite of analytical tools. CalCommander includes software tools for reporting, the determination of activation energy, set time estimation, compressive strength prediction, heat of hydration testing and sulfate optimization.

Example of use: estimating setting times
(Applicable Instruments: any I-Cal, F-Cal or P-Cal instrument)



Isothermal calorimetry can be used to estimate setting times, as heat rates shown in the Power curve correlate with physical test data obtained applying a standard such as, for example, ASTM C403.
In the example to the left, the green curve is mix of a Portland cement with a high range water reducer, the yellow curve is the same cement with 0.4% TEA and a the red curve is the same cement with 0.4% TIPA.
Calmetrix's proprietary I-Cal Set software models the initial and final set for each mix, clearly showing the effect of each admixture on the cement.
The use of calorimetry can greatly reduce the time, effort and cost required for physical testing of setting times by penetration methods. Furthermore, the tight temperature control in an isothermal calorimeter provides an easy way to guarantee reproducible results.

Applications and uses.

I-Cal 8000 HPC is a high precision calorimeter with a large sample size, which makes it suitable for all applications in cement and concrete applications. Like Calmetrix's other isothermal calorimeters, the I-Cal 8000 HPC's main uses are found in R&D and Investigative work on concrete properties, and daily QC needs in Cement and Concrete production.

I-Cal 8000 HPC is typically used to perform the following tasks:

- prediction and estimation of compressive strength or setting times
- sensitivity tests on temperature variations
- testing and resolution of sulfate imbalance issues
- determination of heat of hydration of cement (e.g. ASTM C1702) or cementitious materials
- mix design optimization, selecting type and dosage of admixture, SCM
- troubleshooting complex mixes, detect potential material – admixture incompatibility
- sensitivity tests on variations in admixture or other material content
- determination of activation energy for maturity, strength and thermal crack prediction

Users of I-Cal 8000 HPC can be found in laboratories of Cement Producers, Universities, Concrete Producers, Fly Ash Distributors, Admixture Producers and Testing Laboratories.

Specifications.

Specifications			
Operating Voltage	110 - 240 VAC - 50/60Hz	Sample size	up to 125ml/~340g mortar (12oz.)
Number of Test Channels	8	Baseline over 72 hours *	
Operating Temperature Range	5 to 70°C (41 to 158°F)	Drift,	< 0.1 µW/g/h
Temperature stability	< +/- 0.02 °C in laboratory conditions	Random noise	< +/-4 µW/g
Software Compatibility	CalCommander on Windows XP or later	Dimensions	L21.5"xW16.5"xH22" (55 cm x 42 cm x 56 cm)
Max.recommended test duration	28 days	Weight	104 lbs (47 kg)

* Baseline is measured at 23 °C for 3 days on a 50 g sample. A straight line is fitted to the power (J/g/s) versus time (h) data using a linear regression procedure. The long term drift is the slope and the baseline noise level is the standard deviation around this regression line.

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Innovation and QC for Cement and Concrete ... Made Easy

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I-CAL 4000 HPC

CALMETRIX I-CAL 4000 HPC FOR CEMENT AND CONCRETE SCIENCE

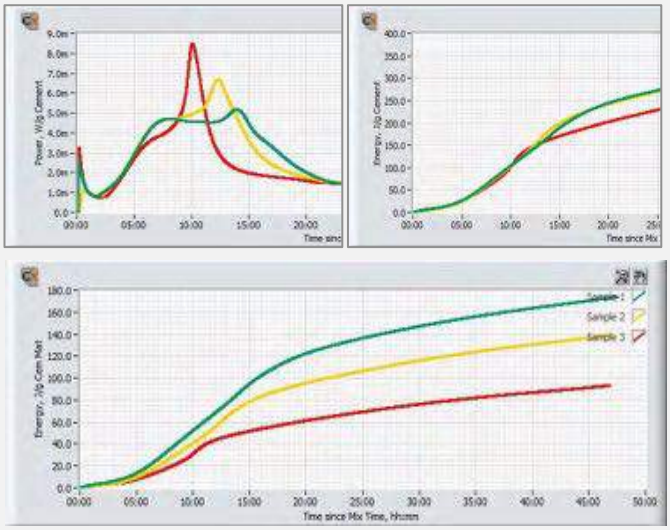
Background: Isothermal Calorimetry in cement and concrete testing.

Isothermal calorimetry measures the heat generated by a cementitious binder as an indicator for the rate of reaction. Since the rate of reaction is very important for engineering properties such as workability, set and early strength development, calorimetry is widely used to develop new binders and mixes, for quality control, and to study the effect of different chemical admixtures and binder compositions on performance.

I-Cal 4000 HPC High Precision Calorimeter for Cement / Concrete Professionals.

The I-Cal 4000 HPC is an 4-channel Isothermal Calorimeter that can be used to test cement paste, mortar or **even real concrete**. Testing on real concrete is particularly important to detect unwanted interactions between complex admixture molecules and binders. A thermal hydration curve is plotted as the ambient temperature around the sample is kept constant. The temperature is easily set via software interface with a feedback loop to ensure optimal control, while precision sensors measure the heat flow generated by the cementitious binders reacting in concrete during the first days. I-Cal 4000 HPC features Calmetrix's proprietary system of variable reference cells to adjust the thermal reference mass for each sample, thereby allowing for increased flexibility and better precision, while its configuration of individual cells reduces cross-talk. I-Cal 4000 HPC complies with ASTM C1679 and ASTM C1702, and is recommended for both short and long term heat of hydration measurements.

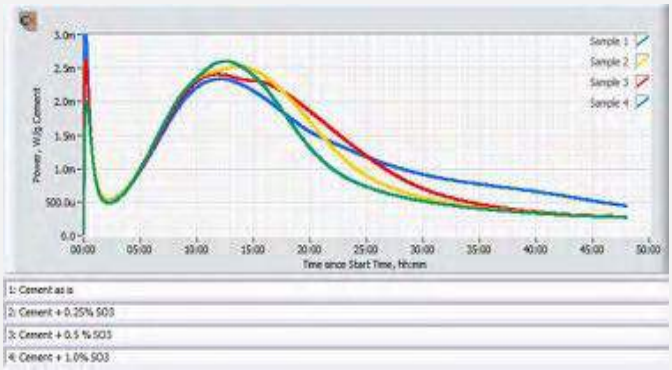
Example: analyze performance of blends with high cement substitution levels
(Applicable Instruments: any I-Cal instrument)



Calorimetry is a convenient tool to assess the performance of blended cements. In this example, we are studying three blends, with 50%, 60% and 70% slag (green, yellow and red, respectively). The top left graph shows power normalized by mass of cement. The narrow and more intense main peak of hydration is indicative of an issue. The upper right graph shows total heat of hydration also normalized by mass of cement. The overlapping green and yellow curves show that increasing slag from 50% to 60% does not disrupt the cement hydration reaction. But the red curve is well below, indicating that the increase from 60% to 70% slag has a negative effect on cement hydration. This is likely attributable to sulfate depletion as aluminate glass present in the slag consumes sulfate in the cement to a point where it can no longer retard the aluminate reaction. The bottom graph shows heat of hydration (energy) by mass of total binder (cement + slag). Heat of hydration is closely correlated to strength gain, especially at early ages. Therefore, the gradually decreasing energy is expected, as higher cement substitution rates are known to have a decreasing effect on early strength gain.

Data generated by I-Cal is retrieved and analyzed with Calmetrix's state-of-the art CalCommander software, which combines ease of use and a suite of analytical tools. CalCommander includes software tools for reporting, the determination of activation energy, set time estimation, compressive strength prediction, heat of hydration testing and sulfate optimization.

Example: sulfate optimization using the depletion peak
(Applicable Instruments: any I-Cal instrument)



Many issues of adverse interaction between admixtures and other materials in concrete are caused by sulfate imbalance. With an isothermal calorimeter, it is easy to optimize sulfate forms and total SO_3 for cements, both with and without admixtures in the mix. This example shows the effect of SO_3 addition to a cement without admixture on the rate of the hydration reaction.

The Cement "as is" (green) has no visible sulfate depletion peak. Addition of sulfate in (0.25%, 0.5% and 1% in the yellow, red and blue curves) moves the sulfate depletion to a later time relative to the main peak. The total energy increases until an optimum is reached, likely in-between the red and blue curves.

Applications and uses.

I-Cal 4000 HPC is a high precision calorimeter with a large sample size, which makes it suitable for all applications in cement and concrete applications. Like Calmetrix's other isothermal calorimeters, the I-Cal 4000 HPC's main uses are found in R&D and Investigative work on concrete properties, and daily QC needs in Cement and Concrete production.

I-Cal 4000 HPC is typically used to perform the following tasks:

- prediction and estimation of compressive strength or setting times
- sensitivity tests on temperature variations
- testing and resolution of sulfate imbalance issues
- determination of heat of hydration of cement (e.g. ASTM C1702) or cementitious materials
- mix design optimization, selecting type and dosage of admixture, SCM
- troubleshooting complex mixes, detect potential material – admixture incompatibility
- sensitivity tests on variations in admixture or other material content
- determination of activation energy for maturity, strength and thermal crack prediction

Users of I-Cal 4000 HPC can be found in laboratories of Cement Producers, Universities, Concrete Producers, Fly Ash Distributors, Admixture Producers and Testing Laboratories.

Specifications.

Specifications			
Power requirements	110 - 240 VAC - 50/60 Hz - 50 W	Sample size	up to 125ml/~340g mortar (12oz.)
Number of Test Channels	4	Baseline over 72 hours *	
Operating Temperature Range	5 to 70°C (41 to 158°F)	Drift,	< 0.05 µW/g/h
Temperature stability	< +/- 0.02 °C in laboratory conditions	Random noise	< +/-2 µW/g
Software Compatibility	CalCommander on Windows XP or later	Dimensions	L21.5"xW16.5"xH22" (55 cm x 42 cm x 56 cm)
Max.recommended test duration	28 days	Weight	104 lbs (47 kg)

* Baseline is measured at 23 °C for 3 days on a 50 g sample. A straight line is fitted to the power (J/g/s) versus time (h) data using a linear regression procedure. The long term drift is the slope and the baseline noise level is the standard deviation around this regression line.

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I-CAL 2000 HPC

CALMETRIX I-CAL 2000 HPC FOR CEMENT AND CONCRETE SCIENCE

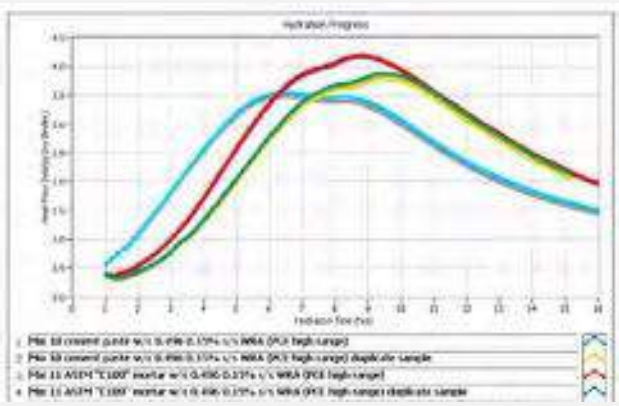
Background: Isothermal Calorimetry in cement and concrete testing.

Isothermal calorimetry measures the heat generated by a cementitious binder as an indicator for the rate of reaction. Since the rate of reaction is very important for engineering properties such as workability, set and early strength development, calorimetry is widely used to develop new binders and mixes, for quality control and to study the effect of different chemical admixtures and binder compositions on the rate of reaction.

I-Cal 2000 HPC High Precision Calorimeter for Cement / Concrete Professionals.

The I-Cal 2000 HPC is a 2-channel Isothermal Calorimeter that can be used to test cement paste, mortar or **even real concrete**. Testing on real concrete is particularly important to detect unwanted interactions between complex admixture molecules and binders. A thermal hydration curve is plotted as the ambient temperature around the sample is kept constant. The temperature is easily set via software interface with a feedback loop to ensure optimal control, while precision sensors measure the heat flow generated by the cementitious binders reacting in concrete during the first days. I-Cal 2000 HPC also features Calmetrix's system of variable reference cells to adjust the thermal reference mass for each sample, thereby allowing for increased flexibility and better precision.

Example of use: effect of mixing energy
(Applicable Instruments: any I-Cal instrument)



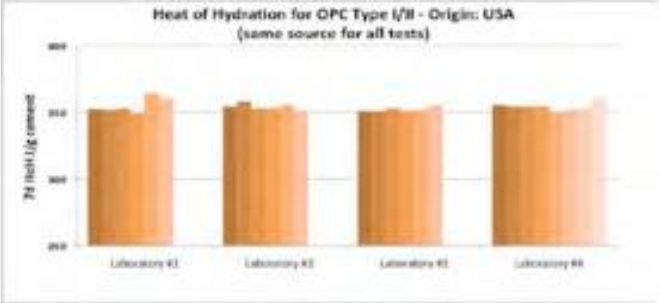
The mixing action in concrete is very different from cement paste, and can lead to very different behaviors in the presence of certain chemical admixtures, such as polycarboxylate based additives. This example shows the differences in the rate of hydration in paste (green & yellow curves) mortar (red curve) and concrete (blue curve) in the presence of a single dose of a high range water reducer. As seen here, paste based samples are usually more retarded than concrete or mortar samples. See "Evaluating the Effect of Mixing Method on Cement Hydration in the Presence of a Polycarboxylate High-Range Water Reducing Admixture by Isothermal Conduction Calorimetry" by S.A. Farrington, ICCC Montreal 2007 for more on this important issue. The implications for researchers are important, as the effect of mixing energy will significantly alter the formulation, dosage and compatibility studies of chemical admixtures in concrete or mortar mixes.

Data generated by I-Cal is retrieved and analyzed with Calmetrix's state-of-the art CalCommander software, which combines ease of use and a suite of analytical tools. CalCommander makes heat of hydration studies easy as a "one-click" experience. Total energy by unit of mass is automatically calculated and a report is generated in the standard required format.

I-Cal 2000 HPC is also fully compliant with both ASTM C1679 and ASTM C1702 "Standard Test Method for Measurement of Heat of Hydration of Hydraulic Cementitious Materials Using Isothermal Conduction Calorimetry". Heat of hydration tests can be conducted on standard cement for short term studies or up to 28 days of continuous measurement.

I-Cal 2000 HPC's two active cells are completely separated, thereby reducing cross talk to less than 0.1%. This makes I-Cal 2000 HPC the best performing isothermal calorimeter in its class.

Example of use: Heat of Hydration testing
(Applicable Instruments: I-Cal 2000 / 4000 / 8000 HPC)



I-Cal 2000 HPC is designed to yield robust results, both in terms of repeatability and in the response to varying outside conditions. The graph on the left shows results of heat of hydration tests performed multiple times in different laboratories (non air-conditioned rooms), using the same cement. The graphical representation shows the consistency of the results obtained with I-Cal 2000 HPC, despite the absence of a controlled room temperature. The Standard deviation was 3.37 J/g (< 1%) for an average heat of hydration value of 353.9 J/g.

Applications and uses.

I-Cal 2000 HPC is a high precision calorimeter with a large sample size, which makes suitable for all applications in cement and concrete applications. Like Calmetrix's other isothermal calorimeters, the I-Cal 2000's main uses are found in R&D and Investigative work on concrete properties, and daily QC needs in Cement and Concrete production.

I-Cal 2000 HPC is typically used to perform the following tasks:

- determination of heat of hydration of cement (e.g. ASTM C1702) or cementitious materials
- prediction and estimation of compressive strength or setting times
- sensitivity tests on temperature variations
- testing and resolution of sulfate imbalance issues
- mix design optimization, selecting type and dosage of admixture, SCM
- troubleshooting complex mixes, detect potential material – admixture incompatibility
- sensitivity tests on variations in admixture or other material content
- determination of activation energy for maturity, strength and thermal crack prediction

Users of I-Cal 2000 HPC can be found among Cement Producers, Universities, Concrete Producers, Fly Ash Distributors, Admixture Producers and Testing Laboratories.

Specifications.

Specifications			
Operating Voltage	110 - 240 VAC - 50/60Hz	Sample size	up to 125ml/~340g mortar (12oz.)
Number of Test Channels	2	Baseline over 72 hours *	
Operating Temperature Range	5 to 70°C (41 to 158°F)	Drift,	< 0.01 µW/g/h
Temperature stability	< +/- 0.02 °C in laboratory conditions	Random noise	< +/-0.5 µW/g
Software Compatibility	CalCommander on Windows XP or later	Dimensions	L17"xW13"xH19" (43 cm x 33 cm x 48 cm)
Max.recommended test duration	28 days	Weight	58 lbs (26 kg)

* Baseline is measured at 23 °C for 3 days on a 50 g sample. A straight line is fitted to the power (J/g/s) versus time (h) data using a linear regression procedure. The long term drift is the slope and the baseline noise level is the standard deviation around this regression line.

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F-CAL

CALMETRIX F-CAL SEMI-ADIABATIC CALORIMETER & SOFTWARE

ASTM C1753 compliant Calorimeter for Cement / Concrete Professionals.

The F-Cal is a Field Calorimeter that can be used to test real concrete, mortar of cement paste both in the confines of a laboratory environment and in the field. F-Cal measures changes in temperature, as a proxy for heat, while the hydration reaction is taking place. As such, it fully conforms to ASTM C1753 (Evaluating Early Hydration of Hydraulic Cementitious Mixtures Using Thermal Measurements). As per their design, F-Cal calorimeters replicate real conditions in a flatwork job, such as, for example, a concrete slab.
The F-Cal calorimeter can accommodate up to eight standard 3"x6" (75mm x 150mm) cylinders. Cylinders can be used to test paste, mortar and real concrete and can be capped to be later used for compressive strength testing.

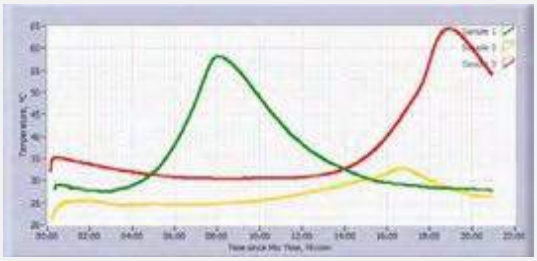
F-Cal is ideal for field applications: it does not require a dedicated computer or a power source. Data is stored in an internal memory with up to 7 days capacity, and can be analyzed with Calmetrix's CalCommander software, which combines ease of use and a suite of analytical tools.

Applications and uses.

The F-Cal is typically used in the following QA/QC applications:

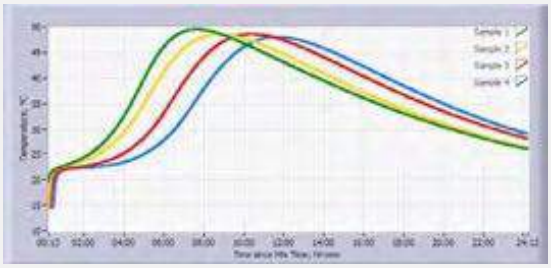
- testing as outlined in ASTM C1753
- on-site troubleshooting for material incompatibility (e.g. admixtures that do not work well for certain cement sources)
- quick estimation of setting times
- screening of materials, e.g. different sources of cement, different admixtures
- robustness test (how performance holds up to variations in material dosages)

Example of use: adverse material interaction
(Applicable Instruments: any F-Cal or I-Cal instrument)



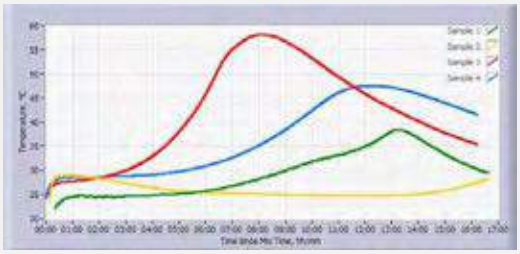
This example shows a potential adverse interaction. The green curve shows a normal Portland cement mix with 25% of a low calcium fly ash. The red curve is the same mix, with a retarder and a mid-range water reducer (brand A) at normal doses. The setting time is severely retarded, but the curve does not show any other adverse interaction. The yellow curve has the same retarder as in the red curve, but a water reducer of a different brand ("brand B"). The curve shows severe interaction, with no strength gain.
The combination of fly ash, and retarder is not compatible with the "brand B" water reducer.

Example of use: optimum admixture dosage
(Applicable Instruments: any F-Cal or I-Cal instrument)



This example shows the effect in a given mix of gradually increasing dosage of a retarder. The progression shown in this example is a close-to-linear response to dosage, Differences in setting times can easily be inferred in the F-Cal calorimeter, with the blue curve setting 3 hours and 30 minutes after the green curve.
The same test could be conducted with different cements to select the one that provides the most robust and predictable response to dosage increases. A common test is also to look at the effect of different admixture addition (upfront, with water or delayed).

Example of use: maximize cement substitution
(Applicable Instruments: any F-Cal or I-Cal instrument)



This example shows the effect of a cement substitution by a high-calcium fly ash,. The red curve is a 100% Portland cement mix. The blue curve is the same mix with 12% substitution by fly ash, the green curve has 17% substitution and the yellow curve 22%. The calorimetry curves reflect the increase in setting time (curves shift to the right) and lower reactivity (lower peaks) leading to a decrease in early strength. In this test, the green curve shows that 17% is very close to a “danger zone”. 22% substitution will severely retard the mix, with no strength gain after one day.

F-Cal is predominantly used by field personnel of Concrete Manufacturers and Suppliers of cement, supplementary cementitious materials or chemical admixtures.

Specifications.

Specifications			
Power Supply	3.6-Volt built-in Lithium Battery	Accuracy	+/- 0.2% at 25°C
Number of Test Channels	8	Response Time	< 2 min. to 90%
Sample Size	Up to 1.9 kg (4.2 lbs)	Resolution	0.0018%
Battery Life	8 years (in continuous use)	Sampling Rate	1 min.
Operating Temperature Range	-40 to 70°C (-40° to 158°F)	Weight	28 lbs (12.7 kg)
Temperature Mesurement Range	-40 to 100°C (-40° to 212°F)	Dimensions	25"x25"x14" (62.5 cmx 62.5 cm x35 cm)

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