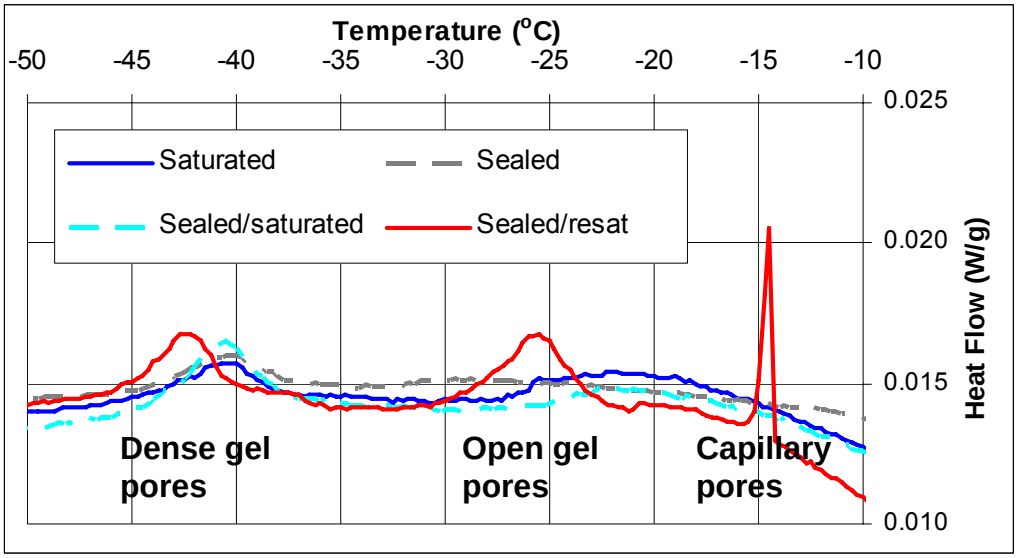
NISTIR 7267

Low Temperature Calorimetry Studies of Hydrating Portland Cement Pastes



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NISTIR 7267

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October 2005

U.S. DEPARTMENT OF COMMERCE
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Abstract

This report presents nearly 200 low temperature calorimetry (LTC) scans performed on hydrating portland cement pastes between 2002 and 2005. Because the LTC scans provide valuable information on the percolation of various size pore networks within the hydrating cement pastes as well as the quantity of freezable water as a function of temperature, it was decided to present a compilation of the plots of all of the LTC results obtained over the course of several research projects. Variables include water-cement mass ratio (*w/c*), curing time, curing temperature, saturation, and limestone and alkali additions. Each plot is characterized by the portland cement used, the mixing solution used, the *w/c*, the curing temperature, the measured degree of hydration (when available), the curing conditions with respect to saturation, the specimen age when tested, the specimen mass, the filename of the raw LTC data, and the testing date of the LTC run. The experimental procedures used to prepare and evaluate the samples are briefly presented, along with a set of observations obtained from interpretation of the numerous individual data sets.

Keywords: Building technology; curing; freezing; hydration; low temperature calorimetry; percolation.

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Introduction

Low temperature calorimetry (LTC) can be conveniently used to examine the percolation of various size pore networks in hydrating cement pastes [1]. During a freezing scan, as the temperature is lowered, water will freeze in progressively smaller pores. For hydrating cement pastes, as shown on the cover of this report and duplicated in Figure 1 below, up to three peaks may be observed in a typical freezing scan, corresponding to percolated networks of capillary pores, open gel pores, and dense gel pores, respectively, adopting the naming convention introduced in [1]. This experimental technique has been utilized extensively in several recent studies to provide valuable information on the influence of curing conditions and alkali additions on the depercolation (and sometimes the repercolation) of the capillary porosity in hydrating portland cement pastes [2-5]. During the course of these studies, nearly 200 individual LTC scans were conducted on a wide variety of hydrated cement paste specimens. Because most of these data could not be included in references [2-5], in this report, all of the plots generated for these scans are presented individually. It is envisioned that this graphical database will be of use for comparison purposes to other researchers utilizing this technique on cement-based materials and may suggest further avenues of research employing LTC.

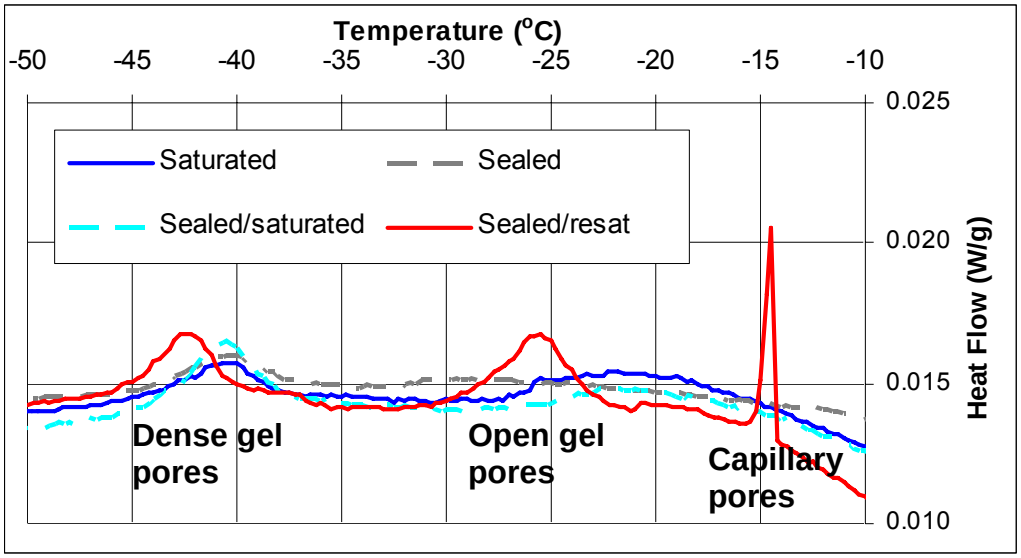

Figure 1 Typical LTC scans for a hydrating portland cement paste.

Experimental Procedure

Cement pastes were prepared by mixing Cement and Concrete Reference Laboratory (CCRL) proficiency cement samples (either CCRL cement 140 or CCRL cement 152) with either distilled water or a solution of alkali compounds dissolved in distilled water, using a temperature-controlled high speed blender at either 20 °C or 40 °C. Details on the particle size distributions and phase compositions of the two cements can be found in an online database available at http://ciks.cbt.nist.gov/bentz/phpct/database/images. CCRL cement 152 was used for the studies where curing conditions (temperature and saturation) and water-cement mass ratio (*w/c*=0.35 or *w/c*=0.45) were the major variables [2,5], while CCRL cement 140 was used in a study (*w/c*=0.40) where the alkali type and content of the cement paste were varied [3, 4]. The alkali solutions were prepared by adding the appropriate compounds (see Table 1) to distilled water and stirring with a glass rod until complete dissolution. Cement 140 is a low-alkali cement, containing only 0.093 % Na_2O and 0.186 % K_2O per unit mass of cement. The additional alkalis prepared for each mixture are listed in Table 1; their masses were selected to provide the same number of moles of additional cations (K^+, Na^+, and Li^+) in each mixture. After mixing, cast cylindrical wafers (≈5 g) of the pastes were placed in sealed plastic vials. A small quantity of water was added to the tops of some of the wafers to maintain saturated curing conditions. The capped vials were placed either in a walk-in environmental chamber maintained at 20 °C or in a water bath maintained at 40 °C.

Table 1: Mixture proportions of the CCRL proficiency cement sample 140 paste mixtures prepared with various alkali additions.

Material	Mixture 1	Mixture 2	Mixture 3	Mixture 4	Mixture 5
Cement	300 g	300 g	300 g	300 g	300 g
Water	120 g	120 g	120 g	120 g	120 g
K_2SO_4		2.79 g			
Na_2SO_4		2.28 g			
KOH*			2.02 g		
NaOH			1.30 g		
LiOH				2.7 g	
$LiNO_3$					4.42 g

*89 % purity as supplied by chemical company.

For the CCRL cement 152 specimens with *w/c*=0.45 cured at 20 °C, the vials were opened after 4 h of curing and any accumulated bleed water was removed using a small pipette. This resulted in a nominal achieved *w/c*=0.435 for these pastes. Three curing conditions were employed for the CCRL cement 152 studies. In saturated curing, a small amount of distilled water was placed on top of the paste wafers (after removing the bleed water). (All of the CCRL cement 140 paste specimens were also cured under saturated conditions). In sealed curing, the wafers were simply sealed in their plastic vials after removal of the bleed water. In sealed/saturated curing, the wafers were cured under sealed conditions for 7 d, then the plastic vials were opened and a small amount of distilled water was added on top of the wafers. At various ages, specimens of the pastes were removed from the vials for further analysis. For some of the LTC studies to be detailed below, many of the specimens cured under sealed conditions

were crushed to smaller pieces and resaturated for a few days in an attempt to refill any pores that had been emptied during self-desiccation.

For many of the specimens, degree of hydration was estimated based on measurement of their non-evaporable water content. The non-evaporable water content w_n of a sample was determined as the mass loss between 105 ^oC and 1000 ^oC divided by the mass of the ignited sample, corrected for the loss-on-ignition (LOI) of the unhydrated cement powder, determined in a separate LOI measurement. Previously, the expanded uncertainty in the calculated w_n has been estimated to be 0.001 g/g cement, assuming a coverage factor of 2 [6]. The values of w_n were converted to estimated degrees of hydration based on the phase compositions of the cements and published coefficients for the non-evaporable water contents of the various cement clinker phases [7]. Based on a propagation of error analysis, the estimated uncertainty in the calculated degree of hydration is 0.004.

Small pieces of the hydrated cement pastes were used in the LTC experiments. Sample mass was typically between 30 mg and 90 mg. For each LTC experiment, one small piece of the relevant cement paste was surface dried and placed in a small open stainless steel pan. The pan with the sample, along with an empty reference pan of similar mass to the empty sample pan, was placed in the calorimeter cell. Using a protocol developed previously [1], a freezing scan was conducted between 5 ^oC and -55 ^oC at a scan rate of -0.5 ^oC/min. For temperatures between -100 ^oC and 500 ^oC, the equipment manufacturer has specified a constant calorimetric sensitivity of ± 2.5 % and a root-mean-square baseline noise of 1.5 μW. The peaks observed in a plot of heat flow (normalized to the mass of the sample) versus temperature correspond to water freezing in pores with various size entryways (pore necks). The smaller the pore entryway, the more the freezing peak is depressed. Thus, the presence of, absence of, or change in peaks can be used to infer information concerning the characteristic sizes of the "percolated" (connected) water-filled pores in the microstructure of the hydrating cement pastes.

One advantage of LTC over mercury intrusion porosimetry, and other techniques for assessing pore size and connectivity, is that specimens are evaluated without any external drying that might damage their pore structure. Of course, the LTC technique can only assess the size and connectivity of **water-filled** pores. For non-saturated curing conditions, it is assumed that the "empty" pores formed due to self-desiccation will not contain any freezable water and thus will not show up on the LTC scans. A further complication for LTC studies with variable alkali contents is the change in freezing point depression due to the variable ionic concentration of the (freezing) pore solution. For the experiments presented here, the initial dosages of added alkalis in the cement paste mixtures would be expected to depress the freezing point of bulk water between about 1 ^oC and 2 ^oC [8].

Table 2 on the following page is provided to give some guidance as to the mixtures and curing conditions corresponding to the various sets of graphs.

Table 2: Plots corresponding to different sets of cement paste mixtures.

Cement	w/c or w/s	Curing Temperature (^{o}C)	Starting Figure	Ending Figure
152	0.25	20	4	30
152	0.35	20	31	86
152	0.435	20	87	94
152 + 20 % limestone	0.35	20	95	104
152	0.25	40	105	120
152	0.35	40	121	140
152	0.45	40	141	152
140	0.40	20	153	192

Processed Data (Graphs)

Control Materials

Cement: CCRL Cement 140
Solution: None
w/c: N/A
Temperature: N/A
Degree of hydration: N/A

Curing: N/A
Age when tested: N/A
Sample mass: 45.1 mg
Filename: c140powder
Date tested: April 18, 2005

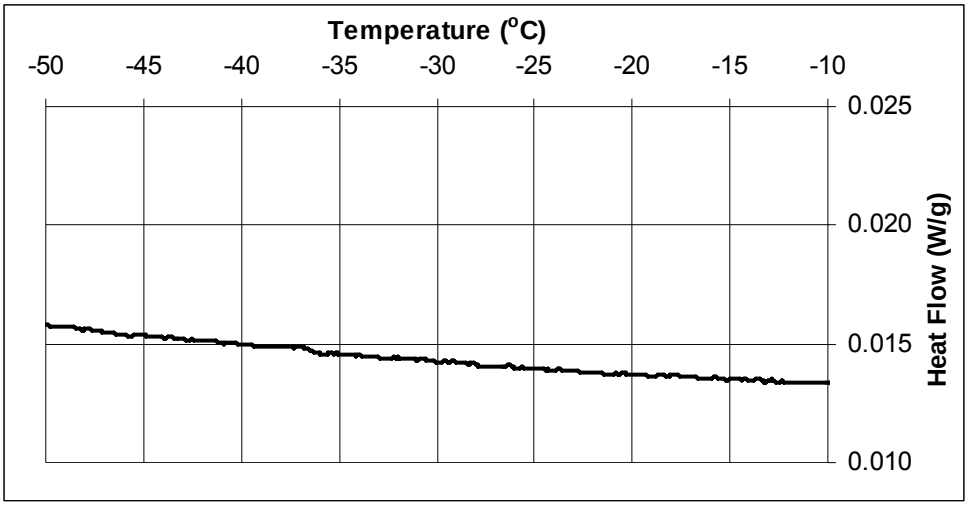

Figure 2 LTC scan for CCRL Cement 140 (dry) powder.

Cement: N/A
Solution: Tap water
w/c: N/A
Temperature: N/A
Degree of hydration: N/A

Curing: N/A
Age when tested: N/A
Sample mass: 25.2 mg
Filename: tapwatersmall
Date tested: April 28, 2005

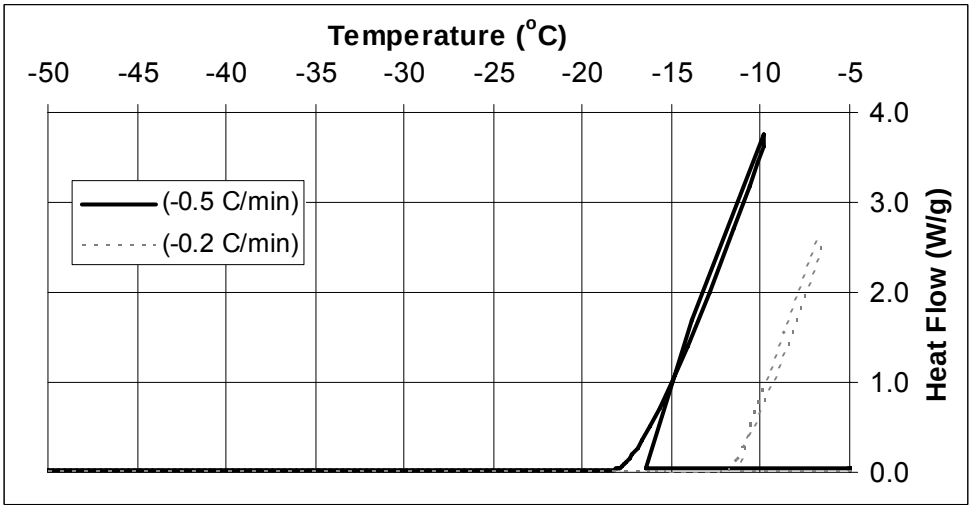

Figure 3 LTC scan for Gaithersburg tap water at two different scan rates.

CCRL Cement 152

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: 0.284

Curing: Saturated
Age when tested: 1 d
Sample mass: 75.0 mg
Filename: c152w025T20Csat1d
Date tested: May 17, 2005

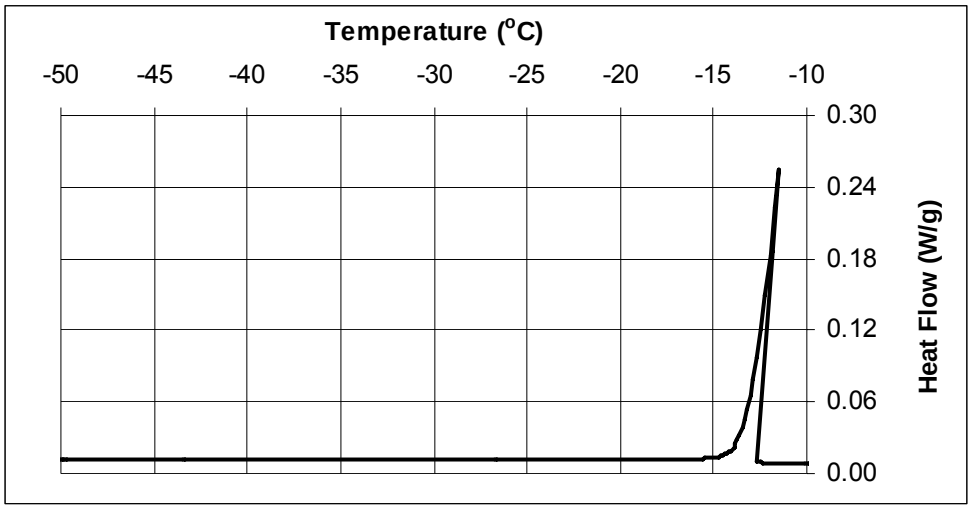

Figure 4 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 1 d under saturated conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: 0.285

Curing: Sealed
Age when tested: 1 d
Sample mass: 57.3 mg
Filename: c152w025T20Cseal1d
Date tested: May 17, 2005

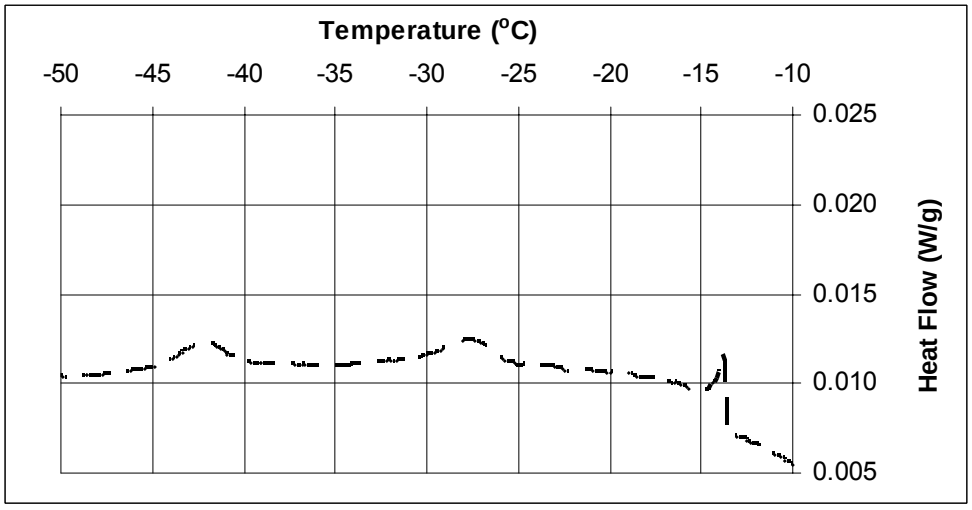

Figure 5 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 1 d under sealed conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: 0.403

Curing: Saturated
Age when tested: 2 d
Sample mass: 65.4 mg
Filename: c152w025T20Csat2d
Date tested: May 18, 2005

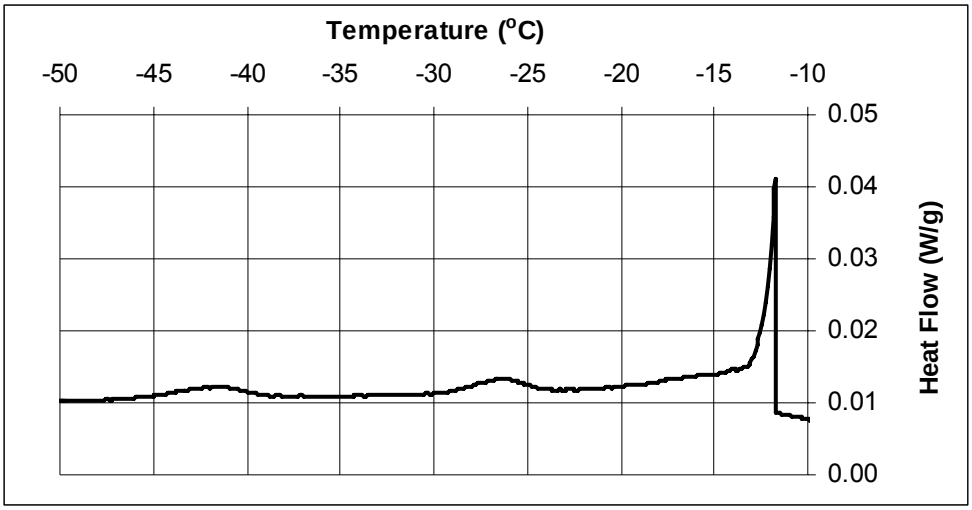

Figure 6 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 2 d under saturated conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: 0.381

Curing: Saturated
Age when tested: 2 d
Sample mass: 43.7 mg
Filename: c152w025T20Cseal2d
Date tested: May 18, 2005

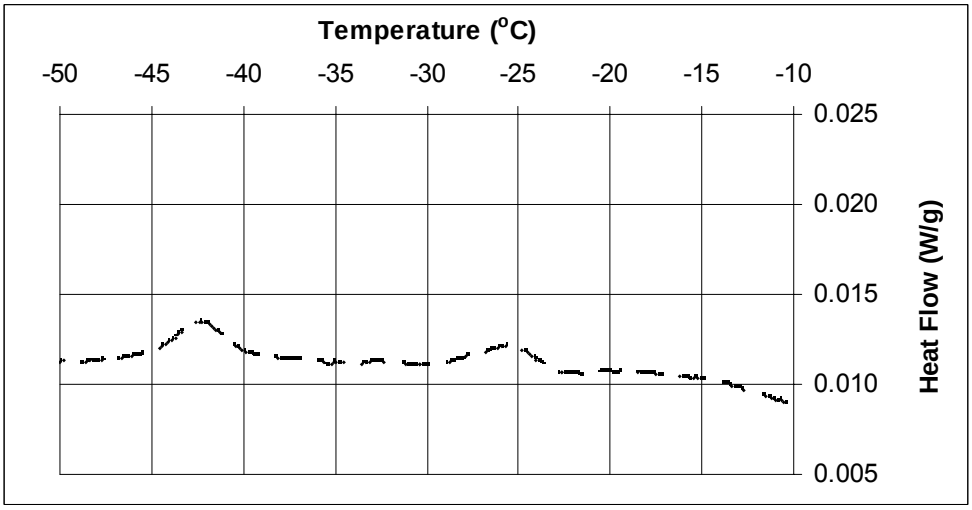

Figure 7 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 2 d under sealed conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 1 d/resaturated
Age when tested: 2 d
Sample mass: 78.4 mg
Filename: c152w025T20Csealresat1t2d
Date tested: May 18, 2005

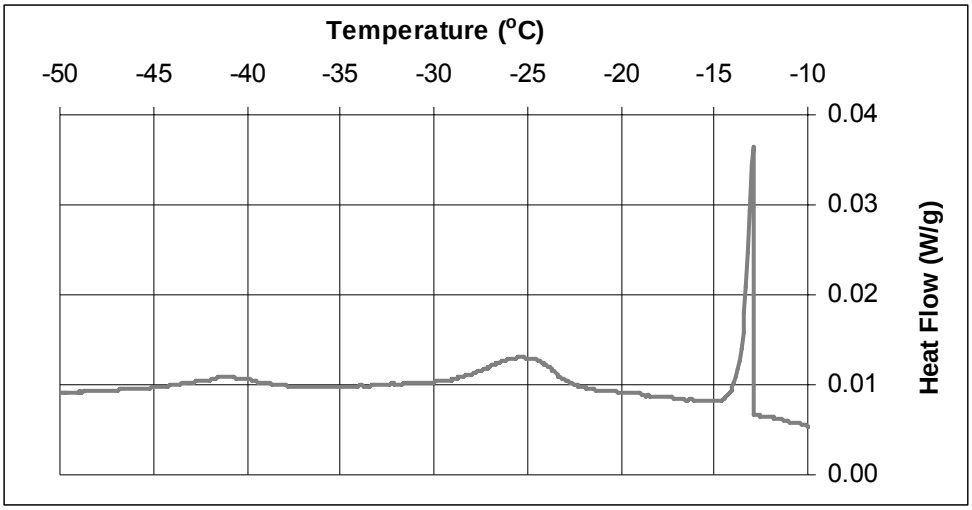

Figure 8 LTC scan for CCRL Cement 152, *w/c*=0.25, cured at 20 °C for 1 d under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: 0.456

Curing: Saturated
Age when tested: 3 d
Sample mass: 58.6 mg
Filename: c152w025T20Csat3d
Date tested: May 19, 2005

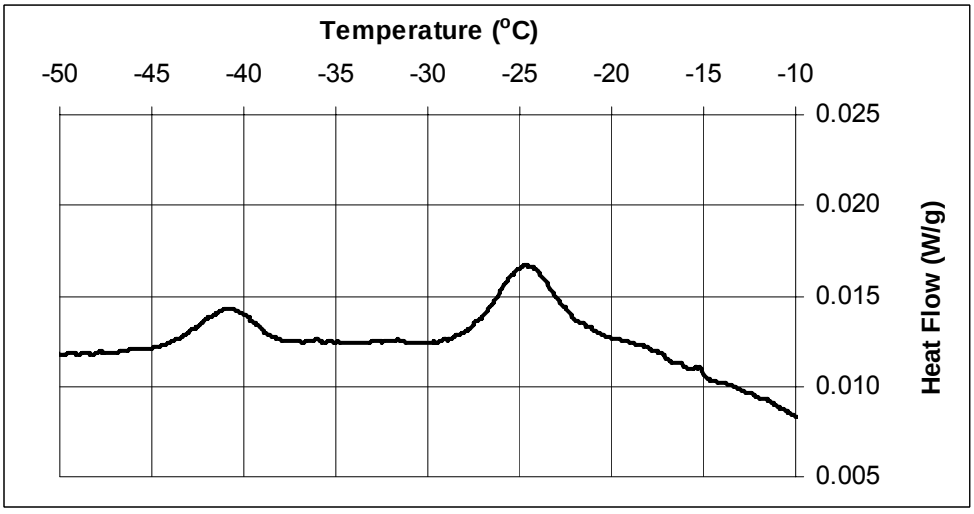

Figure 9 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 3 d under saturated conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: 0.412

Curing: Sealed
Age when tested: 3 d
Sample mass: 40.1 mg
Filename: c152w025T20Cseal3d
Date tested: May 19, 2005

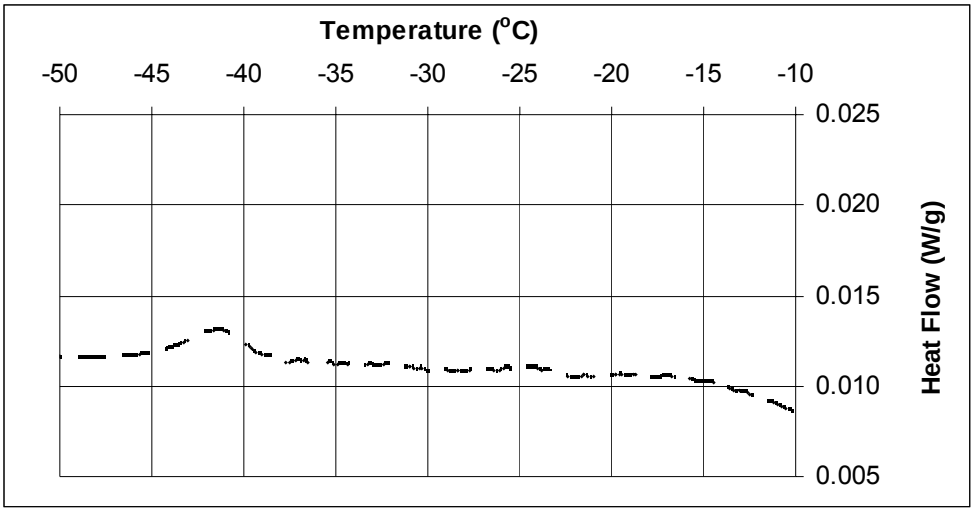

Figure 10 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 3 d under sealed conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 2 d/resaturated
Age when tested: 3 d
Sample mass: 68.1 mg
Filename: c152w025T20Csealresat2t3d
Date tested: May 19, 2005

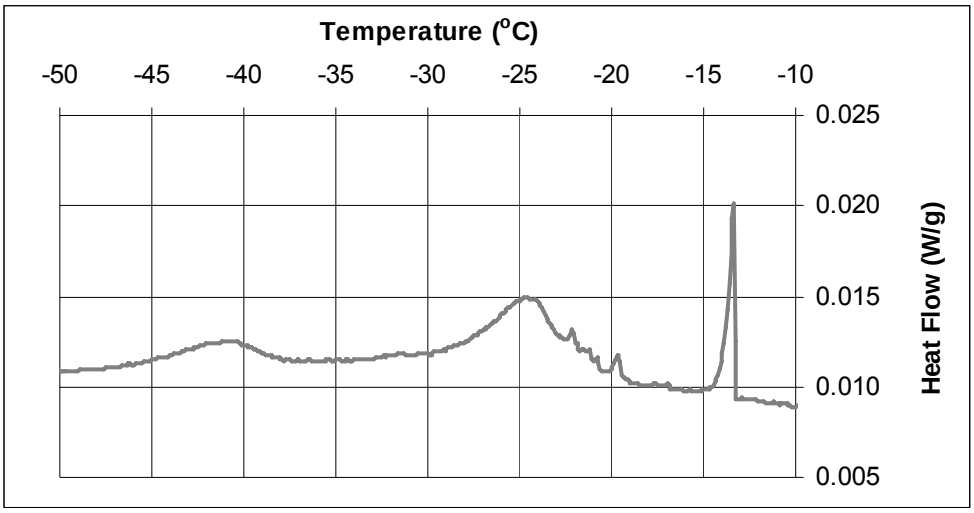

Figure 11 LTC scan for CCRL Cement 152, *w/c*=0.25, cured at 20 °C for 2 d under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 3 d/resaturated
Age when tested: 4 d
Sample mass: 59.1 mg
Filename: c152w025T20Csealresat3t4d
Date tested: May 20, 2005

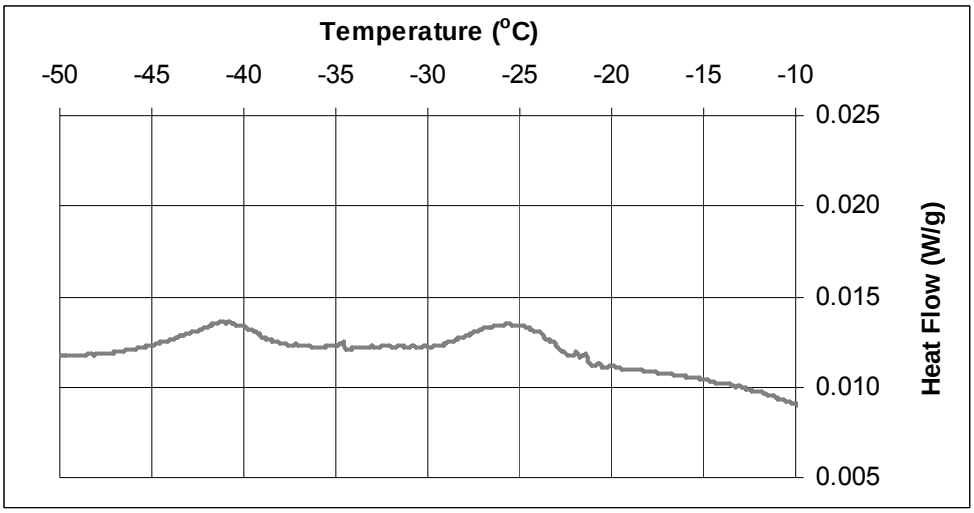

Figure 12 LTC scan for CCRL Cement 152, *w/c*=0.25, cured at 20 °C for 3 d under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: 0.615

Curing: Saturated
Age when tested: 7 d
Sample mass: 25.7 mg
Filename: c152w025T20Csat7d
Date tested: May 23, 2005

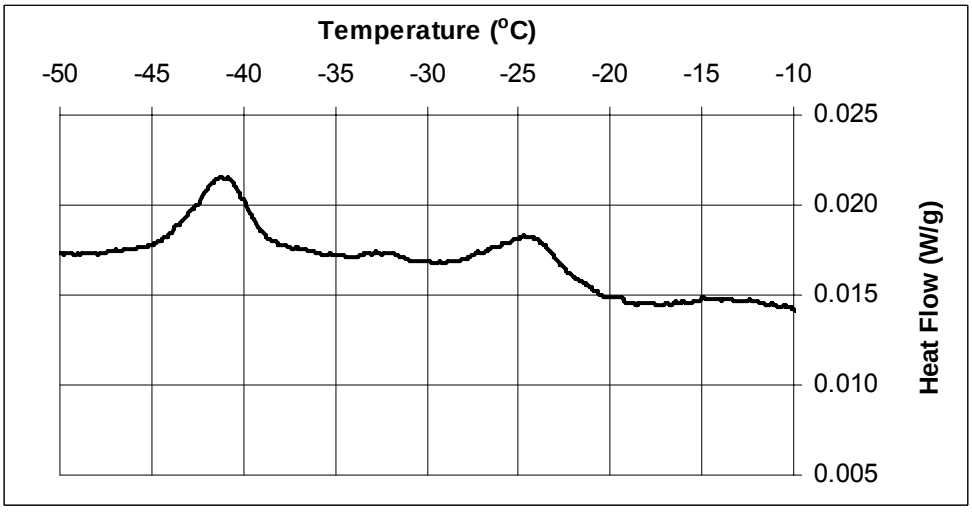

Figure 13 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 7 d under saturated conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: 0.458

Curing: Sealed
Age when tested: 7 d
Sample mass: 45.3 mg
Filename: c152w025T20Cseal7d
Date tested: May 23, 2005

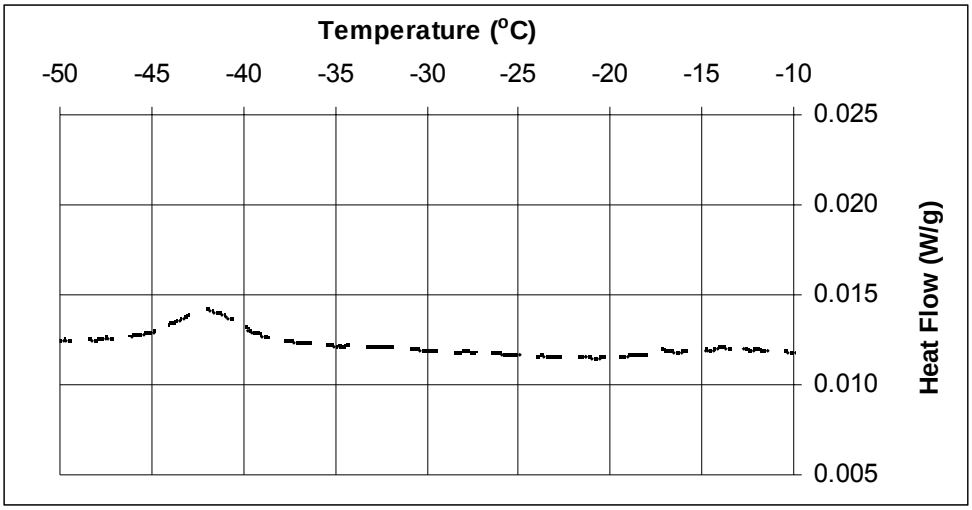

Figure 14 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 7 d under sealed conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 7 d/resaturated
Age when tested: 8 d
Sample mass: 59.2 mg
Filename: c152w025T20Csealresat7t8d
Date tested: May 24, 2005

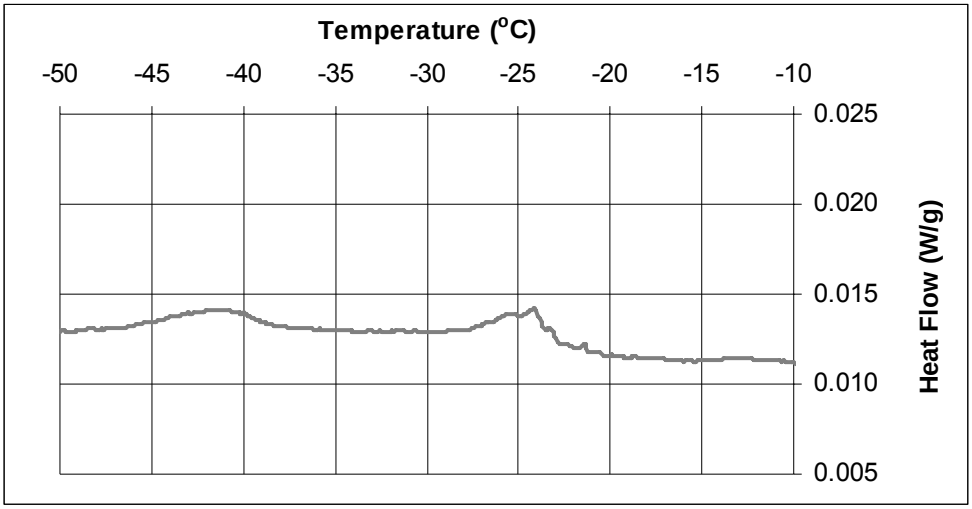

Figure 15 LTC scan for CCRL Cement 152, *w/c*=0.25, cured at 20 °C for 7 d under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: 0.669

Curing: Saturated
Age when tested: 15 d
Sample mass: 59.1 mg
Filename: c152w025T20Csat15d2
Date tested: May 31, 2005

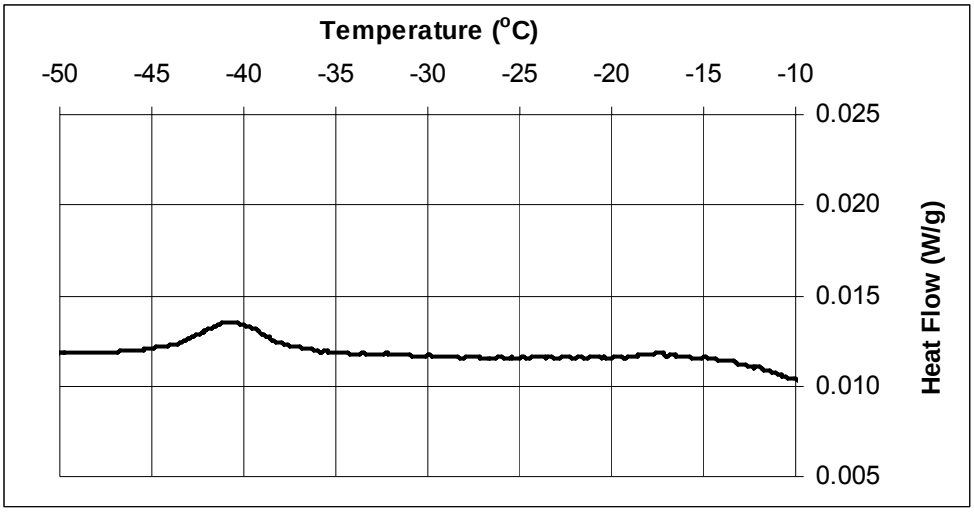

Figure 16 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 15 d under saturated conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: 0.488

Curing: Sealed
Age when tested: 15 d
Sample mass: 45.2 mg
Filename: c152w025T20Cseal15d
Date tested: May 31, 2005

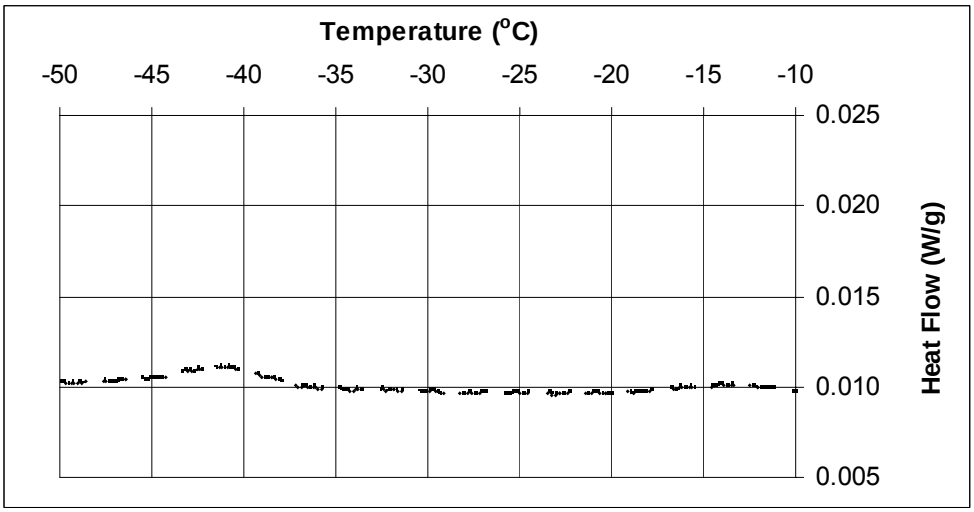

Figure 17 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 15 d under sealed conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 15 d/resaturated
Age when tested: 16 d
Sample mass: 59.2 mg
Filename: c152w025T20Csealresat15t16d
Date tested: June 1, 2005

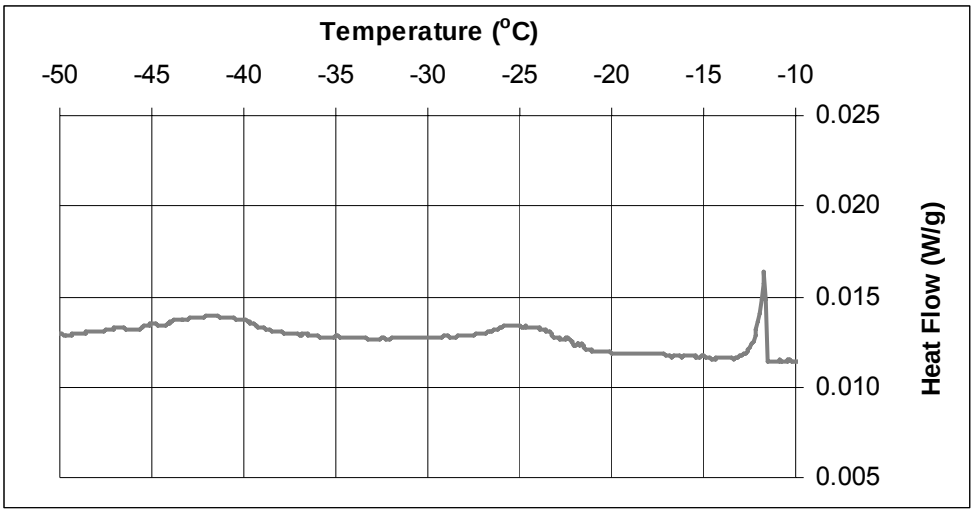

Figure 18 LTC scan for CCRL Cement 152, *w/c*=0.25, cured at 20 °C for 15 d under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: 0.679

Curing: Saturated
Age when tested: 21 d
Sample mass: 63.3 mg
Filename: c152w025T20Csat21d
Date tested: June 6, 2005

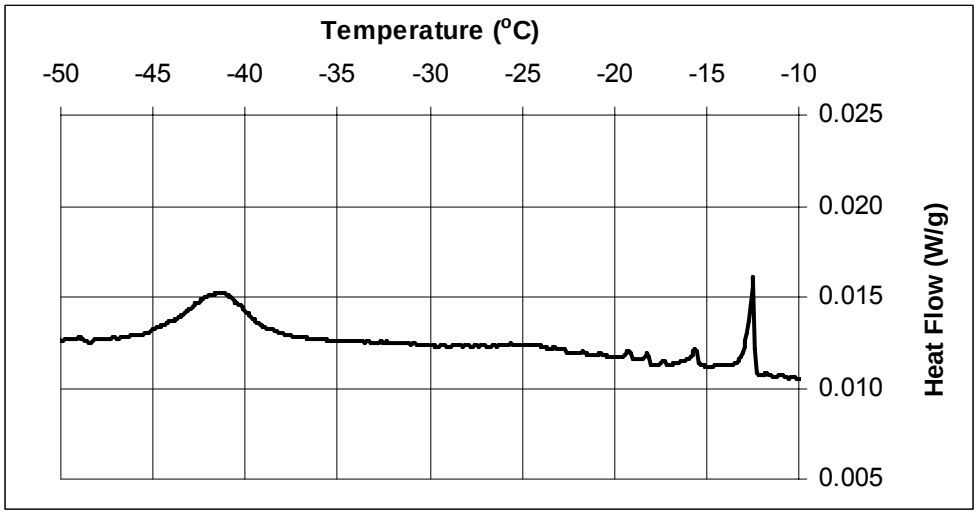

Figure 19 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 21 d under saturated conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: 0.474

Curing: Sealed
Age when tested: 21 d
Sample mass: 65.8 mg
Filename: c152w025T20Cseal21d
Date tested: June 6, 2005

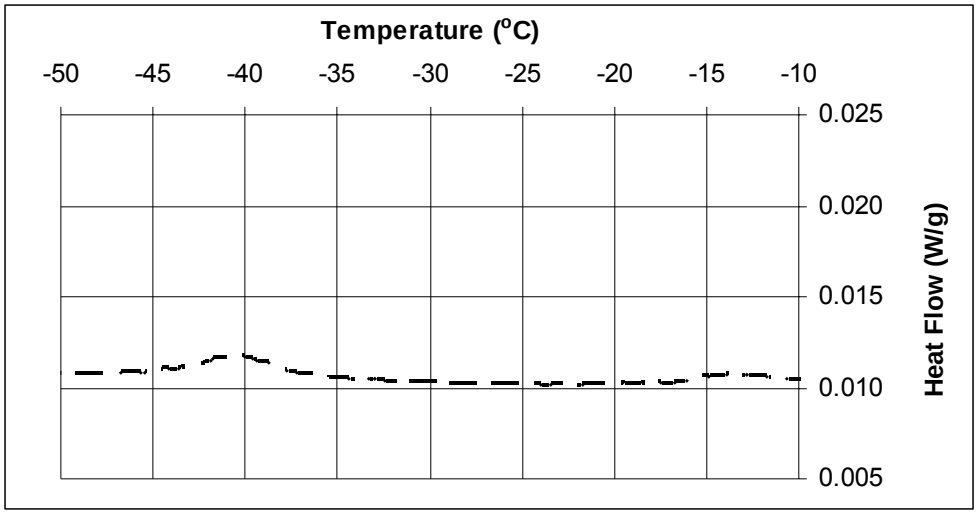

Figure 20 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 21 d under sealed conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 21 d/resaturated
Age when tested: 22 d
Sample mass: 71.6 mg
Filename: c152w025T20Csealresat21t22d
Date tested: June 7, 2005

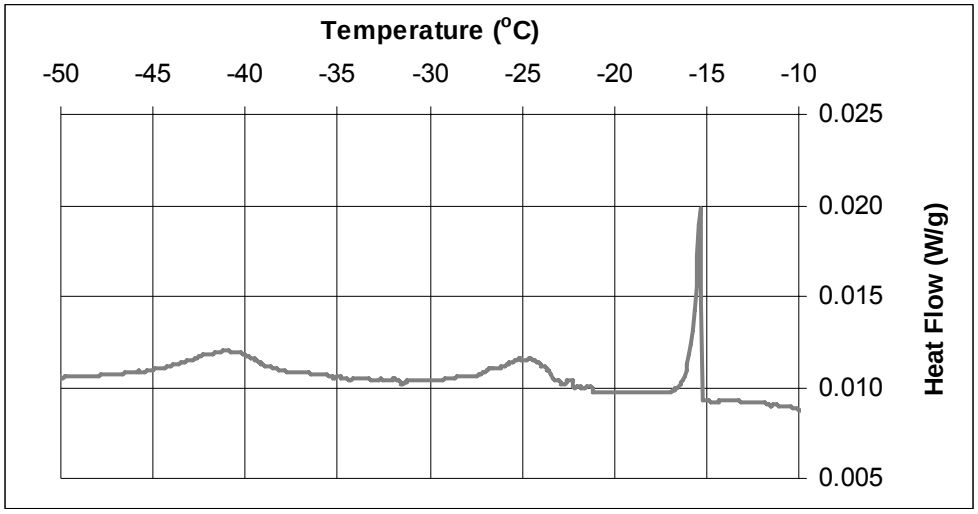

Figure 21 LTC scan for CCRL Cement 152, *w/c*=0.25, cured at 20 °C for 21 d under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: 0.702

Curing: Saturated
Age when tested: 36 d
Sample mass: 72.0 mg
Filename: c152w025T20Csat36d
Date tested: June 21, 2005

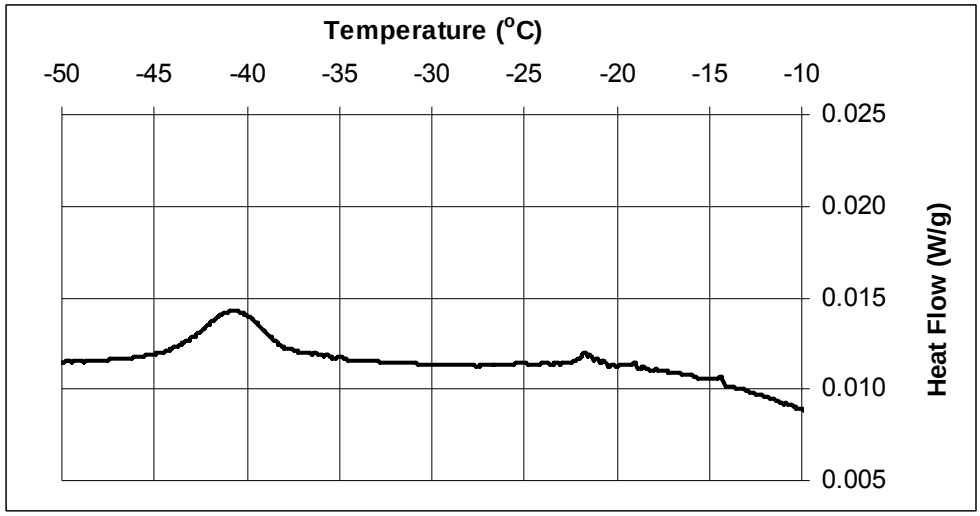

Figure 22 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 36 d under saturated conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: 0.500

Curing: Sealed
Age when tested: 37 d
Sample mass: 59.3 mg
Filename: c152w025T20Cseal37d
Date tested: June 22, 2005

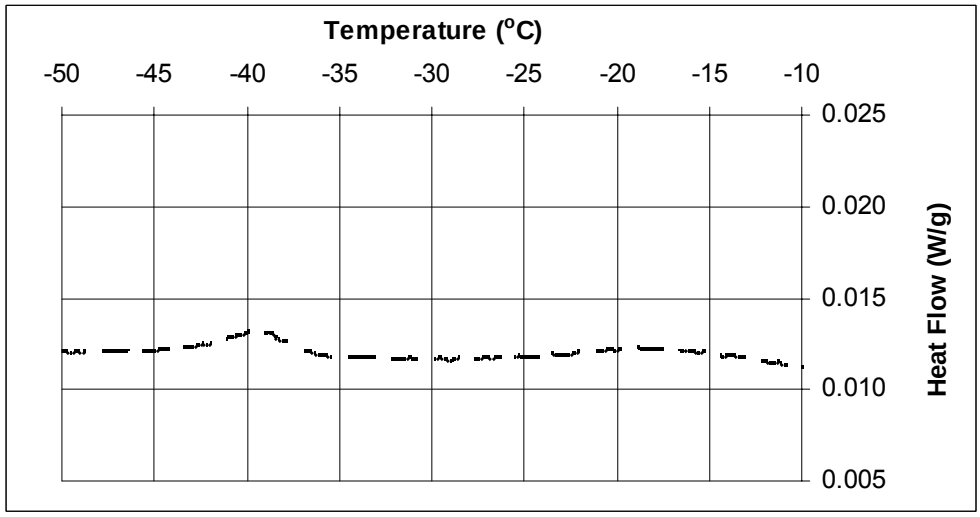

Figure 23 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 37 d under sealed conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 37 d/resaturated
Age when tested: 38 d
Sample mass: 92.1 mg
Filename: c152w025T20Csealresat37t38d
Date tested: June 23, 2005

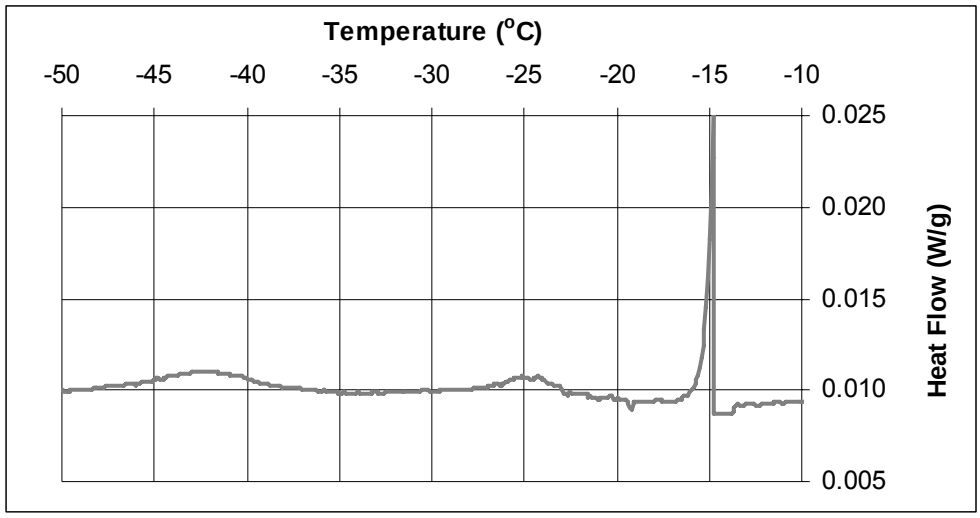

Figure 24 LTC scan for CCRL Cement 152, *w/c*=0.25, cured at 20 °C for 37 d under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: 0.708

Curing: Saturated
Age when tested: 56 d
Sample mass: 84.3 mg
Filename: c152w025T20Csat56d
Date tested: July 11, 2005

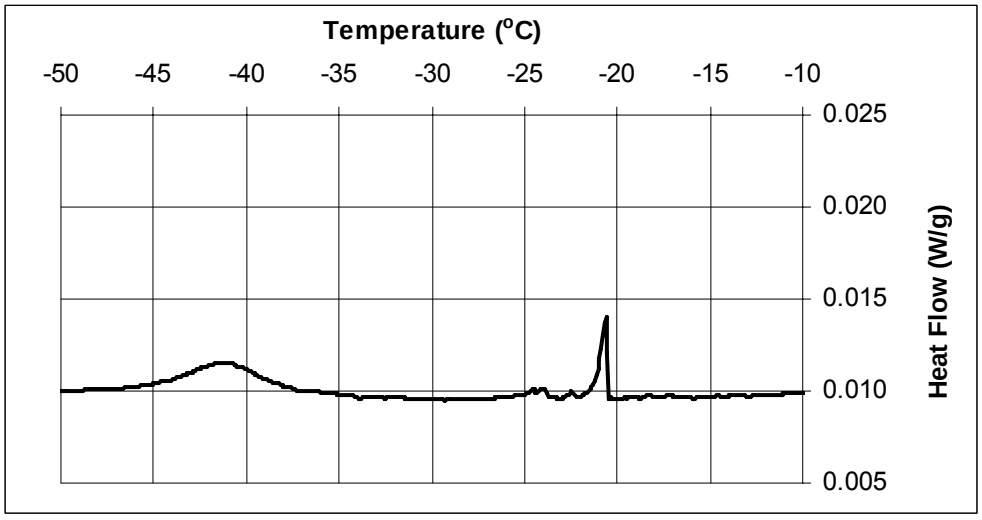

Figure 25 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 56 d under saturated conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: 0.500

Curing: Sealed
Age when tested: 56 d
Sample mass: 79.8 mg
Filename: c152w025T20Cseal56d
Date tested: July 11, 2005

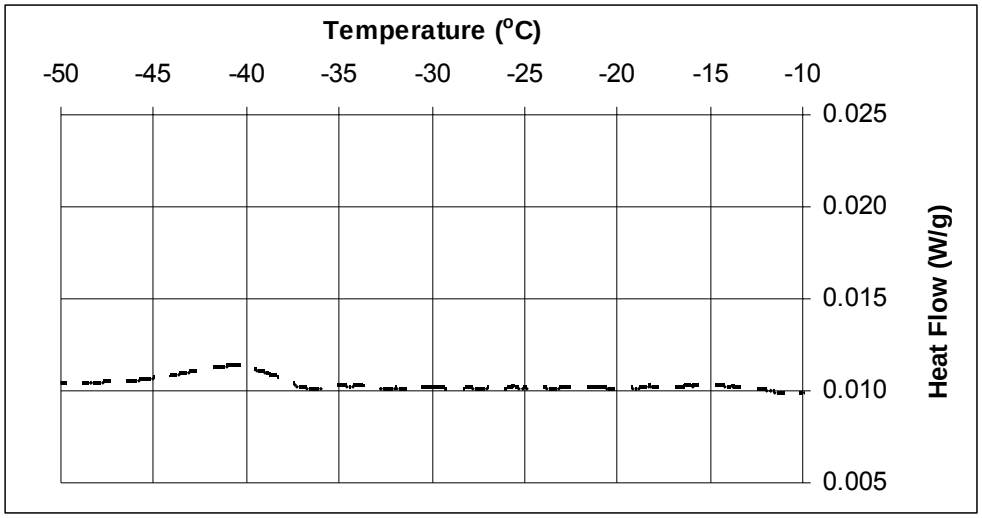

Figure 26 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 56 d under sealed conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 56 d/resaturated
Age when tested: 57 d
Sample mass: 69.3 mg
Filename: c152w025T20Csealresat56t57d
Date tested: July 12, 2005

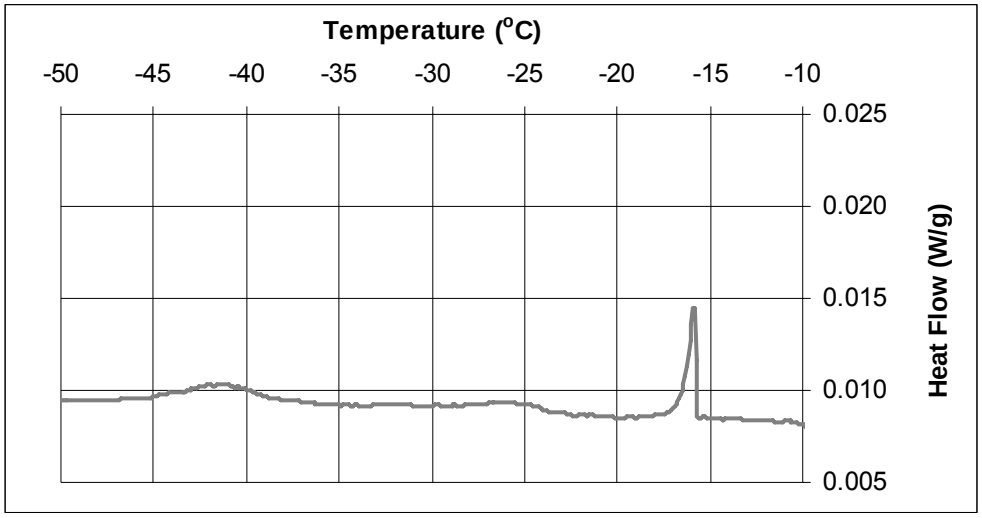

Figure 27 LTC scan for CCRL Cement 152, *w/c*=0.25, cured at 20 °C for 56 d under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: 0.703

Curing: Saturated
Age when tested: 91 d
Sample mass: 64.5 mg
Filename: c152w025T20Csat91d
Date tested: August 15, 2005

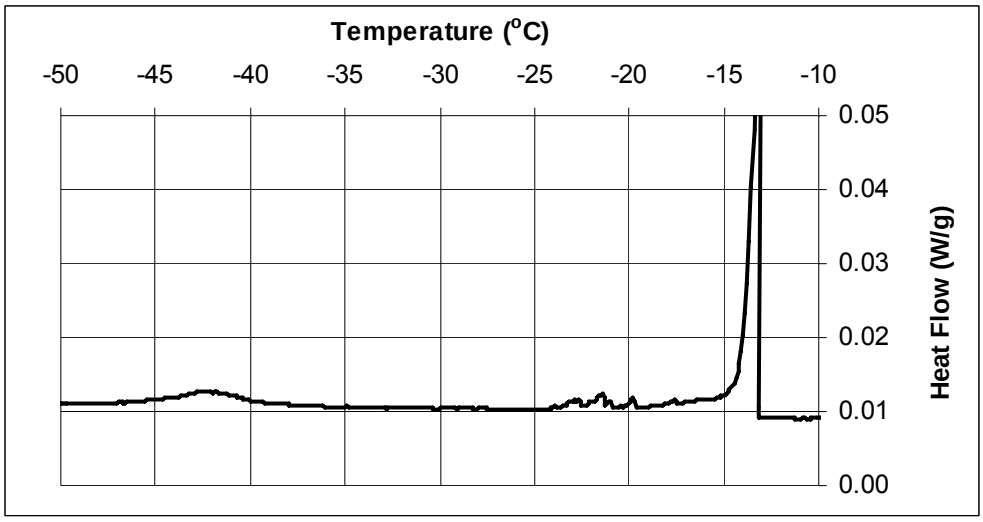

Figure 28 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 91 d under saturated conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: 0.500

Curing: Sealed
Age when tested: 91 d
Sample mass: 60.9 mg
Filename: c152w025T20Cseal91d
Date tested: August 15, 2005

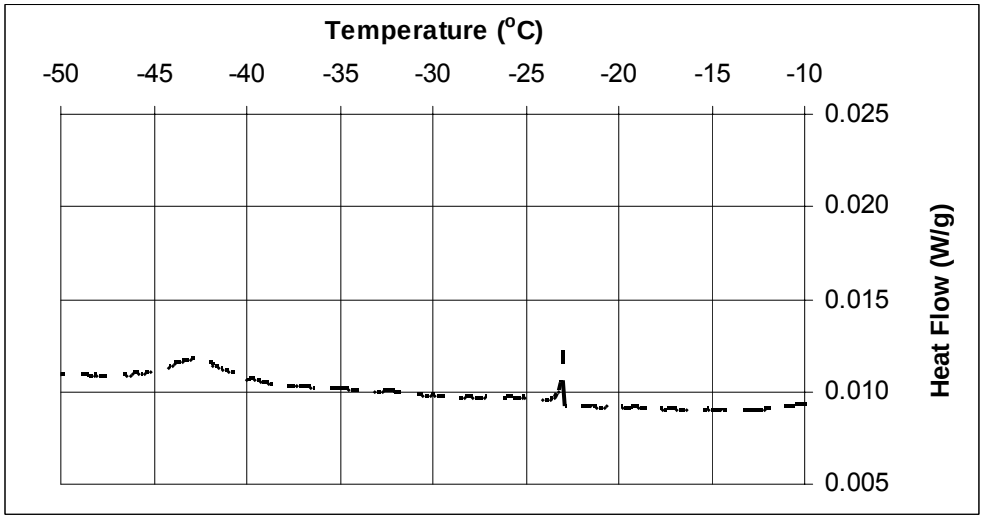

Figure 29 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 91 d under sealed conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 91 d/resaturated
Age when tested: 92 d
Sample mass: 84.6 mg
Filename: c152w025T20Csealresat91t92d
Date tested: August 16, 2005

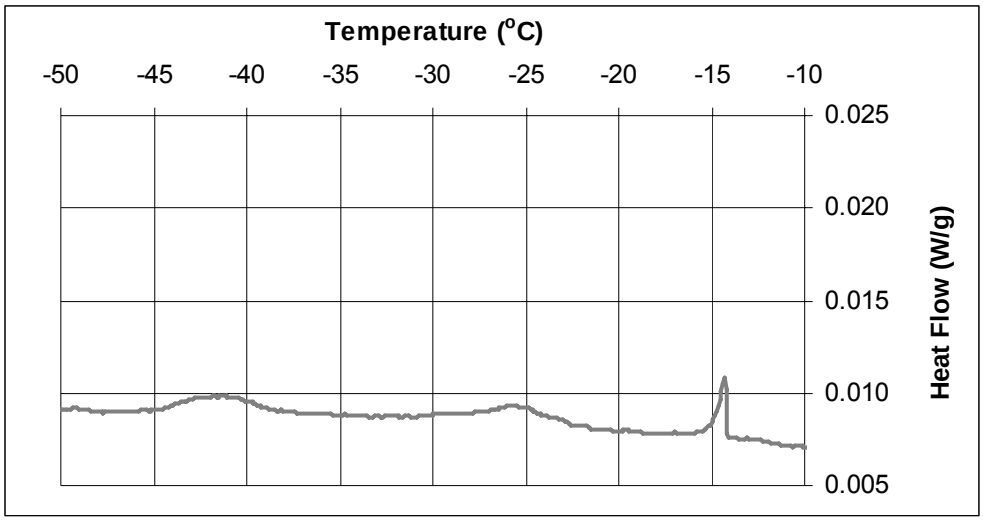

Figure 30 LTC scan for CCRL Cement 152, *w/c*=0.25, cured at 20 °C for 91 d under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: 0.316

Curing: Saturated
Age when tested: 1 d
Sample mass: 52.2 mg
Filename: cem152w35sat1d
Date tested: Nov. 2, 2004

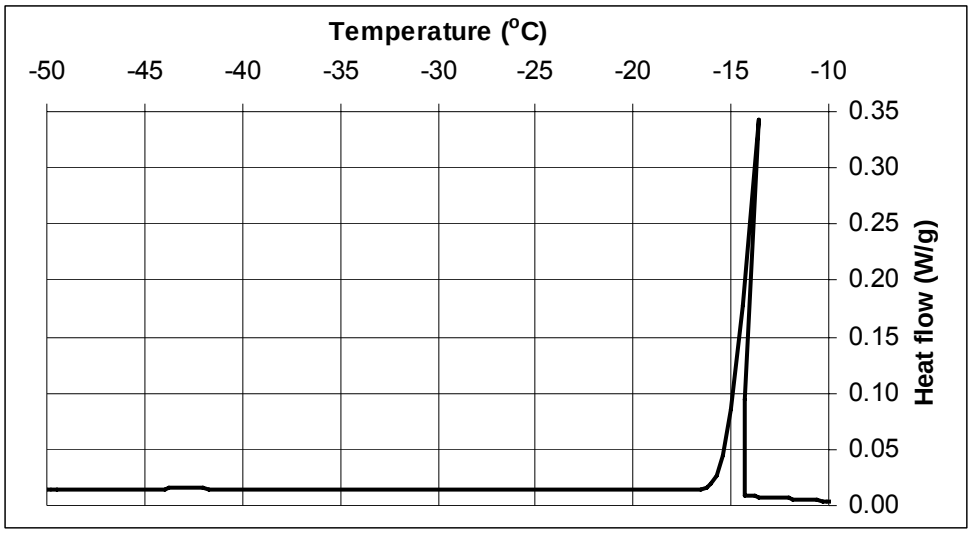

Figure 31 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 1 d under saturated conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: 0.328

Curing: Sealed
Age when tested: 1 d
Sample mass: 38.5 mg
Filename: cem152w35seal1d
Date tested: Nov. 2, 2004

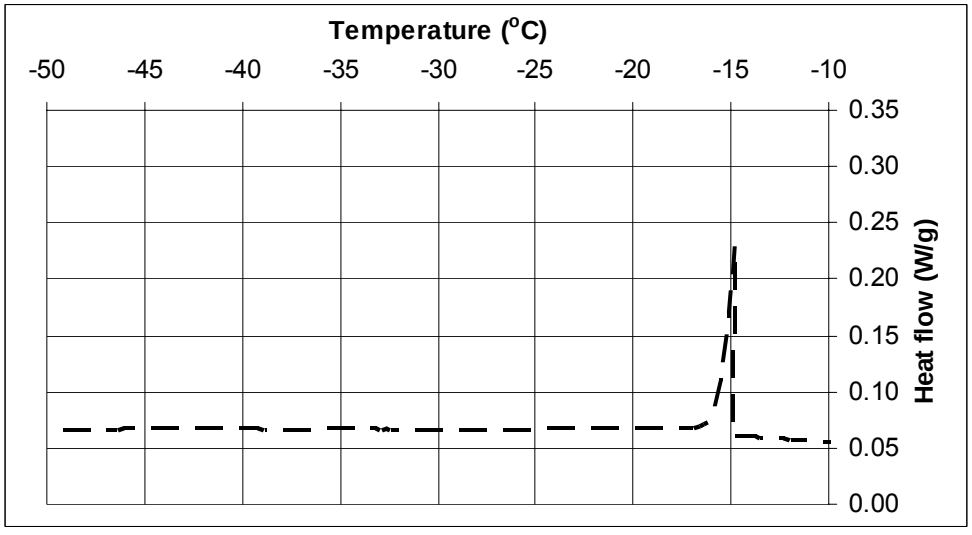

Figure 32 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 1 d under sealed conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: 0.430

Curing: Saturated
Age when tested: 2 d
Sample mass: 53.0 mg
Filename: cem152w35sat2d
Date tested: Nov. 3, 2004

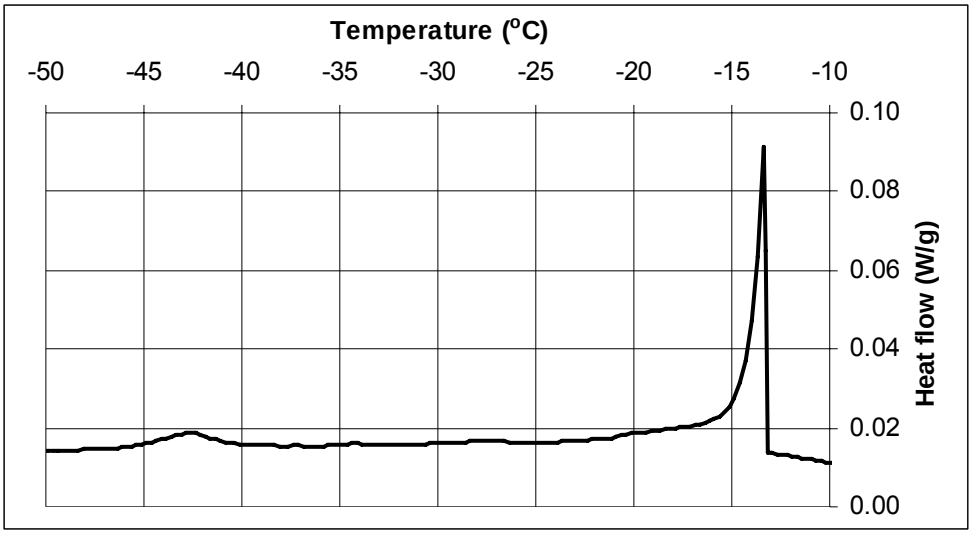

Figure 33 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 2 d under saturated conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: 0.439

Curing: Sealed
Age when tested: 2 d
Sample mass: 61.2 mg
Filename: cem152w35seal2d
Date tested: Nov. 3, 2004

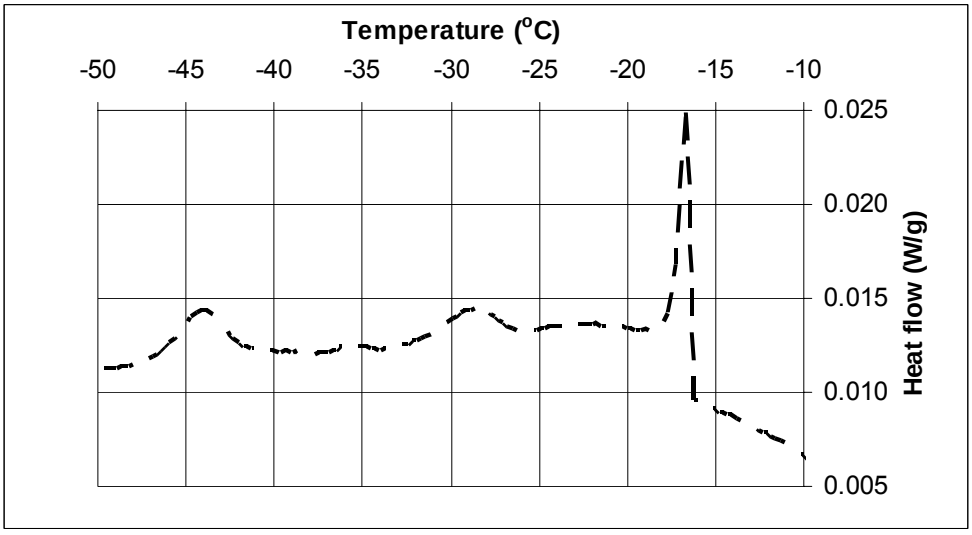

Figure 34 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 2 d under sealed conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 2 d
Sample mass: 53.7 mg
Filename: cem152w35sat2d1221
Date tested: Dec. 22, 2004

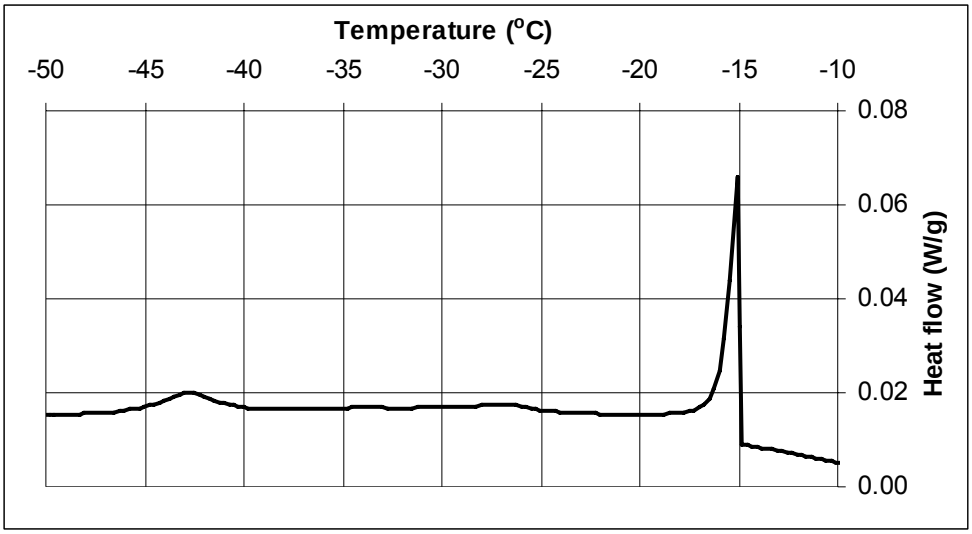

Figure 35 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 2 d under saturated conditions at 20 °C (replicate mixture).

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed
Age when tested: 2 d
Sample mass: 64.2 mg
Filename: cem152w35seal2d1221
Date tested: Dec. 22, 2004

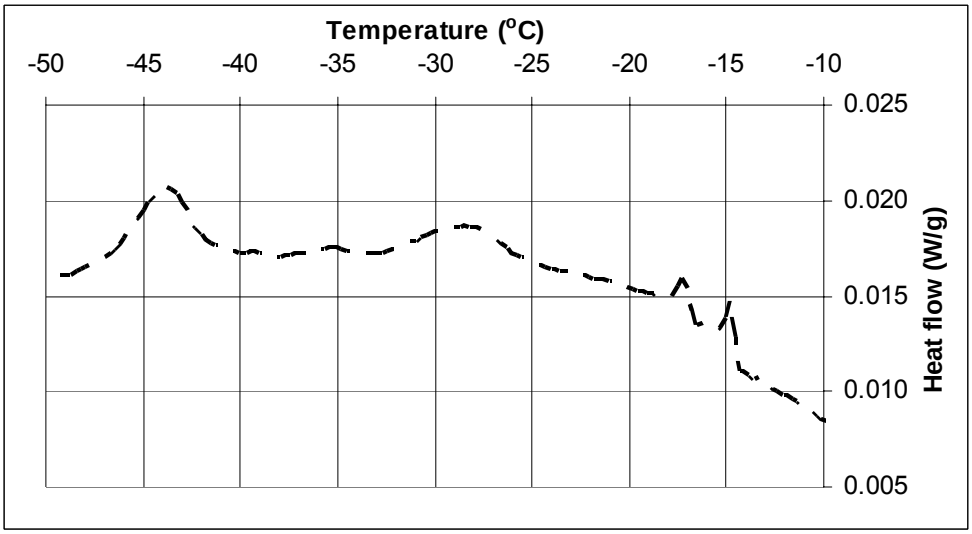

Figure 36 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 2 d under sealed conditions at 20 °C (replicate mixture).

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: 0.502

Curing: Saturated
Age when tested: 3 d
Sample mass: 51.1 mg
Filename: cem152w35sat3d
Date tested: Nov. 4, 2004

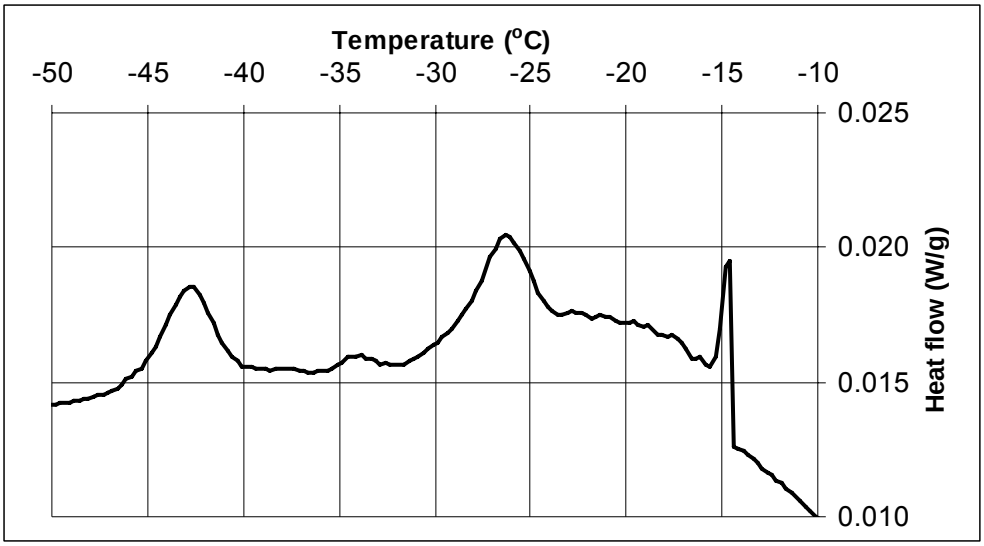

Figure 37 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 3 d under saturated conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: 0.502

Curing: Sealed
Age when tested: 3 d
Sample mass: 56.0 mg
Filename: cem152w35seal3d
Date tested: Nov. 4, 2004

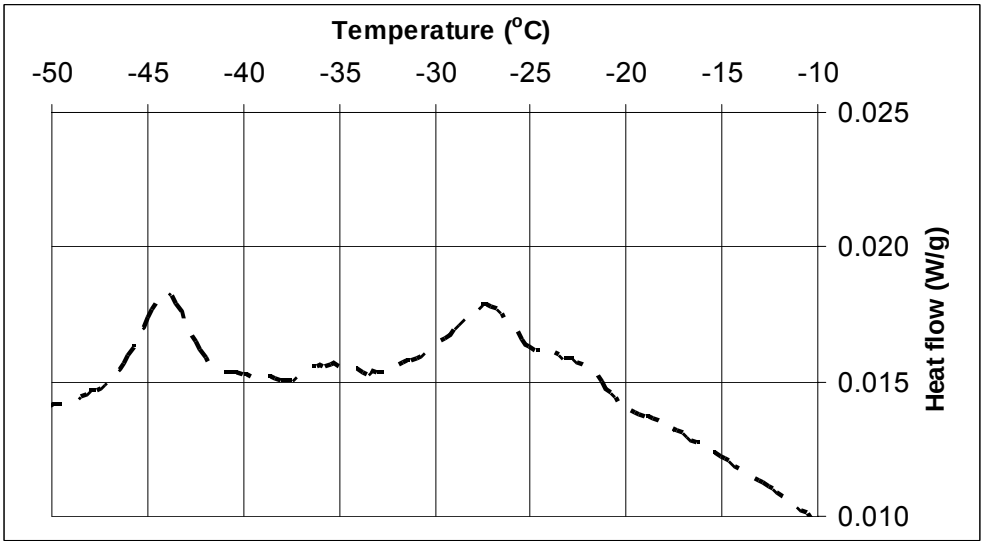

Figure 38 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 3 d under sealed conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 2 d/resaturated
Age when tested: 3 d
Sample mass: 51.3 mg
Filename: cem152w35sealresat2d1222
Date tested: Dec. 23, 2004

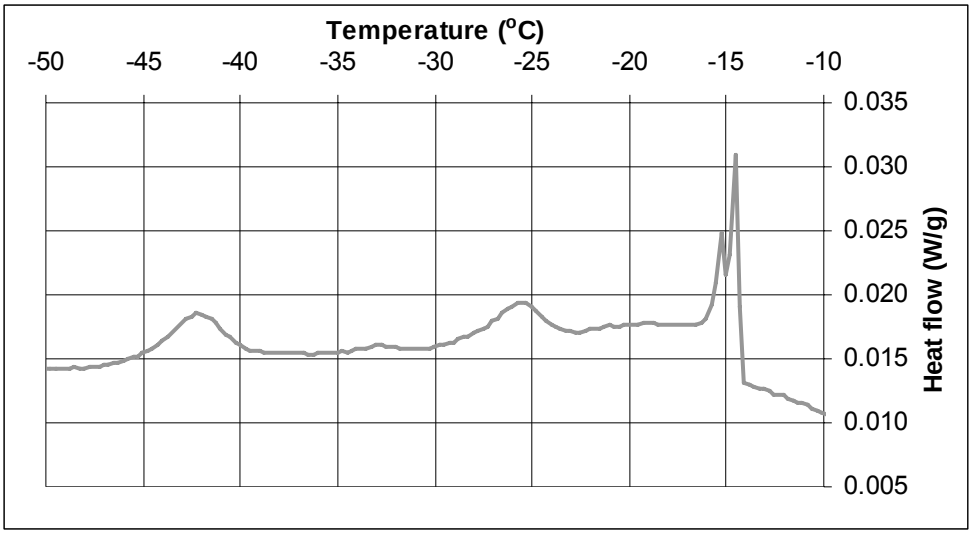

Figure 39 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 2 d under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: 0.568

Curing: Saturated
Age when tested: 4 d
Sample mass: 35.7 mg
Filename: cem152w35sat4d
Date tested: Nov. 5, 2004

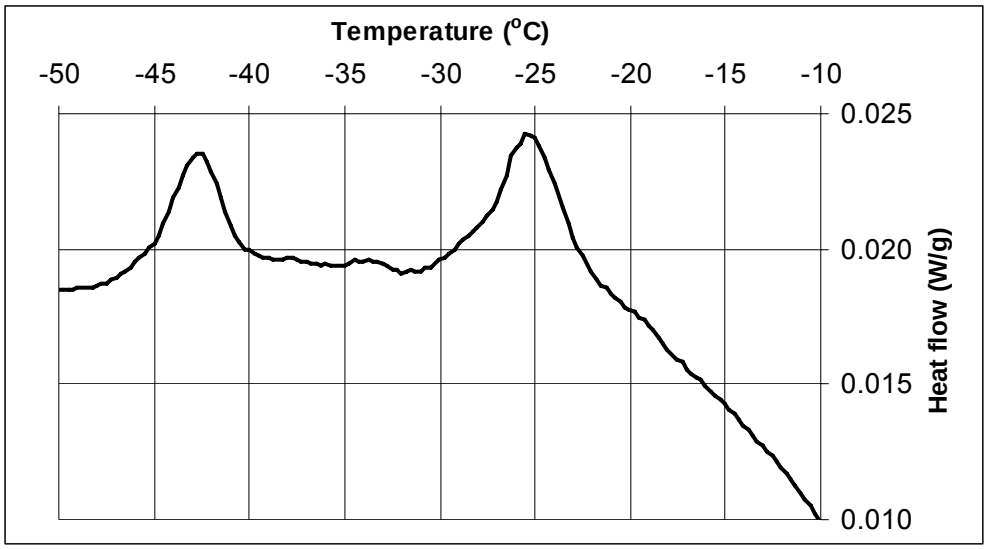

Figure 40 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 4 d under saturated conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: 0.554

Curing: Sealed
Age when tested: 4 d
Sample mass: 58.6 mg
Filename: cem152w35seal4d
Date tested: Nov. 5, 2004

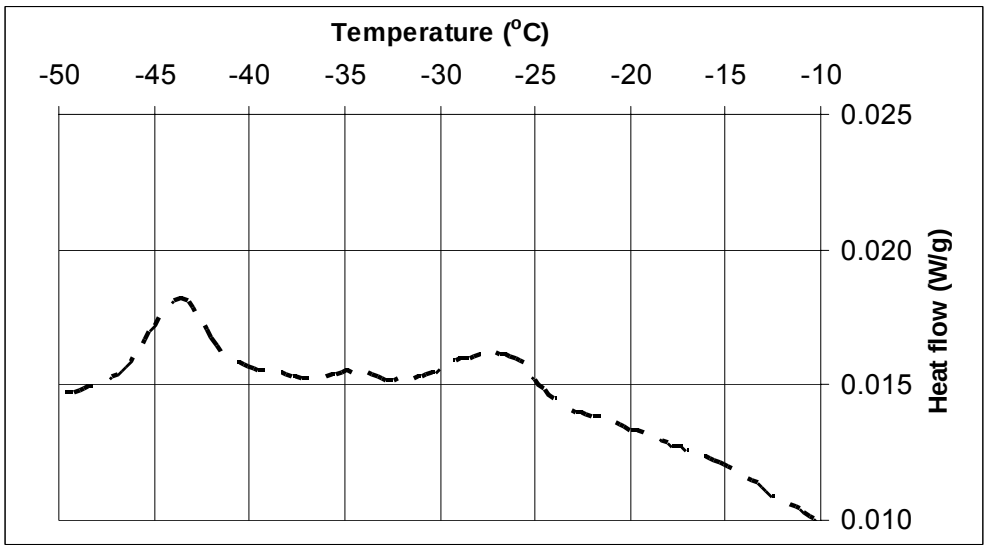

Figure 41 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 4 d under sealed conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 3 d/resaturated
Age when tested: 4 d
Sample mass: 74.3 mg
Filename: cem152w35sealresat3d
Date tested: Nov. 5, 2004

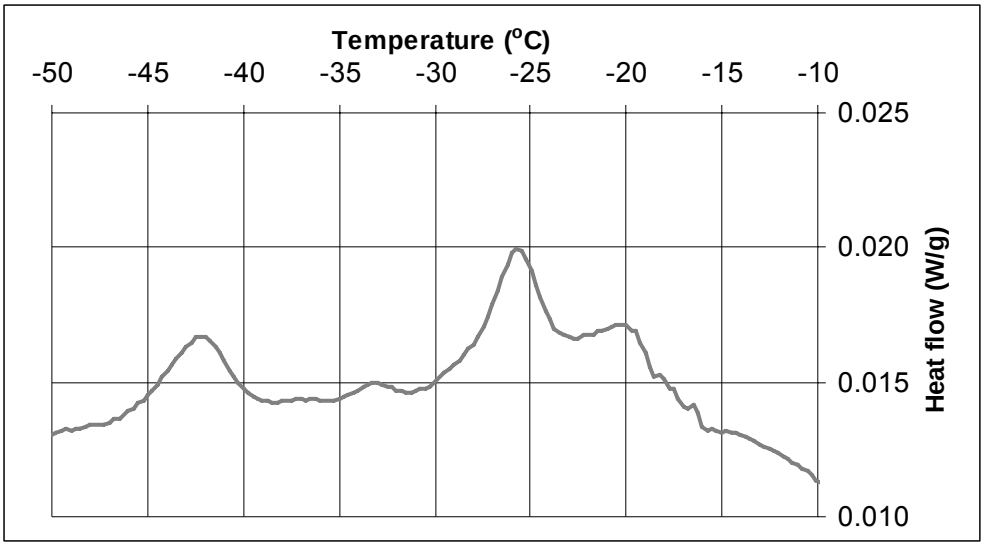

Figure 42 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 3 d under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 4 d/resaturated
Age when tested: 5 d
Sample mass: 58.2 mg
Filename: cem152w35sealresat4d
Date tested: Nov. 6, 2004

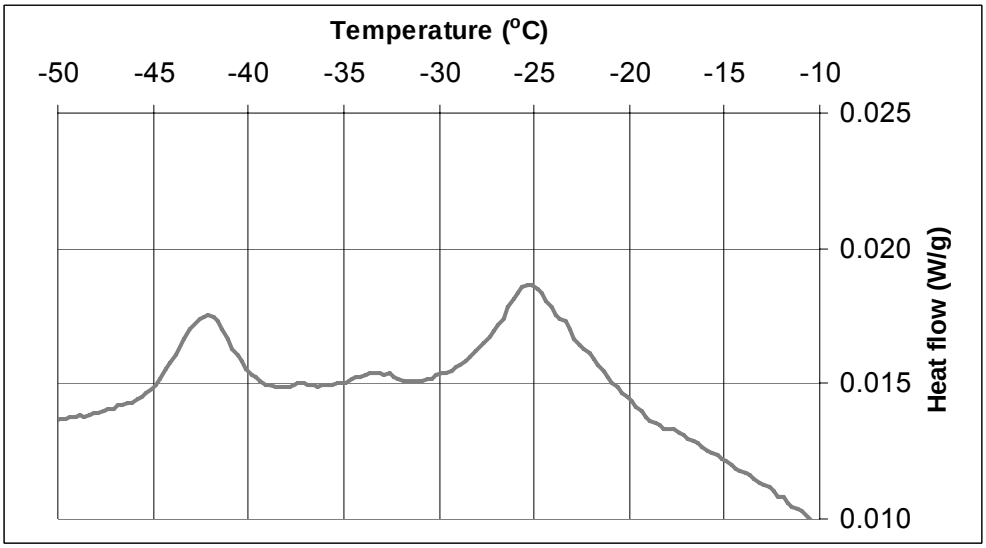

Figure 43 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 4 d under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: 0.597

Curing: Saturated
Age when tested: 5 d
Sample mass: 49.9 mg
Filename: cem152w35sat5d
Date tested: Nov. 6, 2004

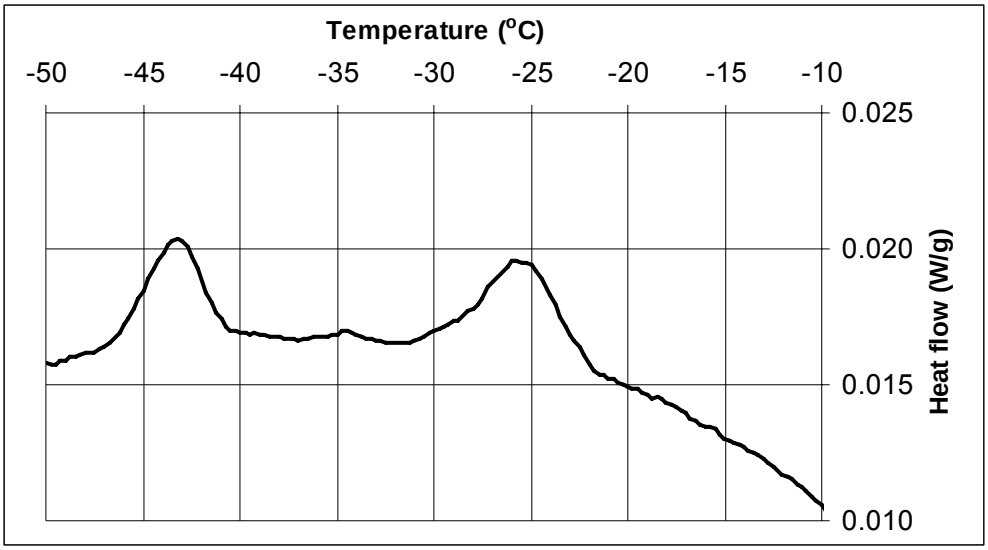

Figure 44 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 5 d under saturated conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: 0.569

Curing: Sealed
Age when tested: 5 d
Sample mass: 74.2 mg
Filename: cem152w35seal5d
Date tested: Nov. 6, 2004

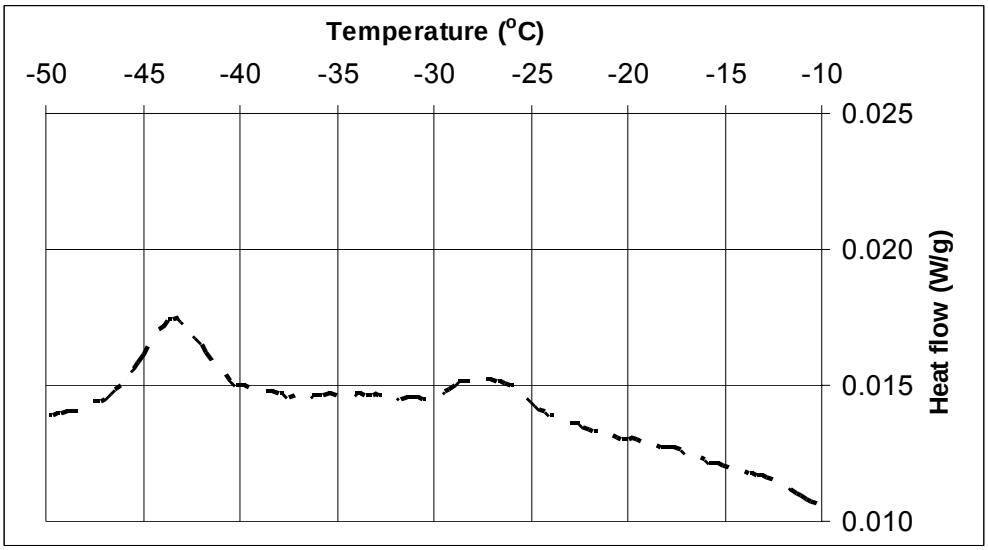

Figure 45 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 5 d under sealed conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: 0.656

Curing: Saturated
Age when tested: 7 d
Sample mass: 45.7 mg
Filename: cem152w35sat7d
Date tested: Nov. 8, 2004

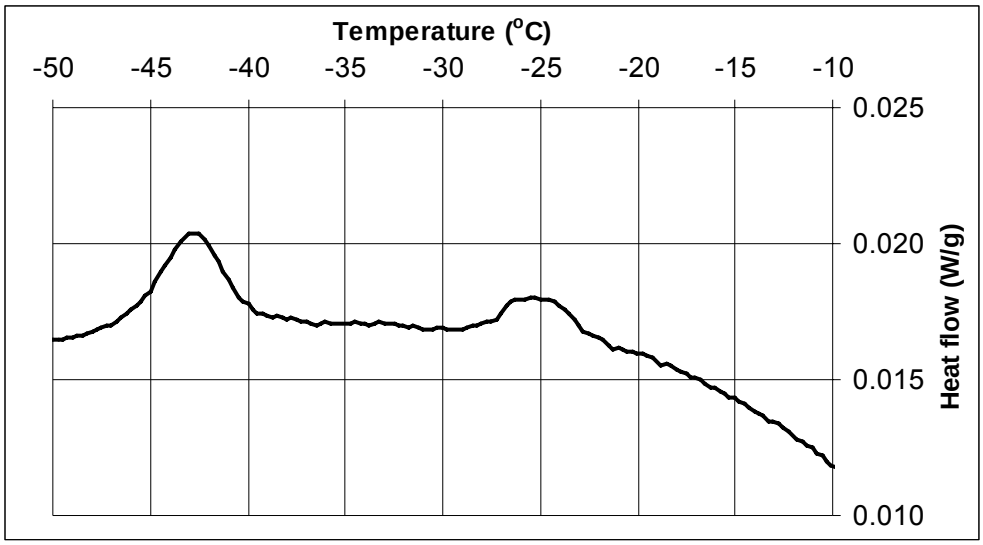

Figure 46 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 7 d under saturated conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: 0.619

Curing: Sealed
Age when tested: 7 d
Sample mass: 43.9 mg
Filename: cem152w35seal7d
Date tested: Nov. 8, 2004

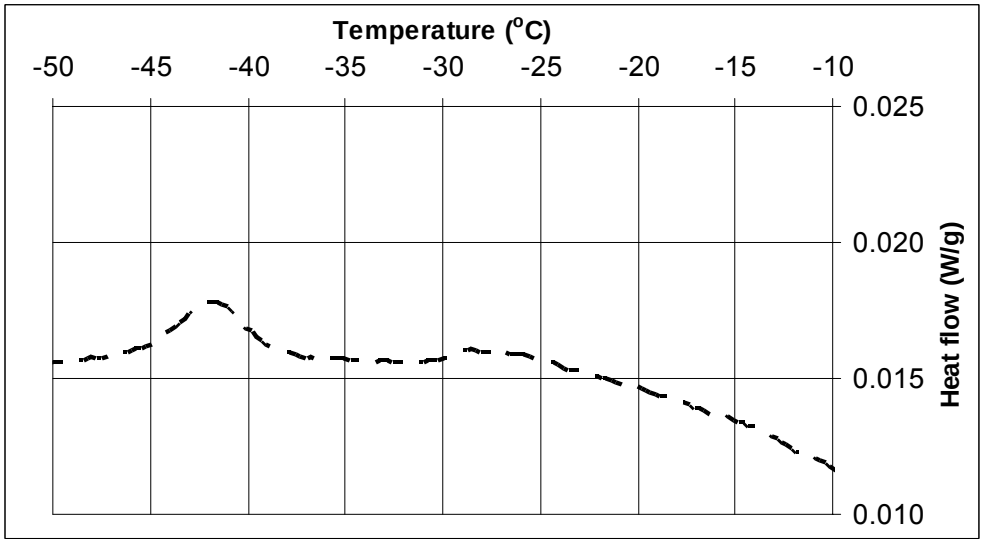

Figure 47 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 7 d under sealed conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 5 d/resaturated
Age when tested: 7 d
Sample mass: 60.4 mg
Filename: cem152w35sealresat5d
Date tested: Nov. 8, 2004

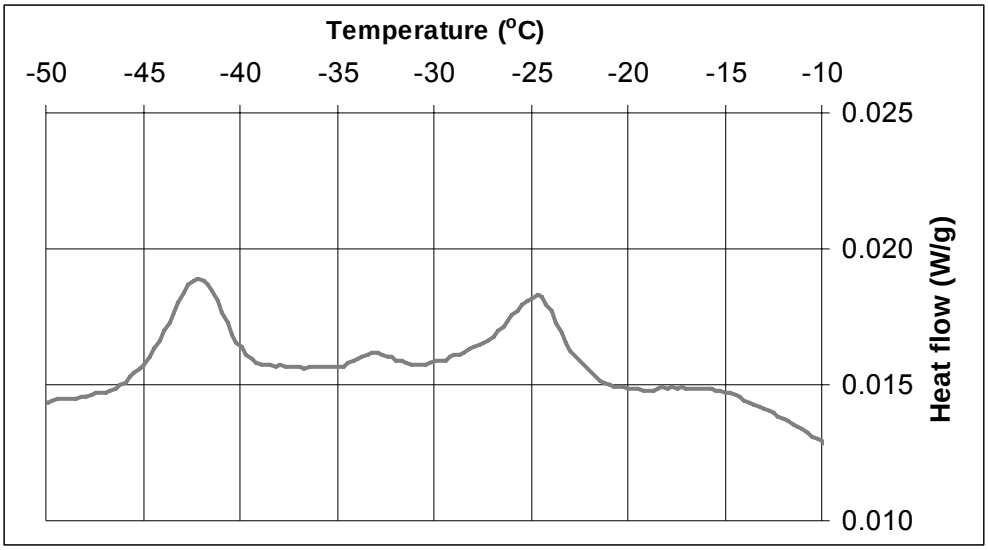

Figure 48 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 5 d under sealed conditions, then resaturated for 2 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 7 d/resaturated
Age when tested: 9 d
Sample mass: 42.1 mg
Filename: cem152w35sealresat7d
Date tested: Nov. 10, 2004

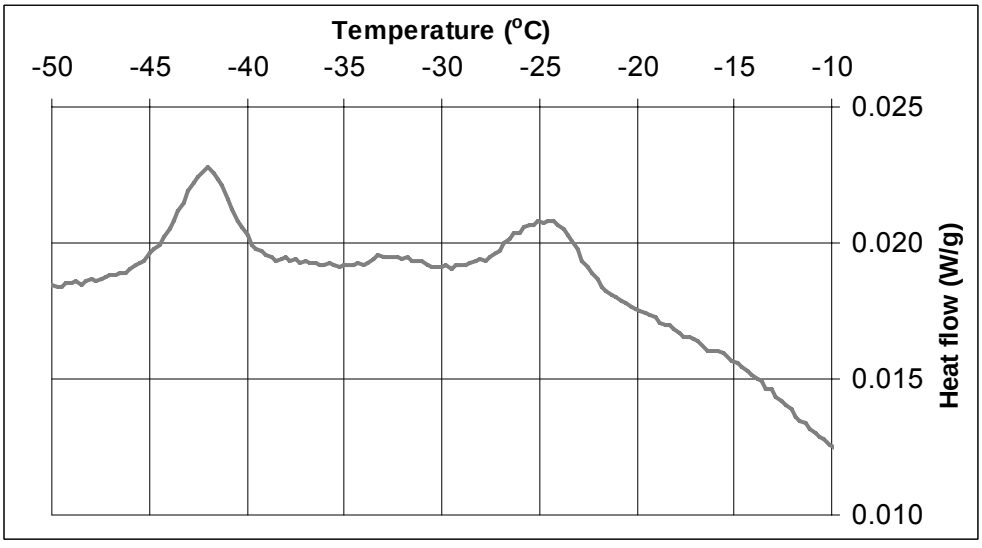

Figure 49 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 7 d under sealed conditions, then resaturated for 2 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 7 d/frozen/resaturated
Age when tested: 8+ d
Sample mass: 44.4 mg
Filename: cem152w35sealresatfr7d
Date tested: Nov. 9, 2004

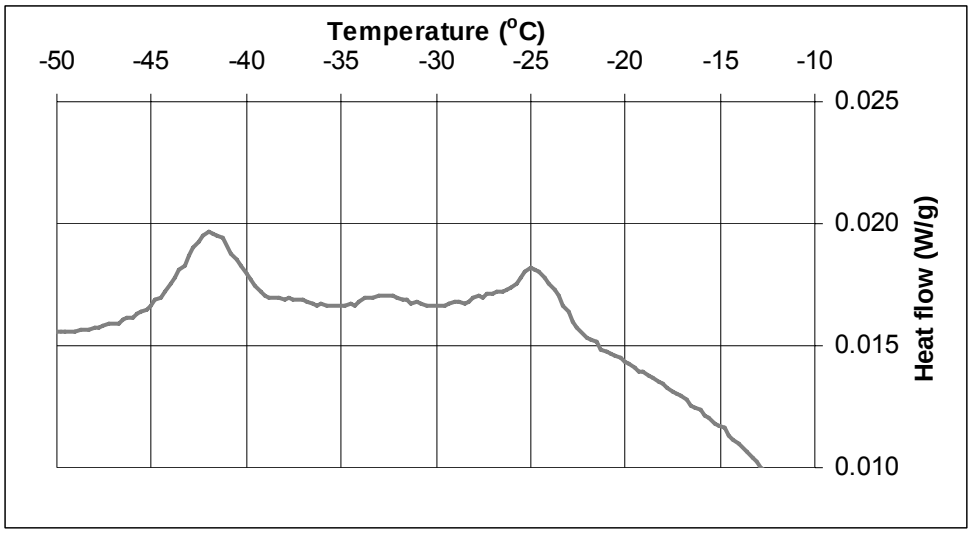

Figure 50 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 7 d under sealed conditions, frozen during an LTC scan (Figure 17), then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 9 d
Sample mass: 61.1 mg
Filename: cem152w35sat9d
Date tested: Nov. 10, 2004

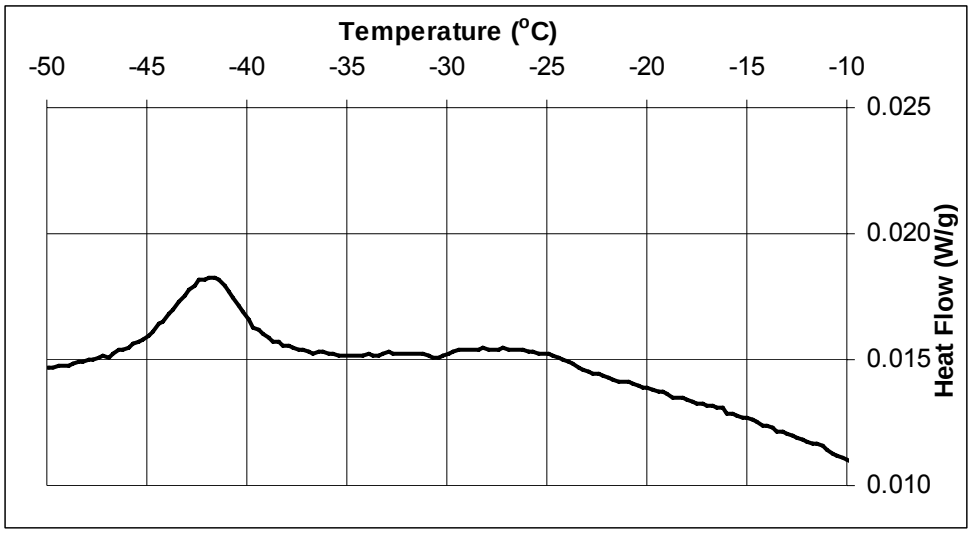

Figure 51 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 9 d under saturated conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed
Age when tested: 9 d
Sample mass: 50.1 mg
Filename: cem152w35seal9d
Date tested: Nov. 10, 2004

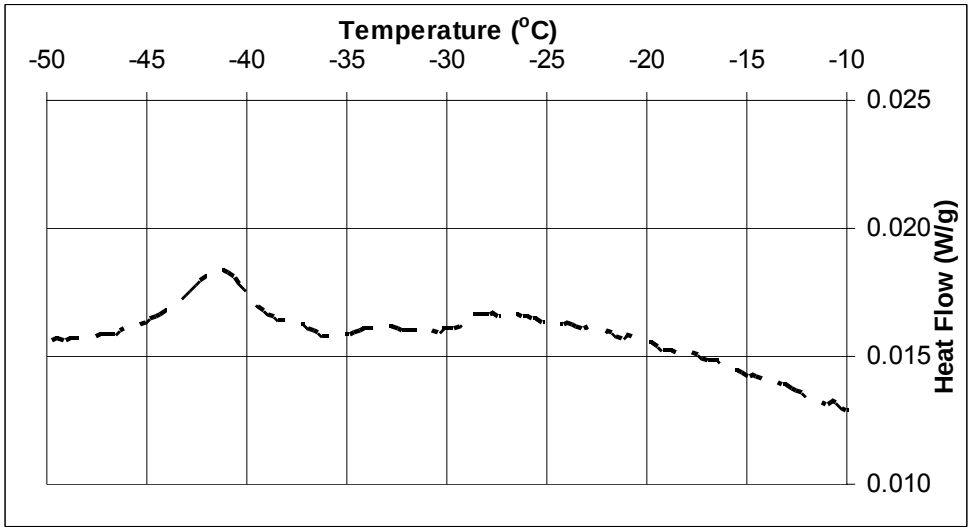

Figure 52 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 9 d under sealed conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: 0.715

Curing: Saturated
Age when tested: 14 d
Sample mass: 49.3 mg
Filename: cem152w35sat14d
Date tested: Nov. 15, 2004

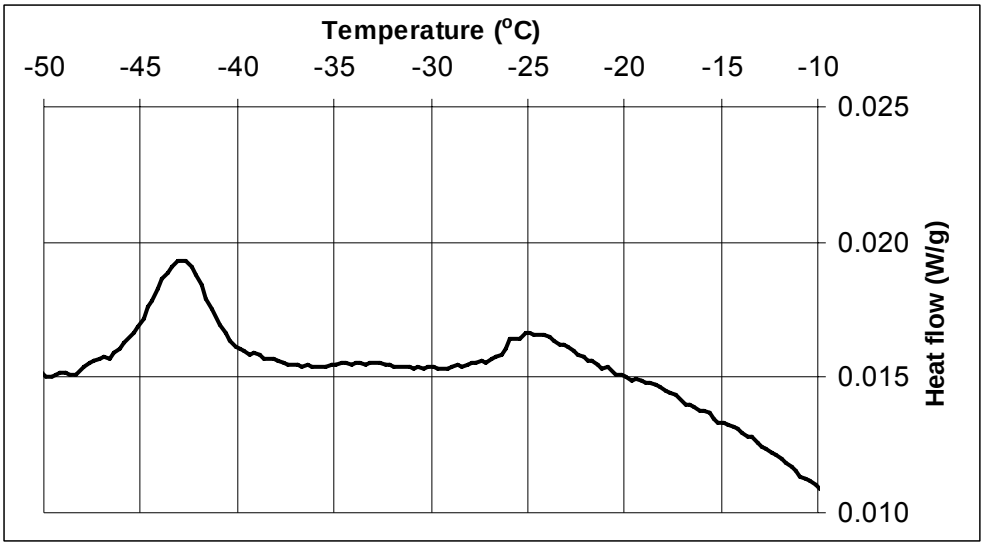

Figure 53 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 14 d under saturated conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: 0.658

Curing: Sealed
Age when tested: 14 d
Sample mass: 46.7 mg
Filename: cem152w35seal14d
Date tested: Nov. 15, 2004

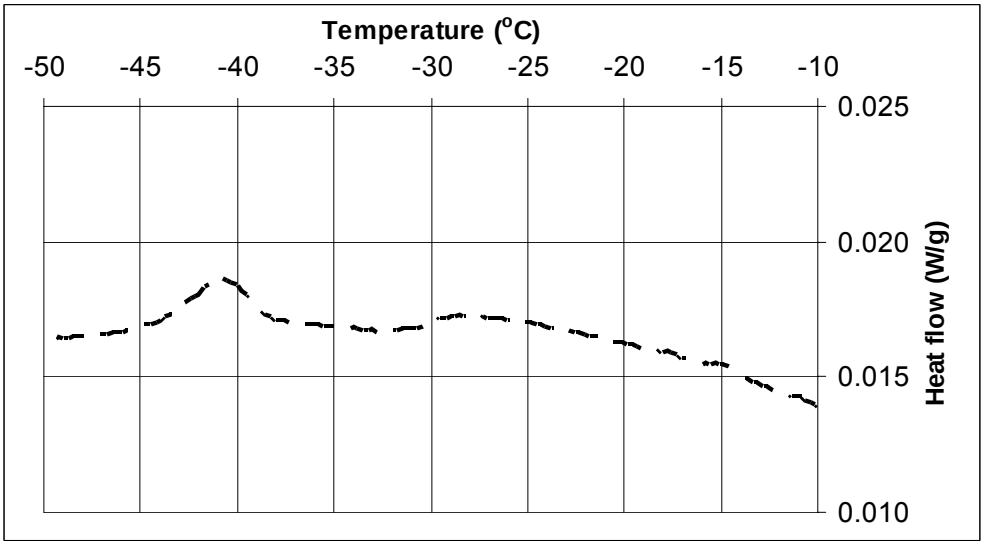

Figure 54 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 14 d under sealed conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 14 d/resaturated
Age when tested: 15 d
Sample mass: 59.0 mg
Filename: cem152w35sealresat14d
Date tested: Nov. 16, 2004

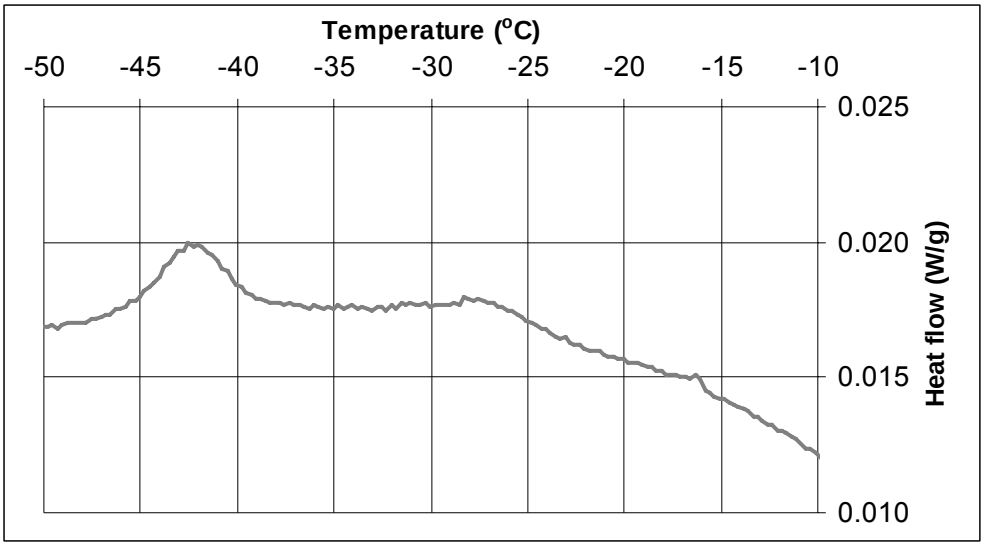

Figure 55 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 14 d under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 14 d/resaturated
Age when tested: 18 d
Sample mass: 35.3 mg
Filename: cem152w35sealresatb14d
Date tested: Nov. 19, 2004

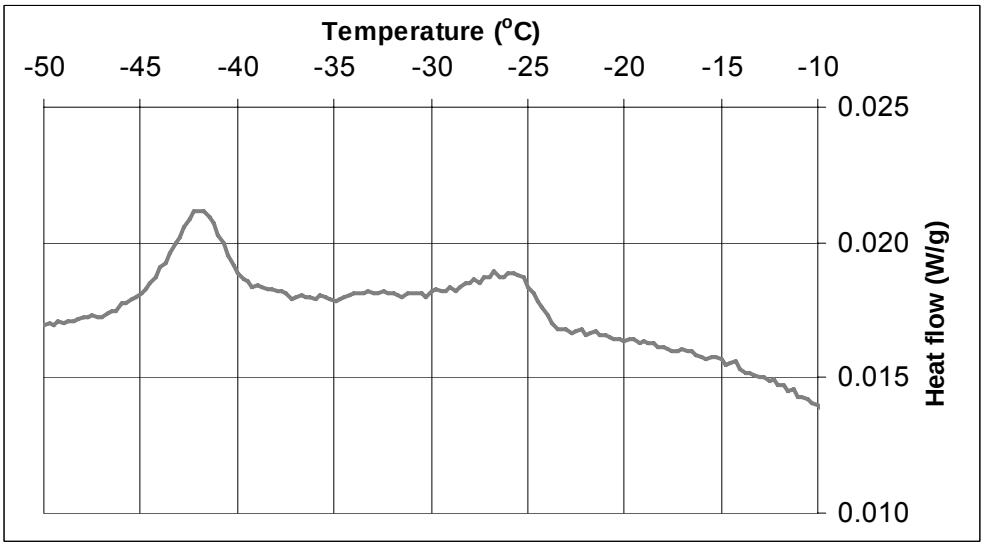

Figure 56 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 14 d under sealed conditions, then resaturated for 4 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 18 d
Sample mass: 80.9 mg
Filename: cem152w35sat18d
Date tested: Jan. 7, 2005

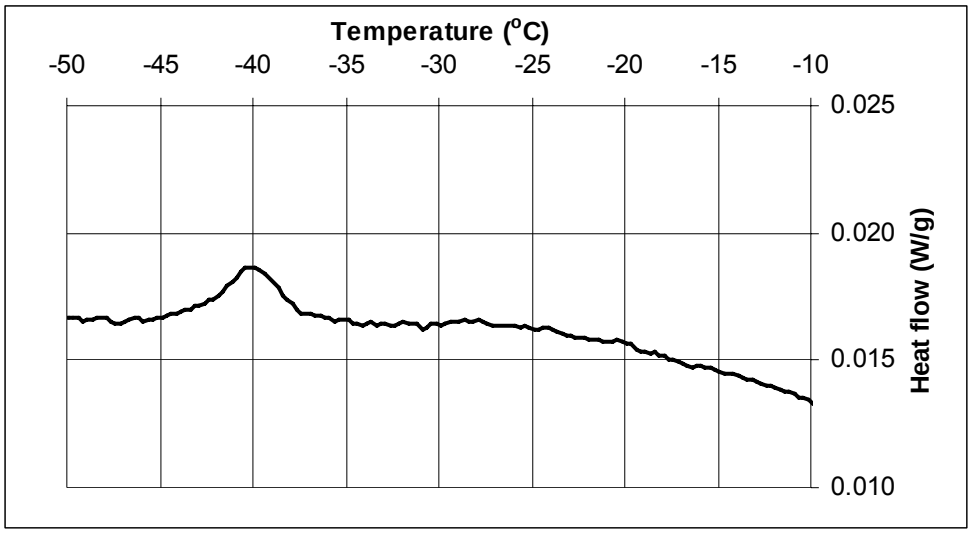

Figure 57 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 18 d under saturated conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed
Age when tested: 18 d
Sample mass: 47.3 mg
Filename: cem152w35seal18d
Date tested: Jan. 7, 2005

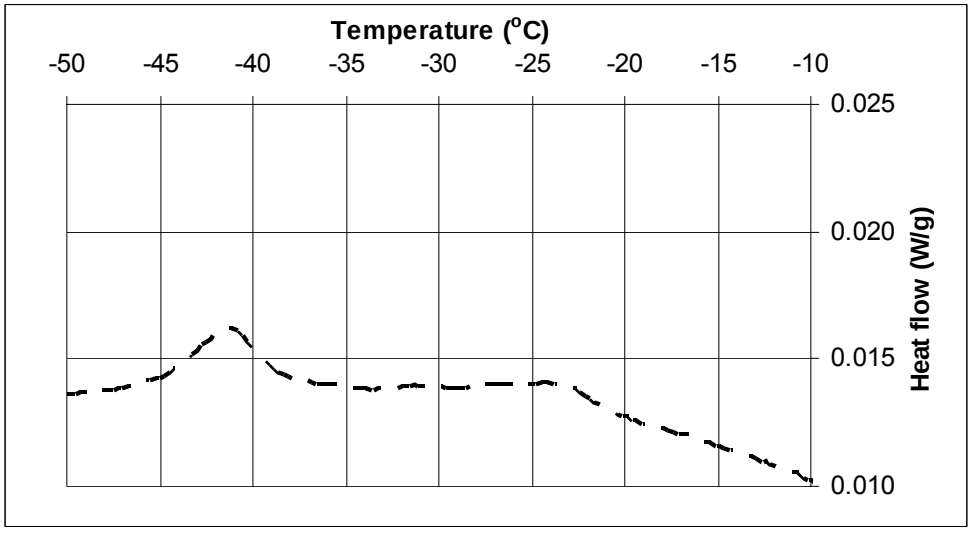

Figure 58 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 18 d under sealed conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 17 d/resaturated
Age when tested: 18 d
Sample mass: 69.0 mg
Filename: cem152w35sealresat18d
Date tested: Jan. 7, 2005

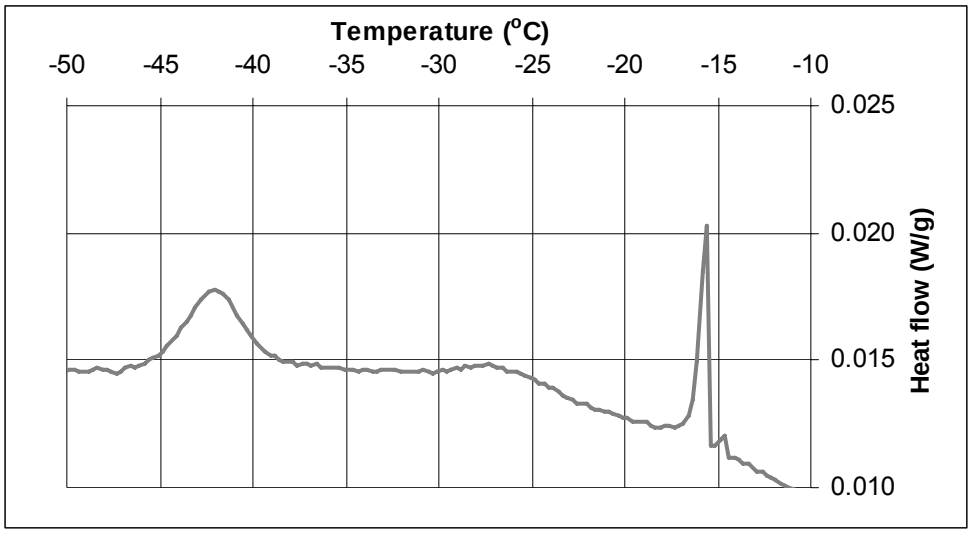

Figure 59 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 17 d under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 14 d/resaturated
Age when tested: 21 d
Sample mass: 43.6 mg
Filename: cem152w35sealresatc14d
Date tested: Nov. 22, 2004

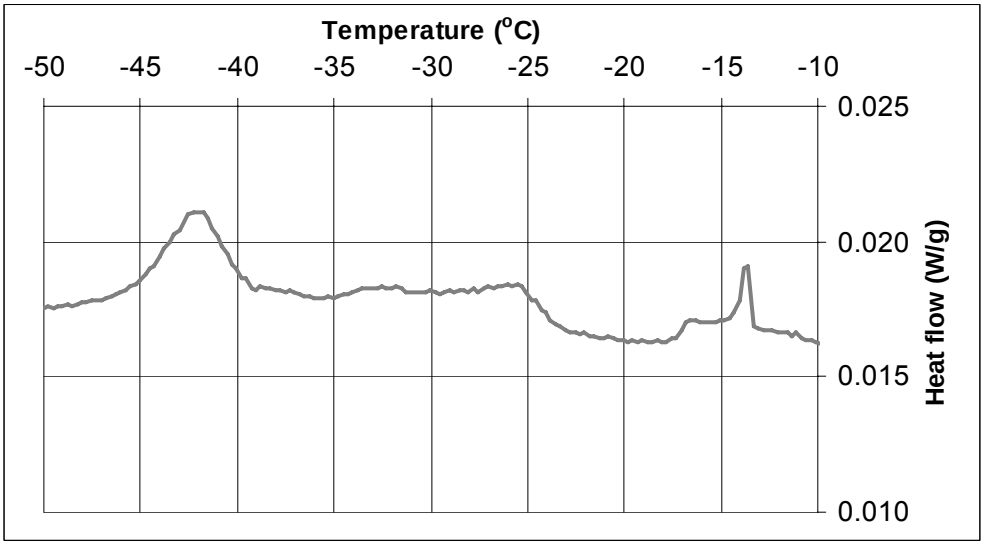

Figure 60 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 14 d under sealed conditions, then resaturated for 7 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 14 d/resaturated
Age when tested: 29 d
Sample mass: 66.5 mg
Filename: cem152w35sealresatd14d
Date tested: Nov. 30, 2004

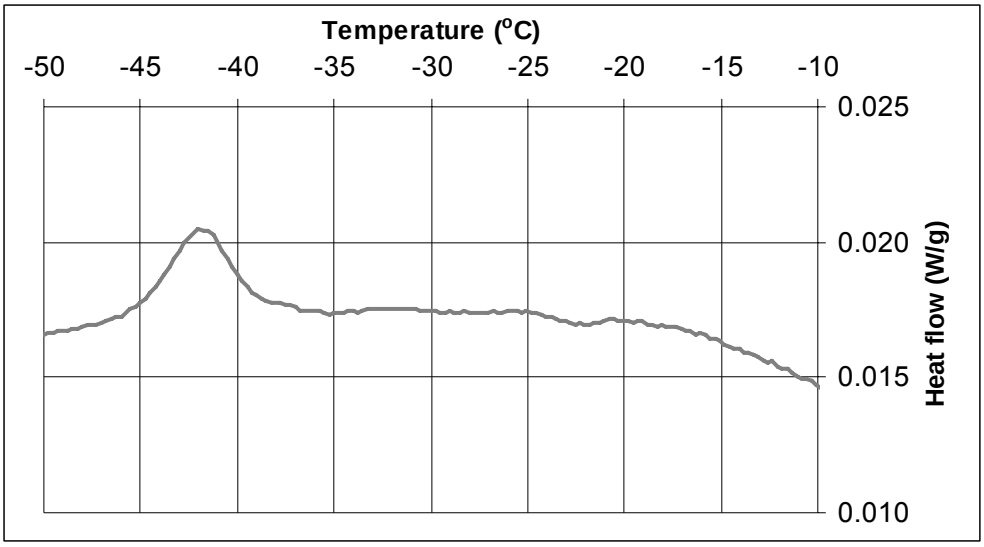

Figure 61 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 14 d under sealed conditions, then resaturated for 15 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: 0.759

Curing: Saturated
Age when tested: 30 d
Sample mass: 64.3 mg
Filename: cem152w35sat30d
Date tested: Dec. 1, 2004

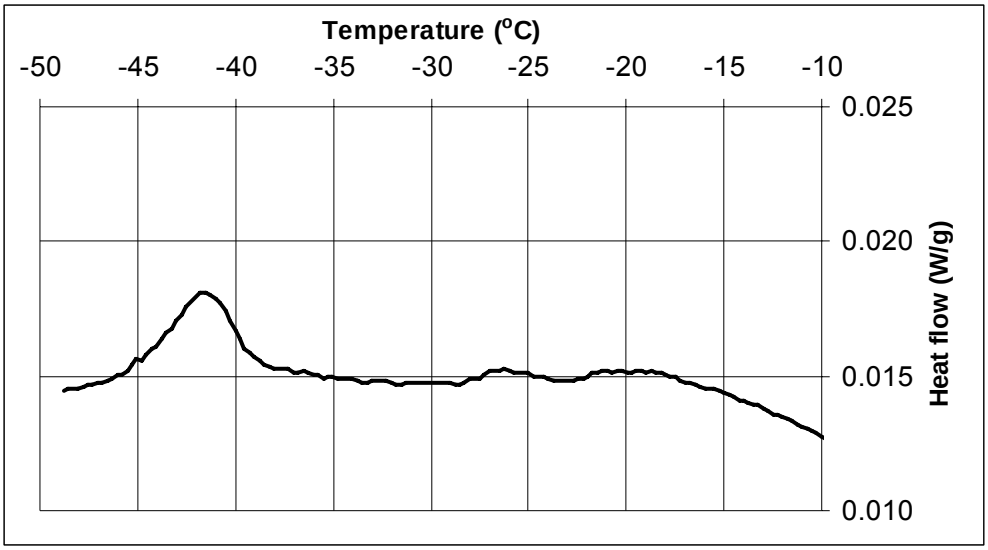

Figure 62 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 30 d under saturated conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: 0.674

Curing: Sealed
Age when tested: 30 d
Sample mass: 43.0 mg
Filename: cem152w35seal30d
Date tested: Dec. 1, 2004

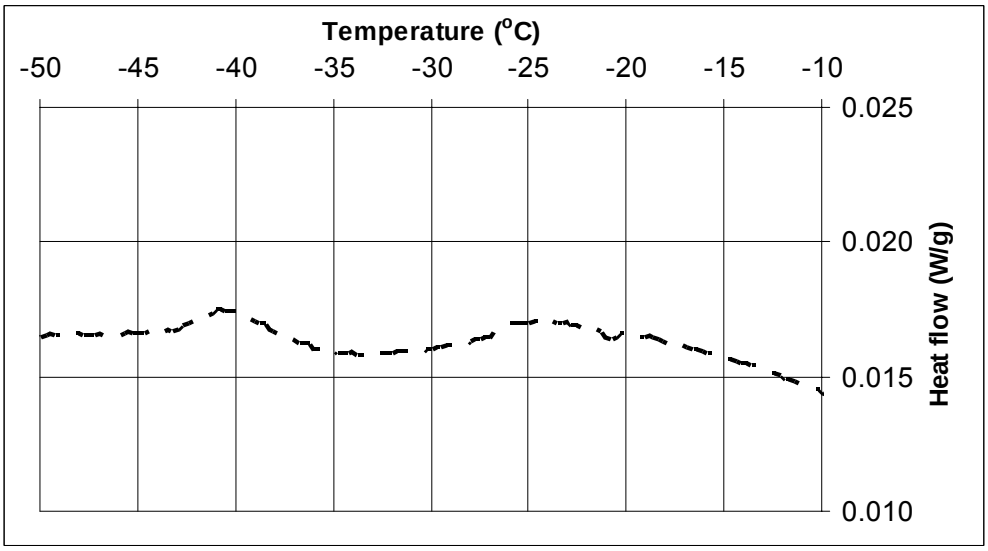

Figure 63 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 30 d under sealed conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 30 d/resaturated
Age when tested: 32 d
Sample mass: 59.9 mg
Filename: cem152w35sealresat30d
Date tested: Dec. 3, 2004

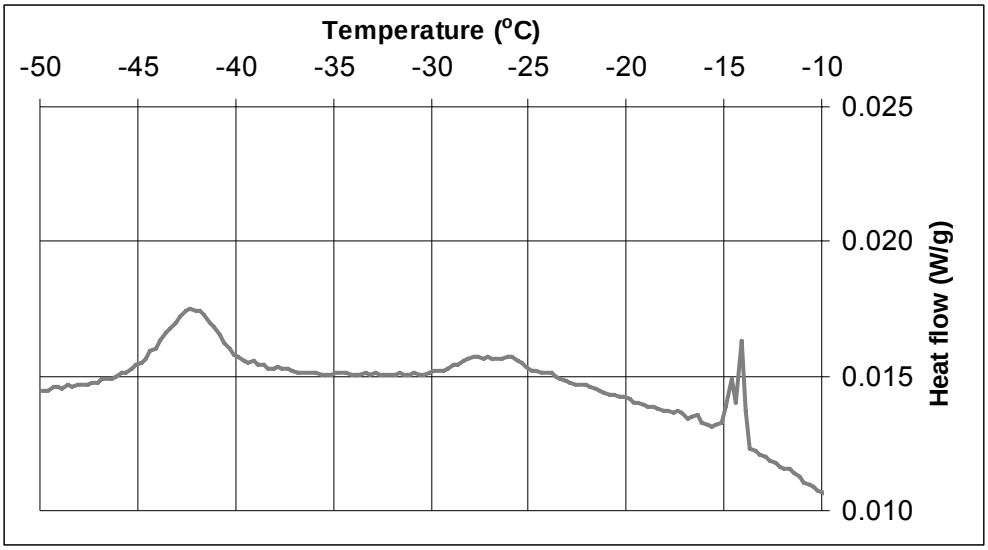

Figure 64 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 30 d under sealed conditions, then resaturated for 2 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 30 d/resaturated
Age when tested: 35 d
Sample mass: 91.4 mg
Filename: cem152w35sealresatb30d
Date tested: Dec. 6, 2004

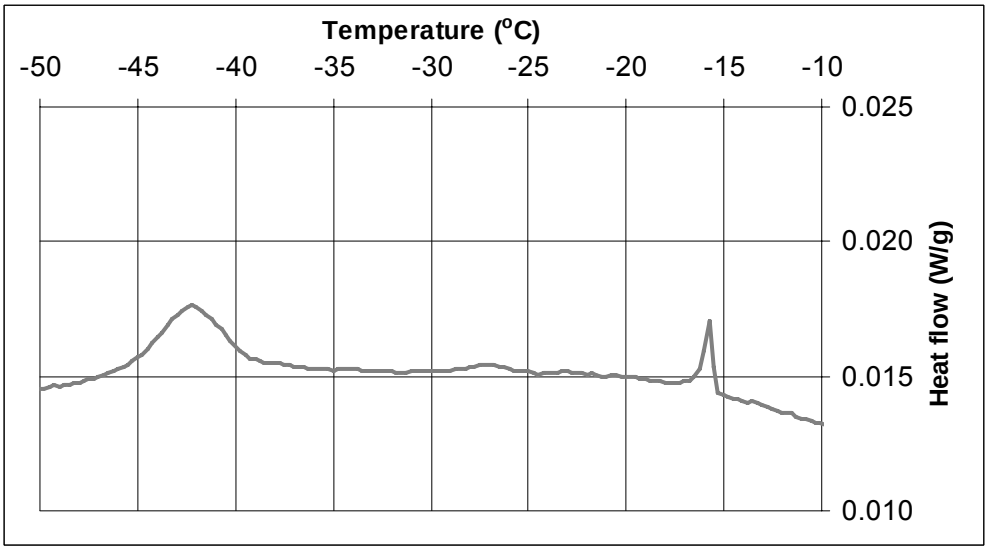

Figure 65 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 30 d under sealed conditions, then resaturated for 5 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 30 d/resaturated
Age when tested: 42 d
Sample mass: 34.1 mg
Filename: cem152w35sealresatd30d
Date tested: Dec. 13, 2004

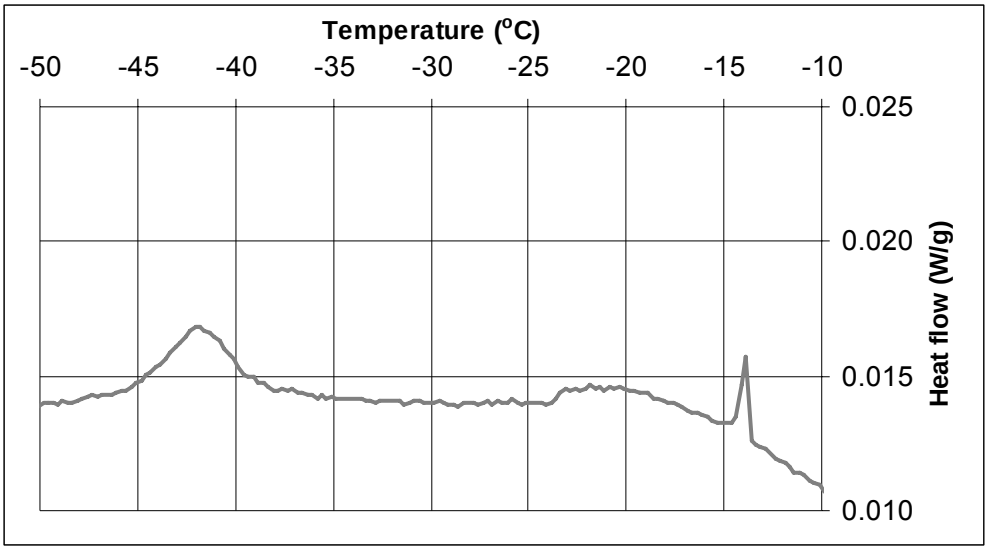

Figure 66 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 30 d under sealed conditions, then resaturated for 12 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 30 d/resaturated
Age when tested: 49 d
Sample mass: 74.2 mg
Filename: cem152w35sealresate30d
Date tested: Dec. 20, 2004

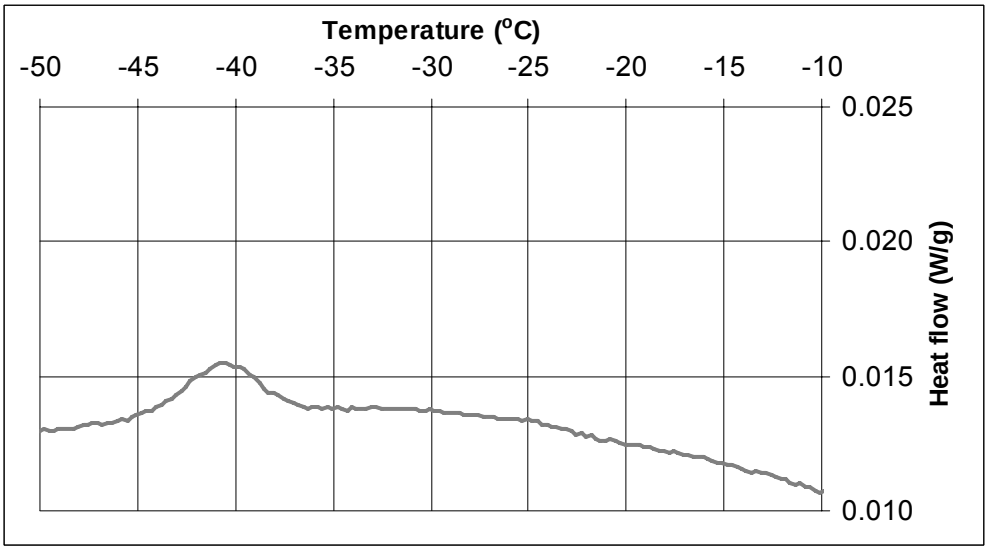

Figure 67 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 30 d under sealed conditions, then resaturated for 19 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 50 d
Sample mass: 72.5 mg
Filename: cem152w35sat50d
Date tested: Dec. 21, 2004

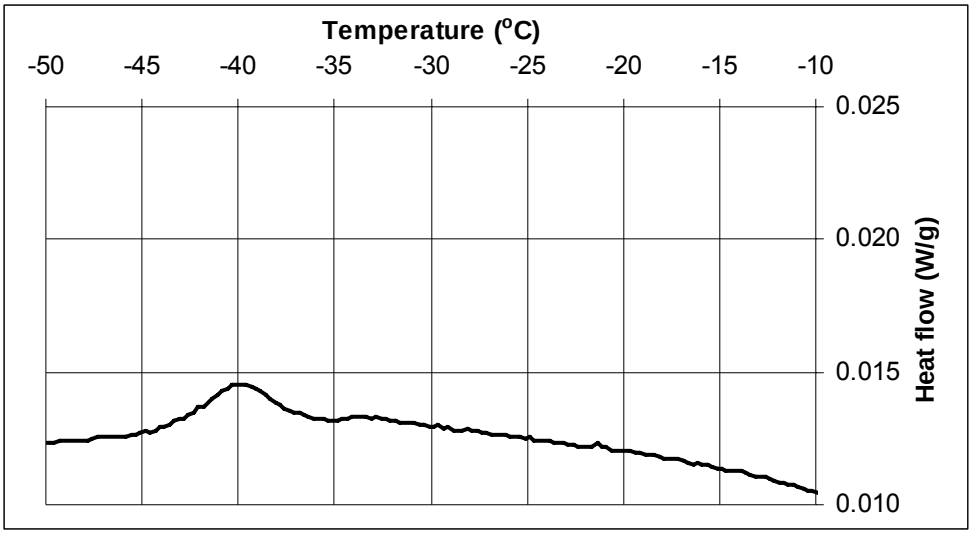

Figure 68 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 50 d under saturated conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed
Age when tested: 50 d
Sample mass: 75.1 mg
Filename: cem152w35seal50d
Date tested: Dec. 21, 2004

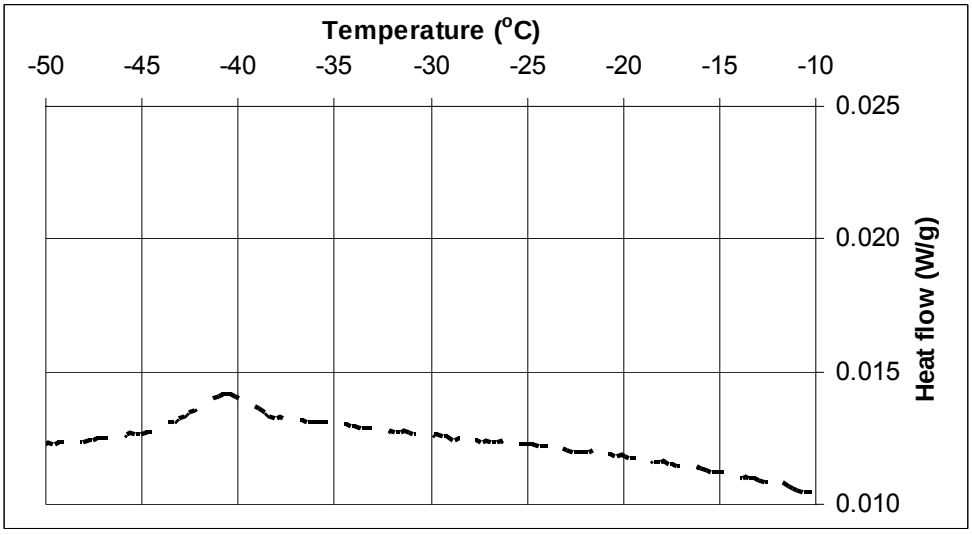

Figure 69 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 50 d under sealed conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 50 d/resaturated
Age when tested: 51 d
Sample mass: 80.5 mg
Filename: cem152w35sealresat50d
Date tested: Dec. 22, 2004

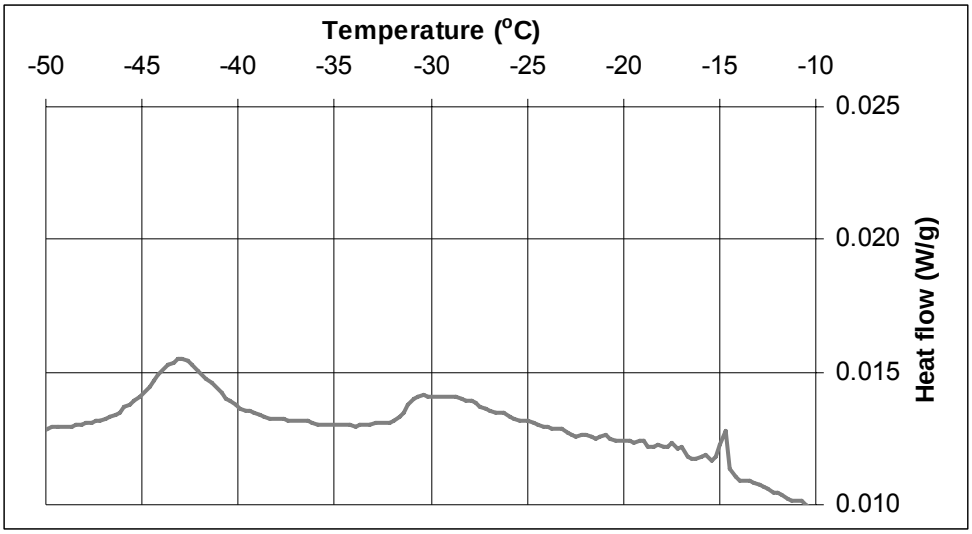

Figure 70 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 50 d under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 50 d/resaturated
Age when tested: 52 d
Sample mass: 50.2 mg
Filename: cem152w35sealresatb50d
Date tested: Dec. 23, 2004

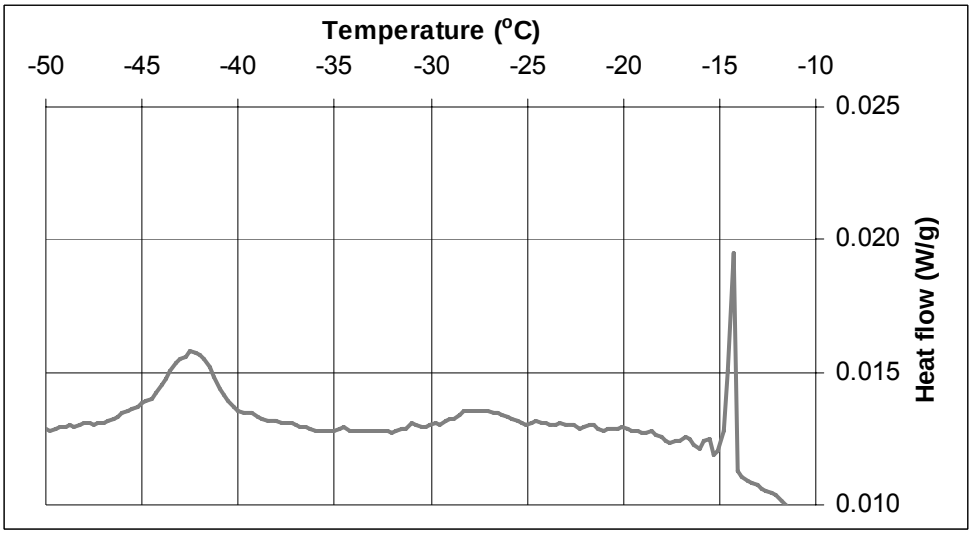

Figure 71 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 50 d under sealed conditions, then resaturated for 2 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 50 d/resaturated
Age when tested: 63 d
Sample mass: 40.3 mg
Filename: cem152w35sealresatc50d
Date tested: Jan. 3, 2005

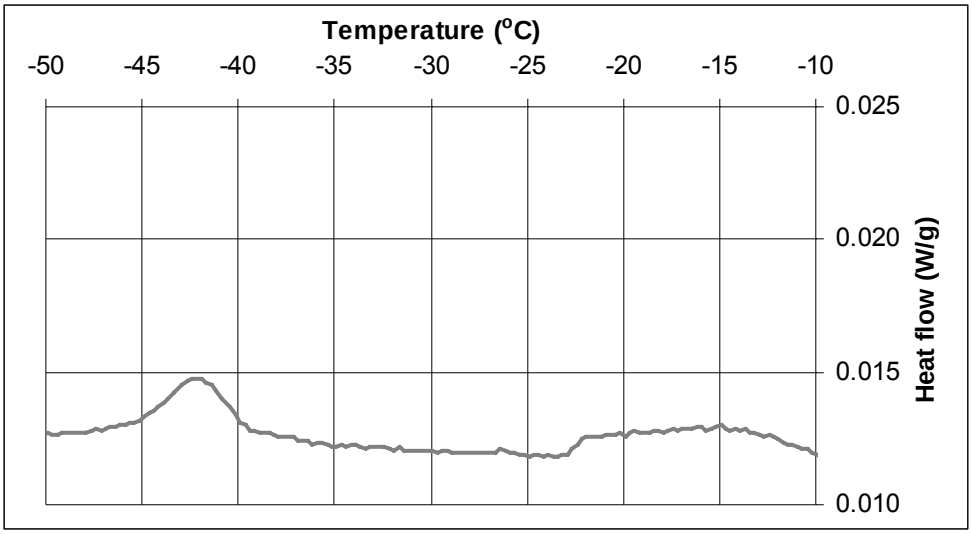

Figure 72 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 50 d under sealed conditions, then resaturated for 13 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 88 d/resaturated
Age when tested: 91 d
Sample mass: 52.2 mg
Filename: cem152w35sealresat91d
Date tested: Jan. 31, 2005

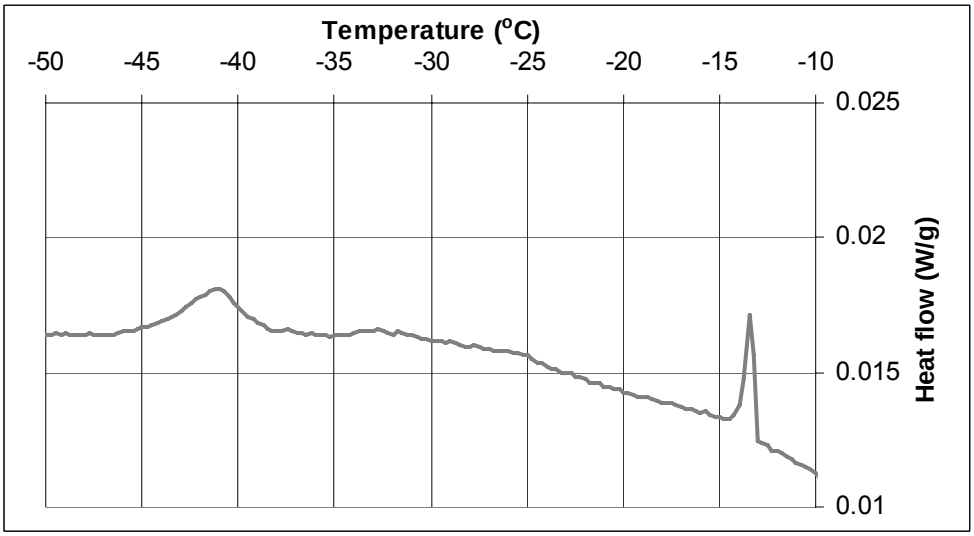

Figure 73 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 88 d under sealed conditions, then resaturated for 3 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 91 d
Sample mass: 68.7 mg
Filename: cem152w35sat91d
Date tested: Jan. 31, 2005

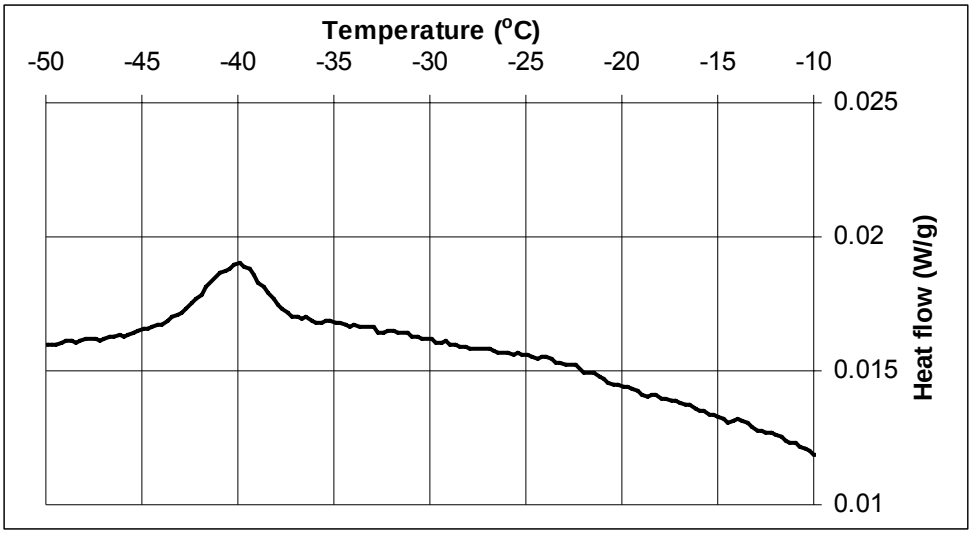

Figure 74 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 90 d under saturated conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed
Age when tested: 91 d
Sample mass: 91.3 mg
Filename: cem152w35sealb91d
Date tested: Jan. 31, 2005

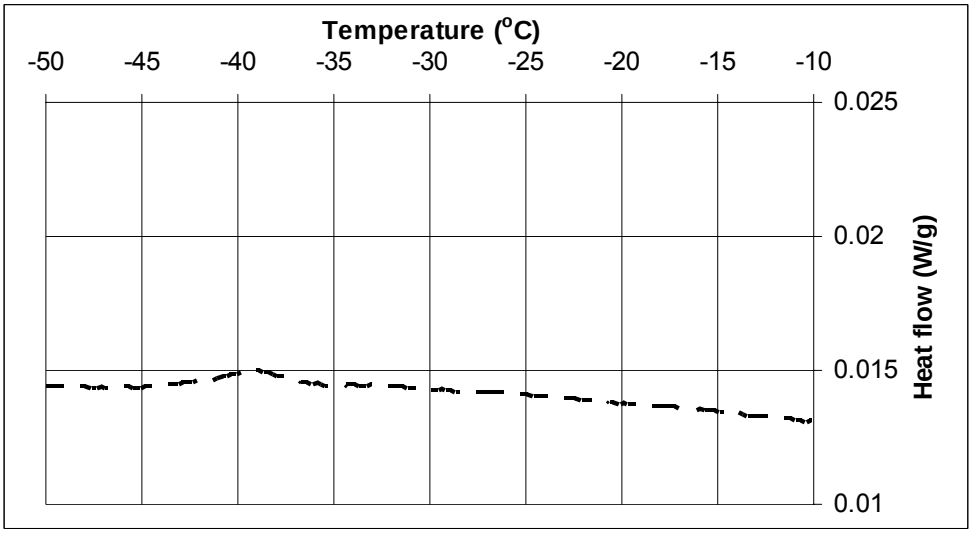

Figure 75 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 90 d under sealed conditions at 20 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: 0.844

Curing: Saturated
Age when tested: 182 d
Sample mass: 70.8 mg
Filename: cem152182dsat
Date tested: Oct. 25, 2004

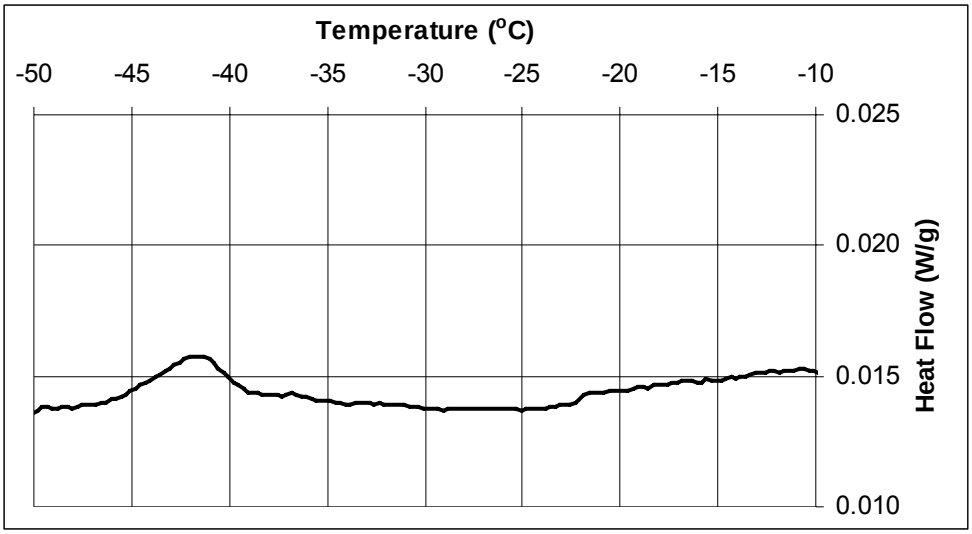

Figure 76 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 182 d at 20 °C under saturated conditions.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: 0.757

Curing: Sealed
Age when tested: 182 d
Sample mass: 53.4 mg
Filename: cem152182dseal
Date tested: Oct. 25, 2004

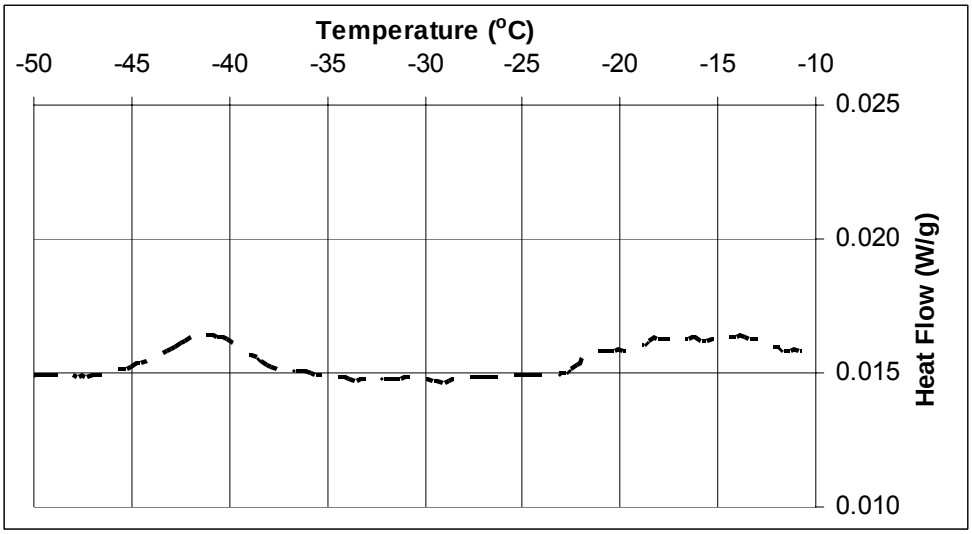

Figure 77 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 182 d at 20 °C under sealed conditions.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: 0.836

Curing: Sealed 7 d/resaturated
Age when tested: 182 d
Sample mass: 58.6 mg
Filename: cem152182dsealsat
Date tested: Oct. 25, 2004

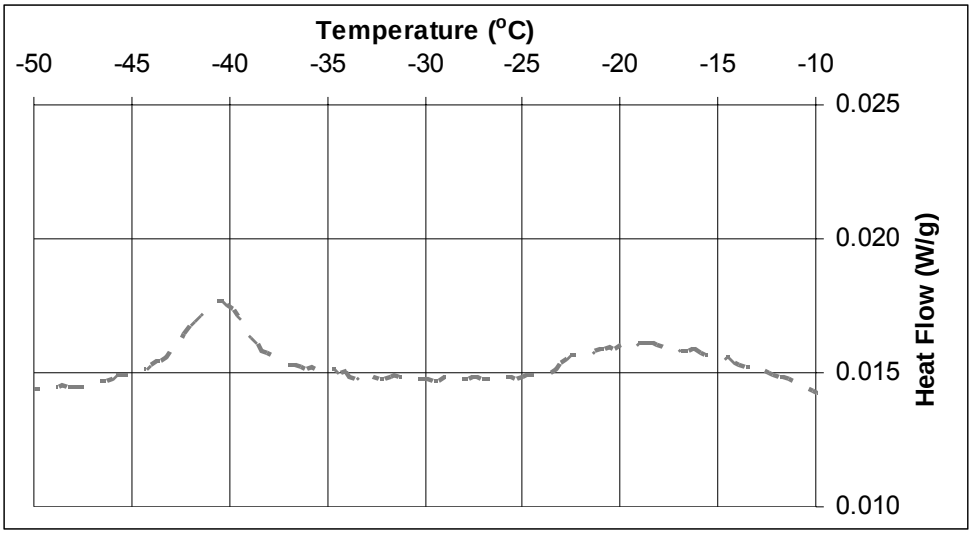

Figure 78 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 7 d under sealed conditions, then resaturated for 175 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 182 d/resaturated
Age when tested: 183 d
Sample mass: 54.3 mg
Filename: cem152182dsealresat
Date tested: Oct. 26, 2004

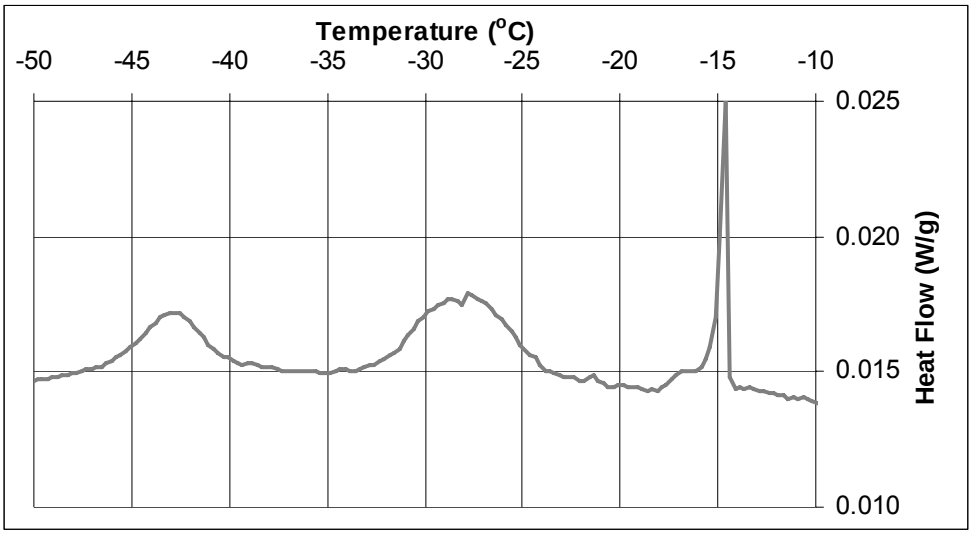

Figure 79 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 182 d under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed
Age when tested: 204 d
Sample mass: 90.5 mg
Filename: c152w35seal204d
Date tested: Nov. 16, 2004

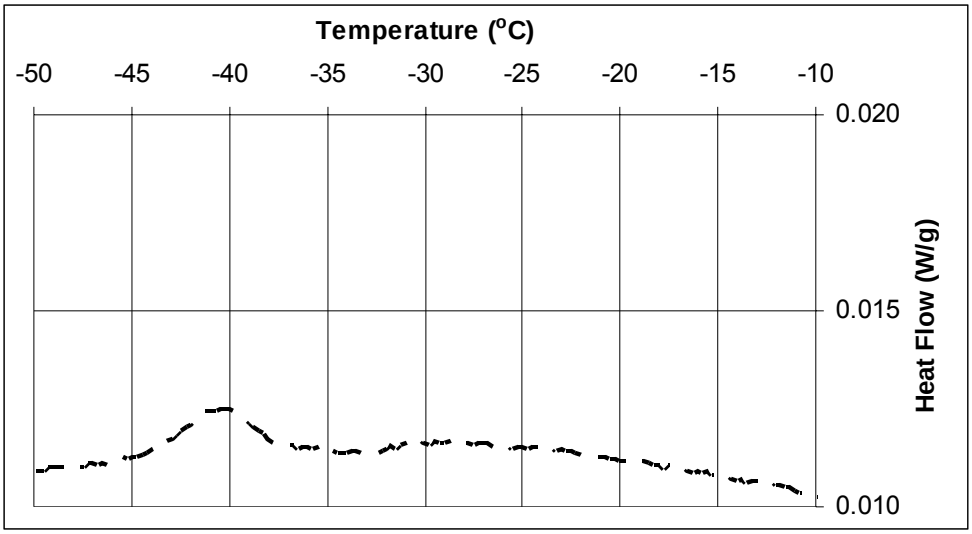

Figure 80 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 204 d at 20 °C under sealed conditions.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 203 d/resaturated
Age when tested: 204 d
Sample mass: 51.1 mg
Filename: c152w35sealresat204d
Date tested: Nov. 16, 2004

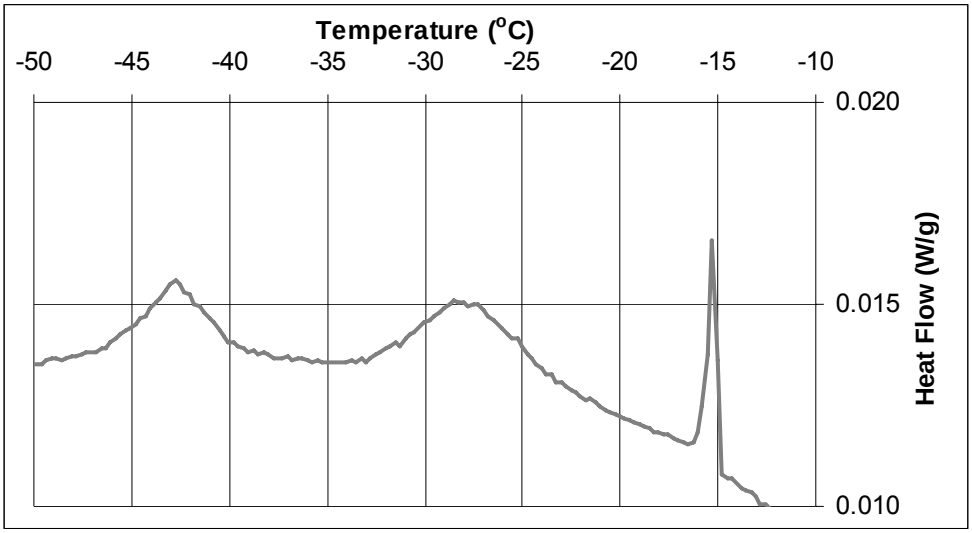

Figure 81 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 203 d under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 203 d/resaturated
Age when tested: 207 d
Sample mass: 51.0 mg
Filename: c152w35sealresatb204d
Date tested: Nov. 19, 2004

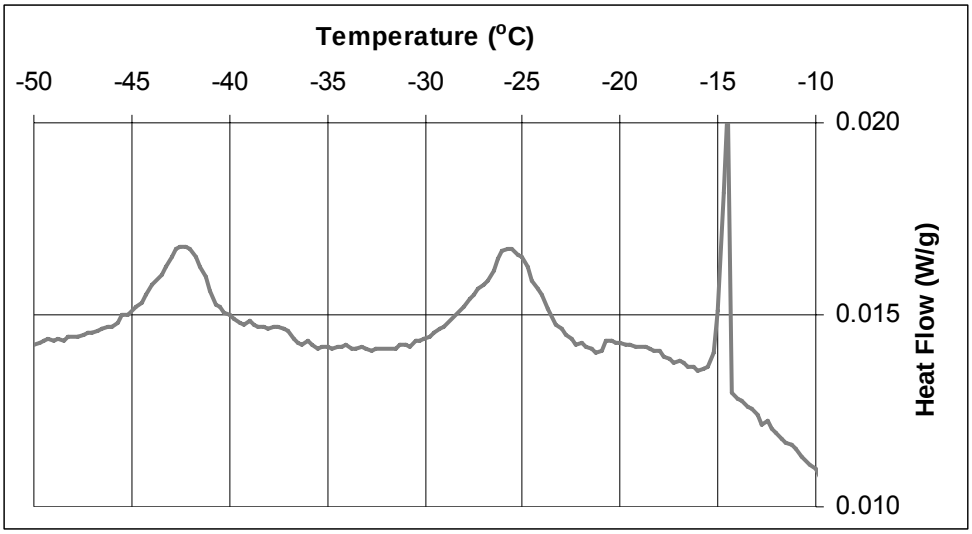

Figure 82 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 203 d under sealed conditions, then resaturated for 4 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: 0.799

Curing: Sealed 203 d/resaturated
Age when tested: 224 d
Sample mass: 66.0 mg
Filename: c152w35sealresatc204d
Date tested: Dec. 6, 2004

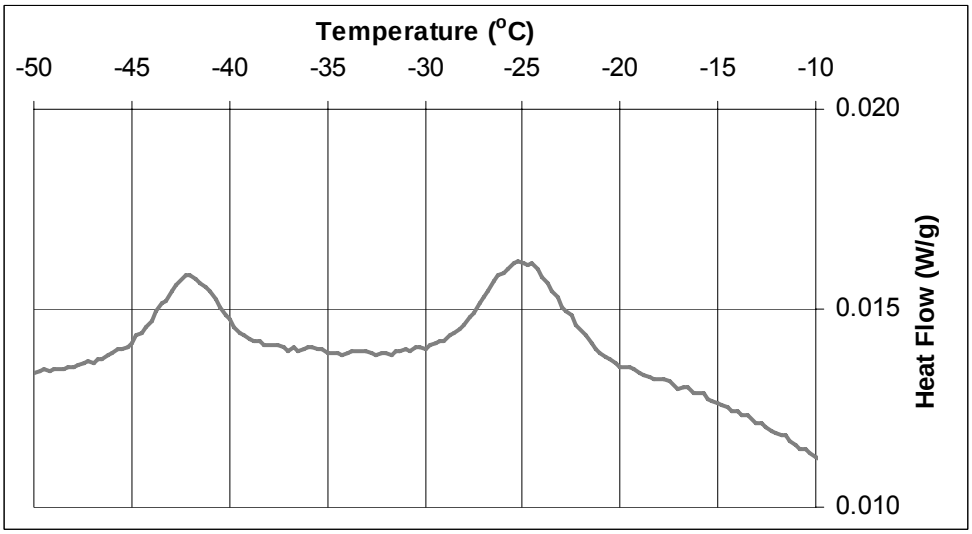

Figure 83 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 203 d under sealed conditions, then resaturated for 21 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 203 d/resaturated
Age when tested: 238 d
Sample mass: 75.3 mg
Filename: c152w35seal204resat2384d
Date tested: Dec. 20, 2004

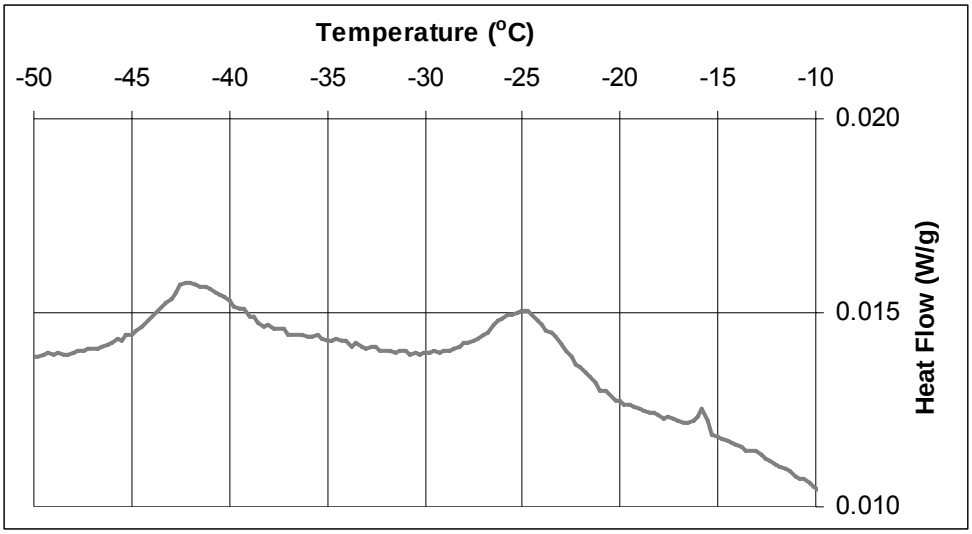

Figure 84 LTC scan for CCRL Cement 152, *w/c*=0.35, cured at 20 °C for 203 d under sealed conditions, then resaturated for 35 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 228 d
Sample mass: 52.9 mg
Filename: c152w35sat228d
Date tested: Dec. 10, 2004

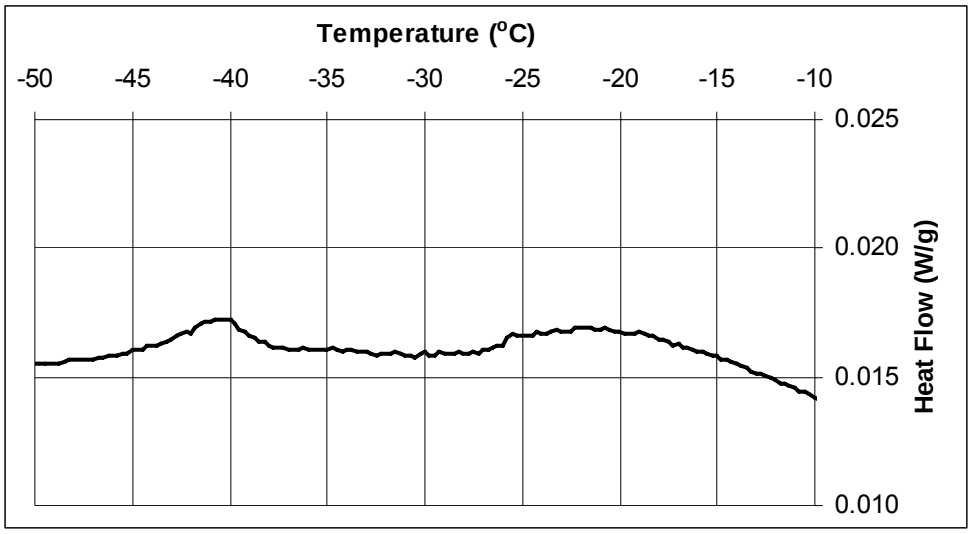

Figure 85 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 228 d at 20 °C under saturated conditions.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 7 d/resaturated
Age when tested: 228 d
Sample mass: 68.1 mg
Filename: c152w35sealsat228d
Date tested: Dec. 10, 2004

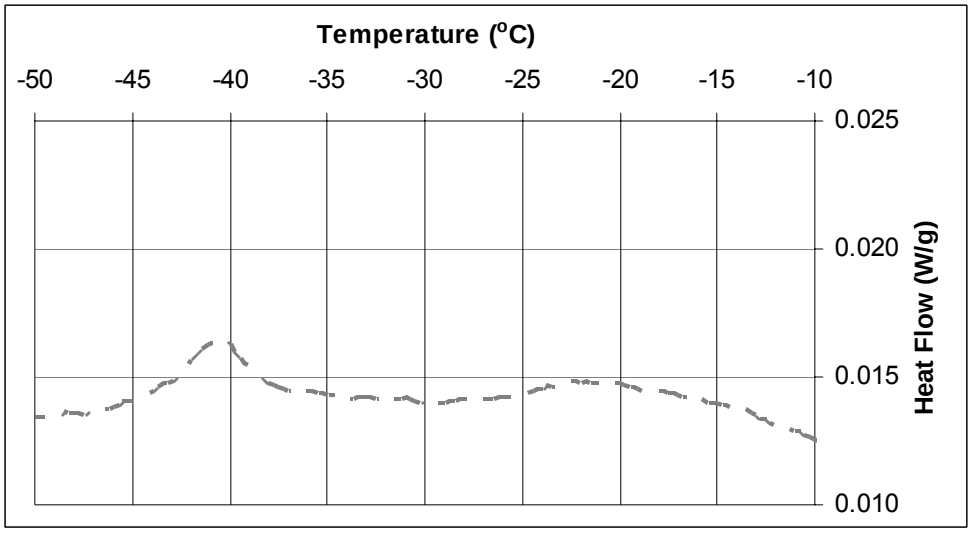

Figure 86 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 7 d at 20 °C under sealed conditions, then resaturated for 221 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.435
Temperature: 20 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 214 d
Sample mass: 48.7 mg
Filename: c152w45sat214d
Date tested: Oct. 29, 2004

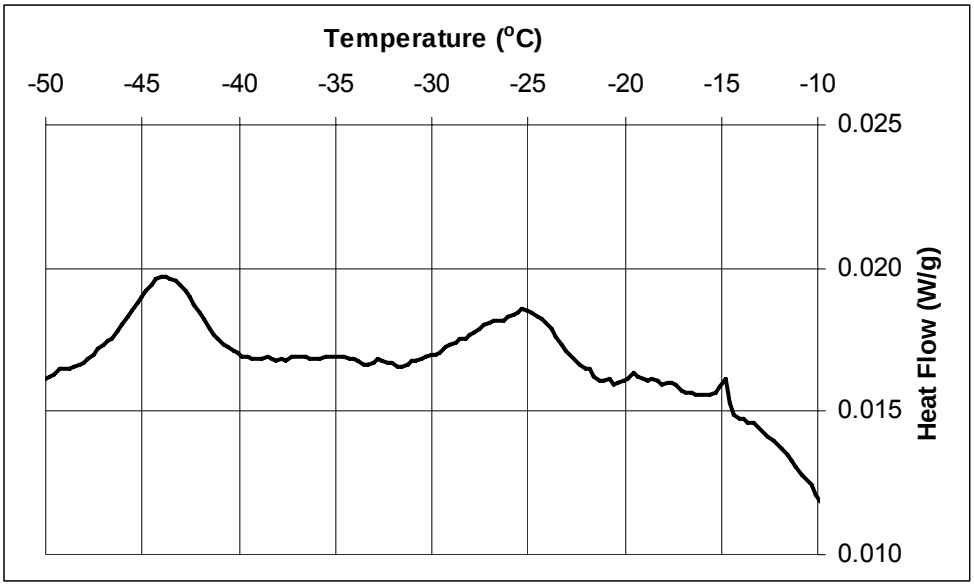

Figure 87 LTC scan for CCRL Cement 152, *w/c*=0.435, cured for 214 d at 20 °C under saturated conditions.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.435
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed
Age when tested: 214 d
Sample mass: 55.2 mg
Filename: c152w45seal214d
Date tested: Oct. 29, 2004

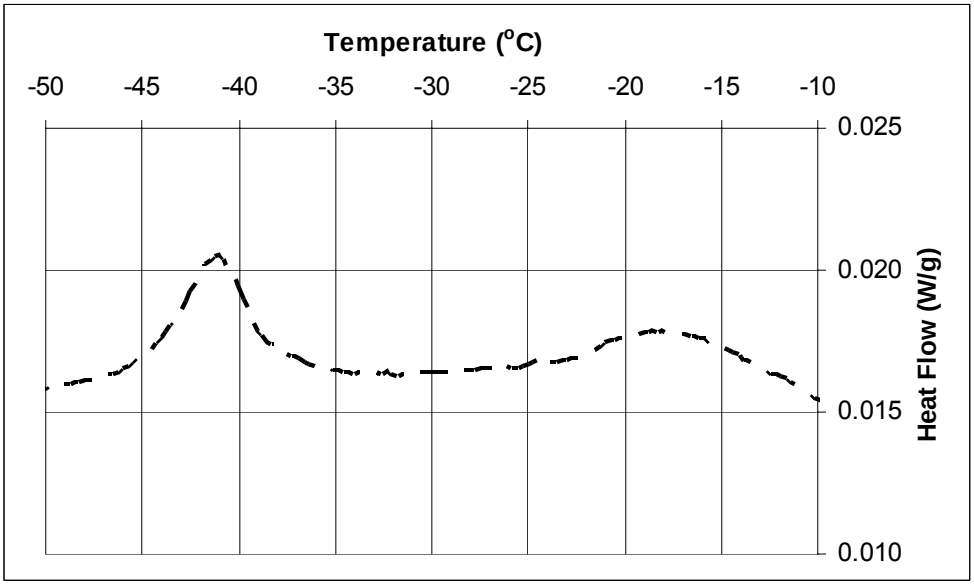

Figure 88 LTC scan for CCRL Cement 152, *w/c*=0.435, cured for 214 d at 20 °C under sealed conditions.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.435
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 7 d/resaturated
Age when tested: 214 d
Sample mass: 54.0 mg
Filename: c152w45sealsat214d
Date tested: Oct. 29, 2004

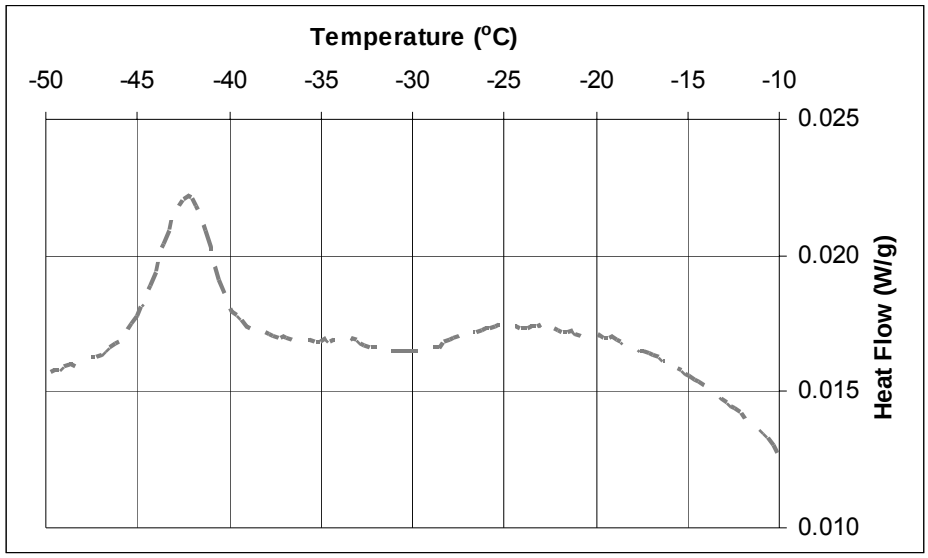

Figure 89 LTC scan for CCRL Cement 152, *w/c*=0.435, cured for 7 d at 20 °C under sealed conditions, then resaturated for 207 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.435
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 214 d/resaturated
Age when tested: 218 d
Sample mass: 60.0 mg
Filename: c152w45sealresat214d
Date tested: Nov. 2, 2004

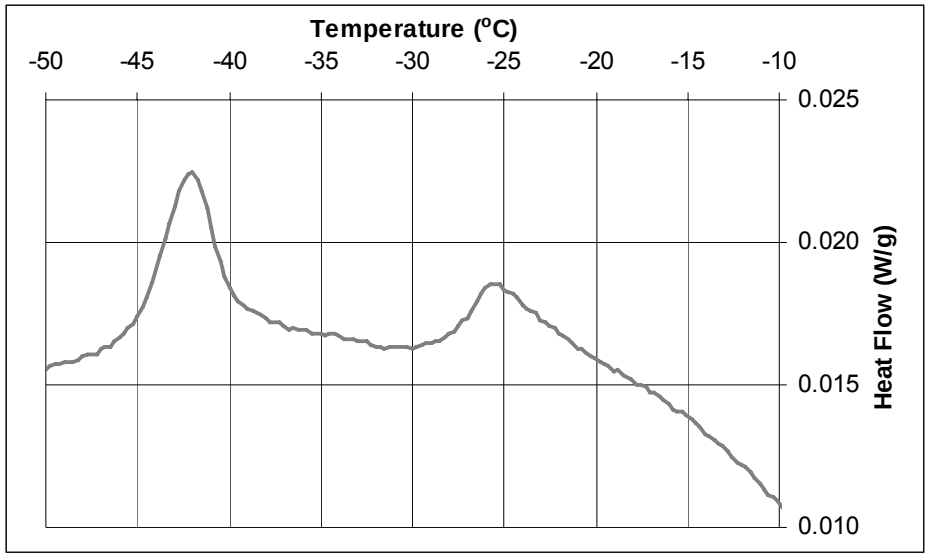

Figure 90 LTC scan for CCRL Cement 152, *w/c*=0.435, cured for 214 d at 20 °C under sealed conditions, then resaturated for 4 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.435
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 214 d/resaturated
Age when tested: 255 d
Sample mass: 51.6 mg
Filename: c152w45sealresatb214d
Date tested: Dec. 9, 2004

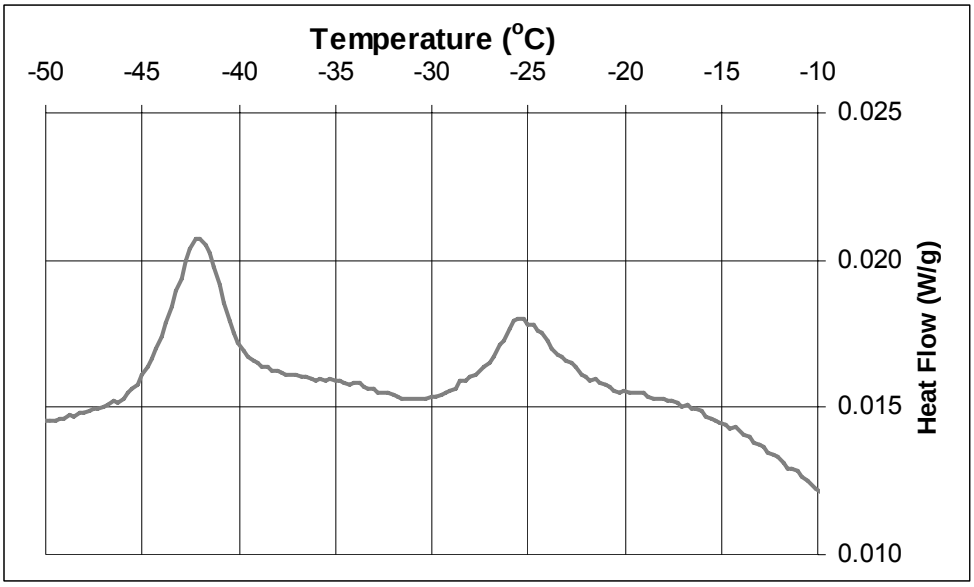

Figure 91 LTC scan for CCRL Cement 152, *w/c*=0.435, cured for 214 d at 20 °C under sealed conditions, then resaturated for 41 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.435
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 204 d/resaturated
Age when tested: 238 d
Sample mass: 75.3 mg
Filename: c152w35seal204resat238d
Date tested: Dec. 20, 2004

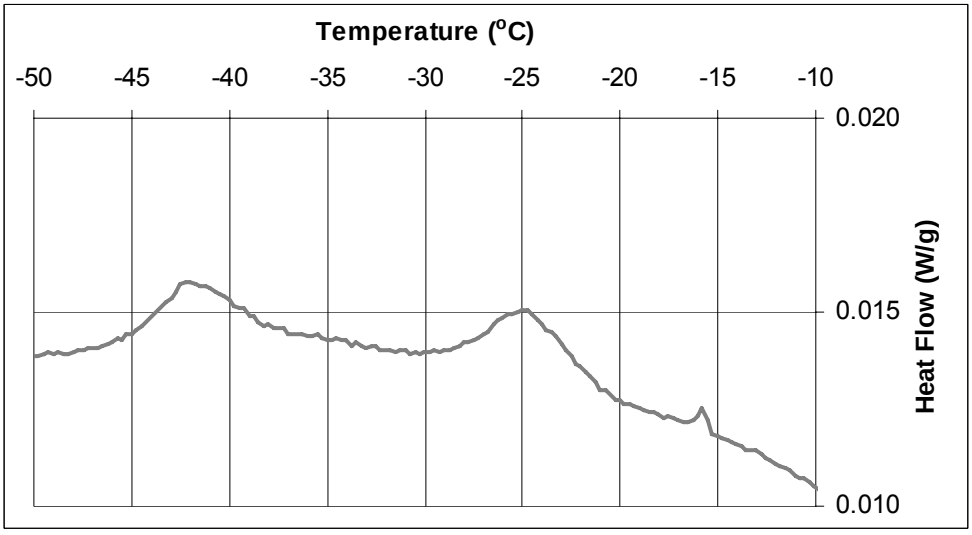

Figure 92 LTC scan for CCRL Cement 152, *w/c*=0.435, cured for 204 d at 20 °C under sealed conditions, then resaturated for 34 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.435
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed
Age when tested: 256 d
Sample mass: 44.0 mg
Filename: c152w435seal256d
Date tested: Dec. 10, 2004

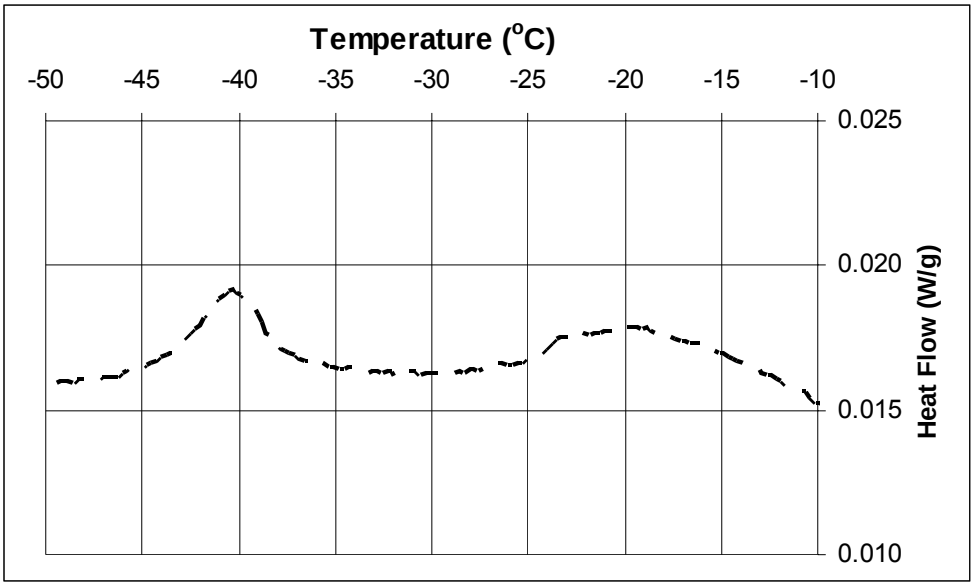

Figure 93 LTC scan for CCRL Cement 152, *w/c*=0.435, cured for 256 d at 20 °C under sealed conditions.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.435
Temperature: 20 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 276 d
Sample mass: 62.2 mg
Filename: c152w435sat276d
Date tested: Dec. 29, 2004

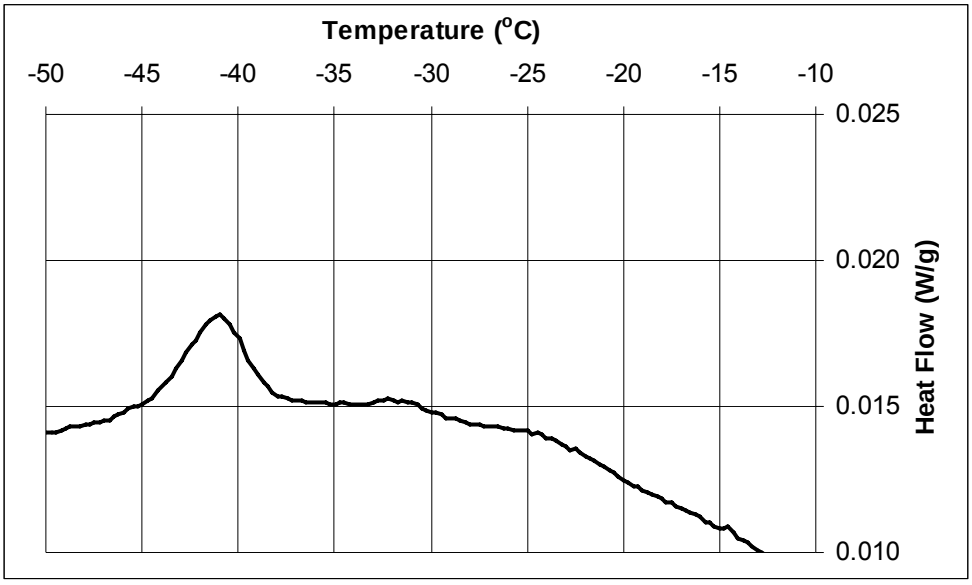

Figure 94 LTC scan for CCRL Cement 152, *w/c*=0.435, cured for 276 d at 20 °C under saturated conditions.

Cement: Cement 152 + 20 % limestone
Solution: Distilled water
w/s: 0.35
Temperature: 20 °C
Degree of hydration: 0.855

Curing: Saturated
Age when tested: 91 d
Sample mass: 59.6 mg
Filename: c152w35lf20sat91d
Date tested: Jan. 24, 2005

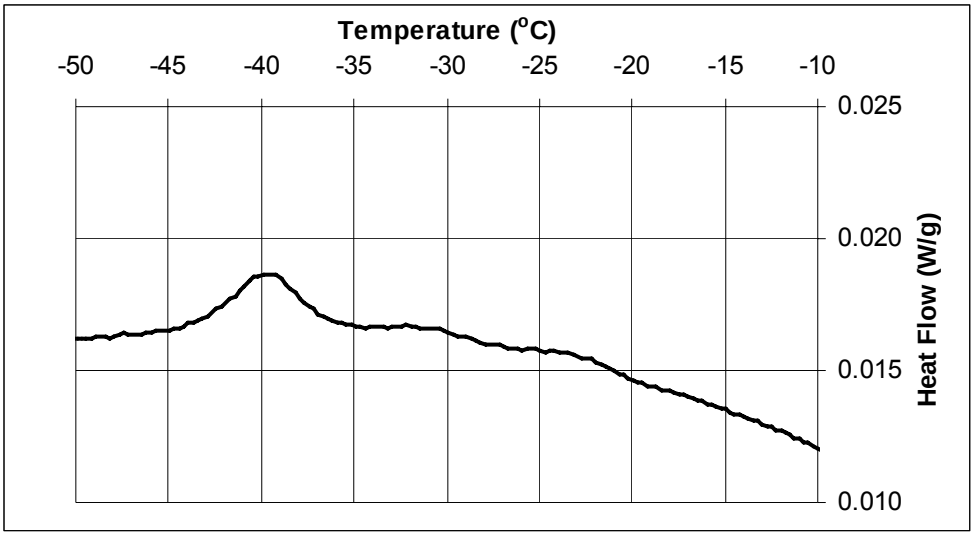

Figure 95 LTC scan for CCRL Cement 152 with 20 % limestone filler substitution, *w/s*=0.35, cured for 91 d at 20 °C under saturated conditions.

Cement: Cement 152 + 20 % limestone
Solution: Distilled water
w/s: 0.35
Temperature: 20 °C
Degree of hydration: 0.763

Curing: Sealed
Age when tested: 91 d
Sample mass: 36.5 mg
Filename: c152w35lf20seal91d
Date tested: Jan. 24, 2005

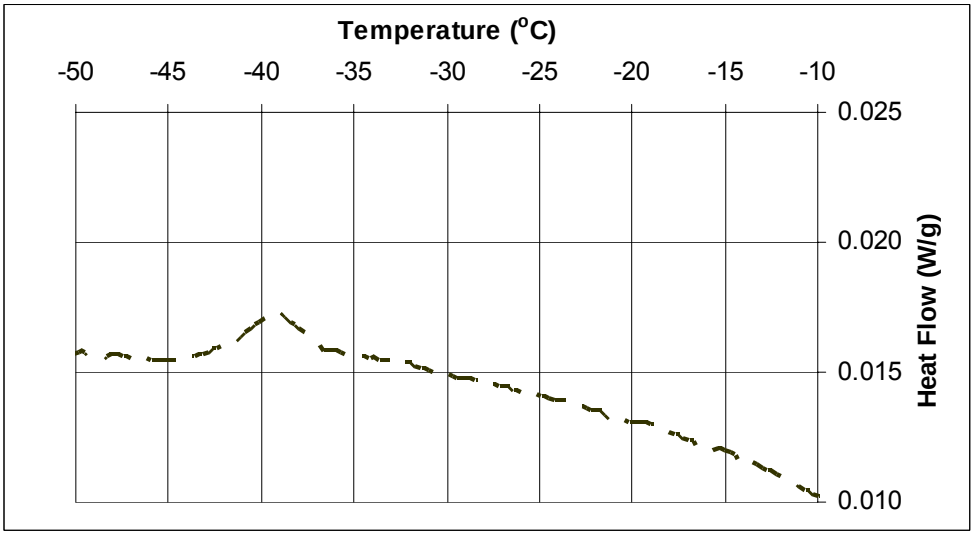

Figure 96 LTC scan for CCRL Cement 152 with 20 % limestone filler substitution, *w/s*=0.35, cured for 91 d at 20 °C under sealed conditions.

Cement: Cement 152 + 20 % limestone
Solution: Distilled water
w/s: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 91 d/resaturated
Age when tested: 92 d
Sample mass: 64.7 mg
Filename: c152w35lf20sealresat91d
Date tested: Jan. 25, 2005

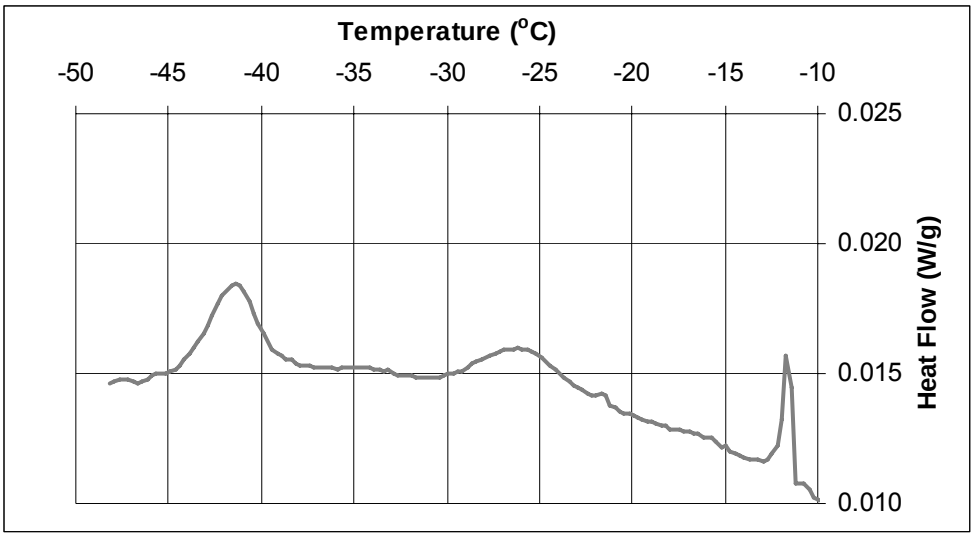

Figure 97 LTC scan for CCRL Cement 152 with 20 % limestone filler substitution, *w/s*=0.35, cured under sealed conditions for 91 d at 20 °C, then resaturated for 1 d.

Cement: Cement 152 + 20 % limestone
Solution: Distilled water
w/s: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 91 d/resaturated
Age when tested: 183 d
Sample mass: 40.5 mg
Filename: c152lf20w35sealresat91t182d
Date tested: April 26, 2005

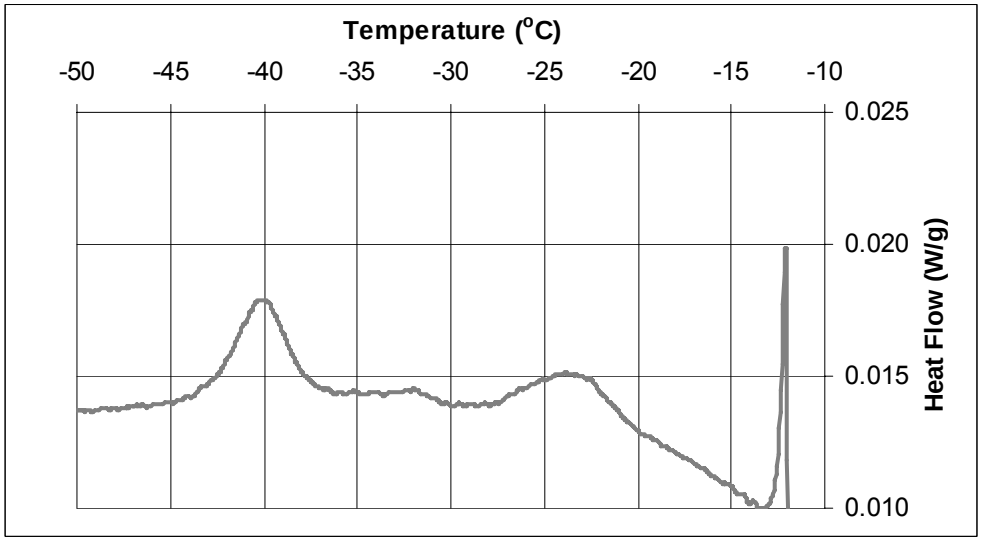

Figure 98 LTC scan for CCRL Cement 152 with 20 % limestone filler substitution, *w/s*=0.35, cured under sealed conditions for 91 d at 20 °C, then resaturated for 92 d.

Cement: Cement 152 + 20 % limestone
Solution: Distilled water
w/s: 0.35
Temperature: 20 °C
Degree of hydration: 0.907

Curing: Saturated
Age when tested: 183 d
Sample mass: 38.9 mg
Filename: c152lf20w35sat182d
Date tested: April 26, 2005

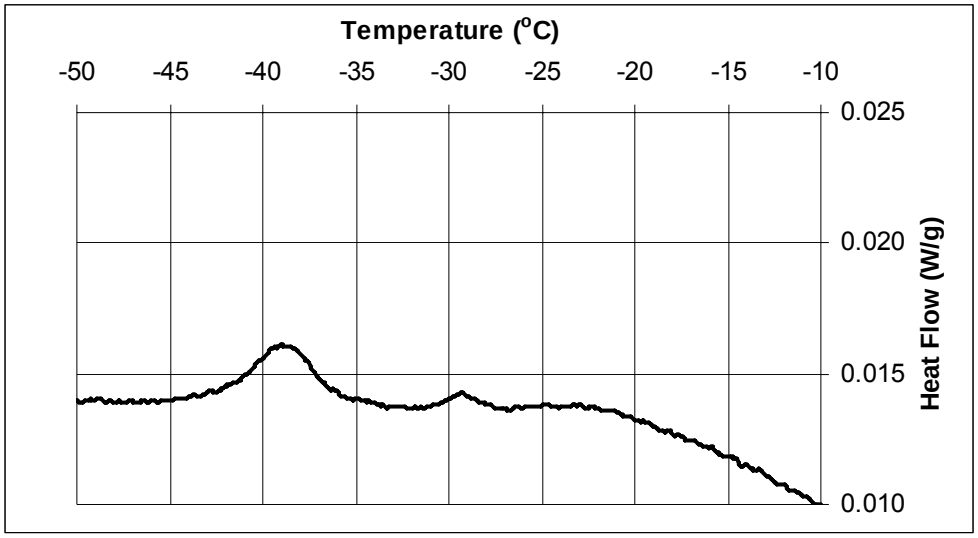

Figure 99 LTC scan for CCRL Cement 152 with 20 % limestone filler substitution, *w/s*=0.35, cured for 183 d at 20 °C under saturated conditions.

Cement: Cement 152 + 20 % limestone
Solution: Distilled water
w/s: 0.35
Temperature: 20 °C
Degree of hydration: 0.828

Curing: Sealed
Age when tested: 183 d
Sample mass: 65.8 mg
Filename: c152lf20w35seal182d
Date tested: April 26, 2005

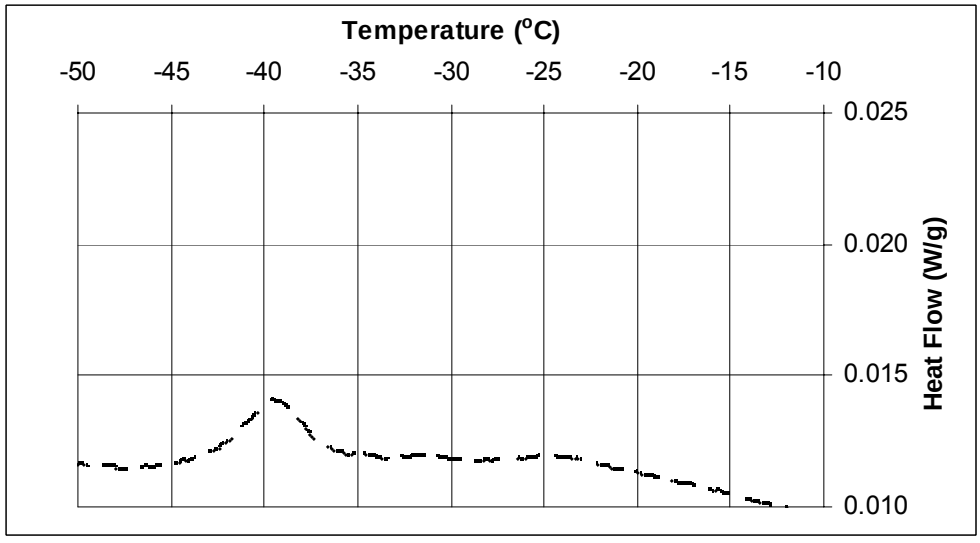

Figure 100 LTC scan for CCRL Cement 152 with 20 % limestone filler substitution, *w/s*=0.35, cured for 183 d at 20 °C under sealed conditions.

Cement: Cement 152 + 20 % limestone
Solution: Distilled water
w/s: 0.35
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 183 d/resaturated
Age when tested: 184 d
Sample mass: 64.7 mg
Filename: c152lf20w35sealresat182t183d
Date tested: April 27, 2005

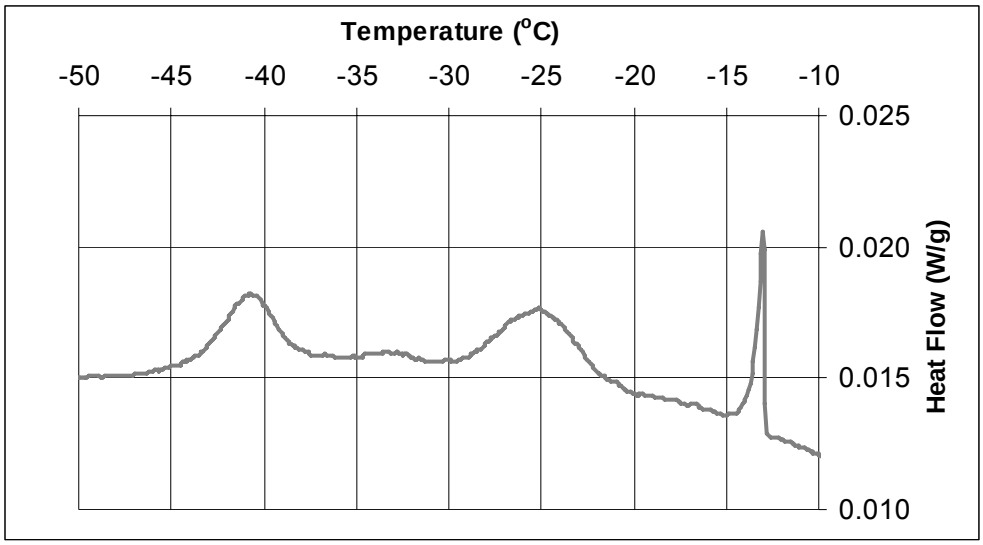

Figure 101 LTC scan for CCRL Cement 152 with 20 % limestone filler substitution, *w/s*=0.35, cured under sealed conditions for 183 d at 20 °C, then resaturated for 1 d.

Cement: Cement 152 + 20 % limestone
Solution: Distilled water
w/s: 0.435
Temperature: 20 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 213 d
Sample mass: 55.0 mg
Filename: c152w45lf20sat213d
Date tested: Dec. 23, 2004

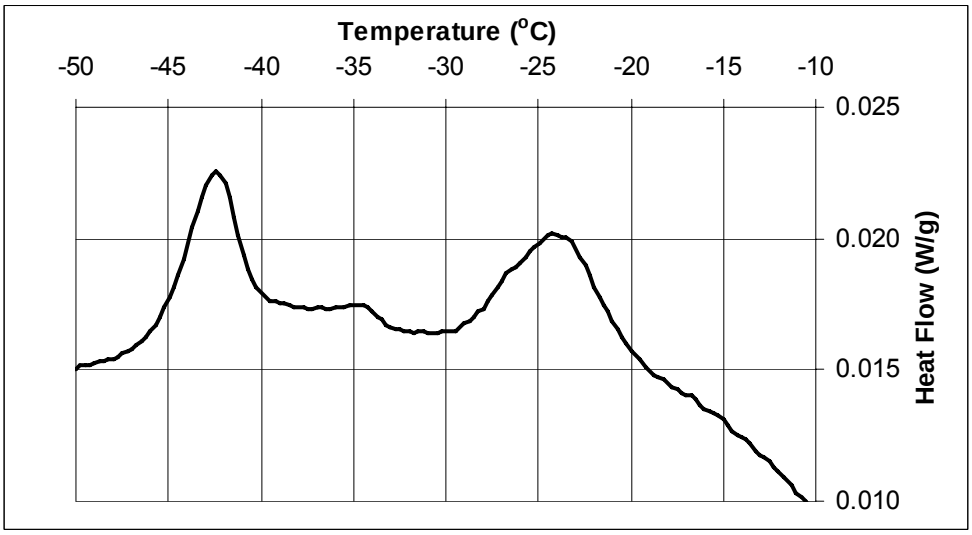

Figure 102 LTC scan for CCRL Cement 152 with 20 % limestone filler substitution, *w/s*=0.435, cured for 213 d at 20 °C under saturated conditions.

Cement: Cement 152 + 20 % limestone
Solution: Distilled water
w/s: 0.435
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed
Age when tested: 219 d
Sample mass: 57.9 mg
Filename: c152w45lfseal219d
Date tested: Dec. 29, 2004

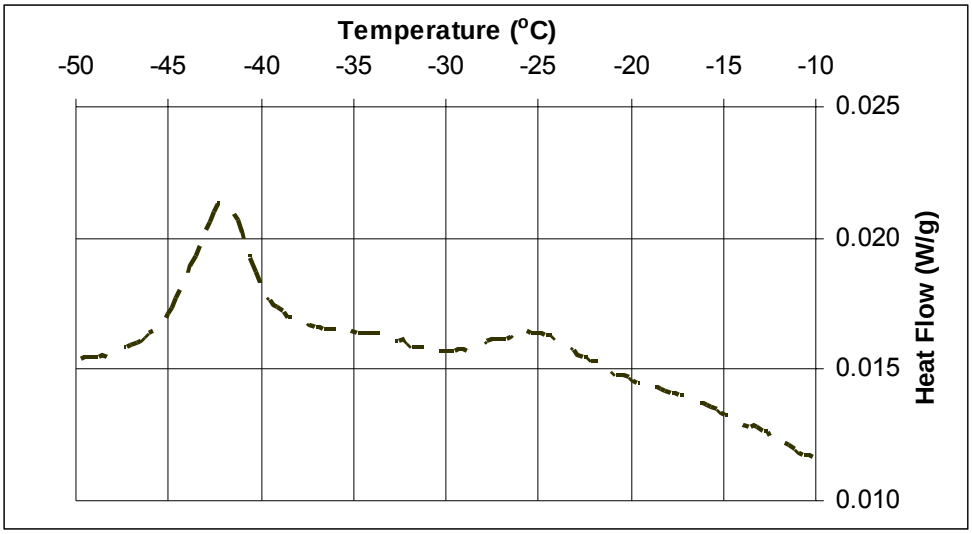

Figure 103 LTC scan for CCRL Cement 152 with 20 % limestone filler substitution, *w/s*=0.435, cured for 219 d at 20 °C under sealed conditions.

Cement: Cement 152 + 20 % limestone
Solution: Distilled water
w/s: 0.435
Temperature: 20 °C
Degree of hydration: N/A

Curing: Sealed 218 d/resaturated
Age when tested: 220 d
Sample mass: 67.5 mg
Filename: c152w45lfseal219d
Date tested: Dec. 29, 2004

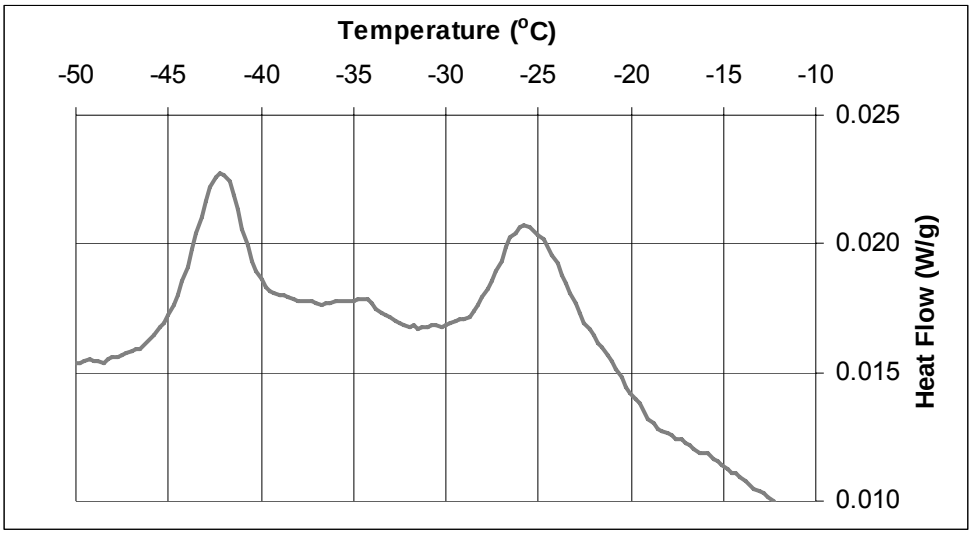

Figure 104 LTC scan for CCRL Cement 152 with 20 % limestone filler substitution, *w/s*=0.435, cured under sealed conditions for 218 d at 20 °C, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 40 °C
Degree of hydration: 0.303

Curing: Saturated
Age when tested: 8 h
Sample mass: 96.4 mg
Filename: c152w025T40Csat8h
Date tested: June 8, 2005

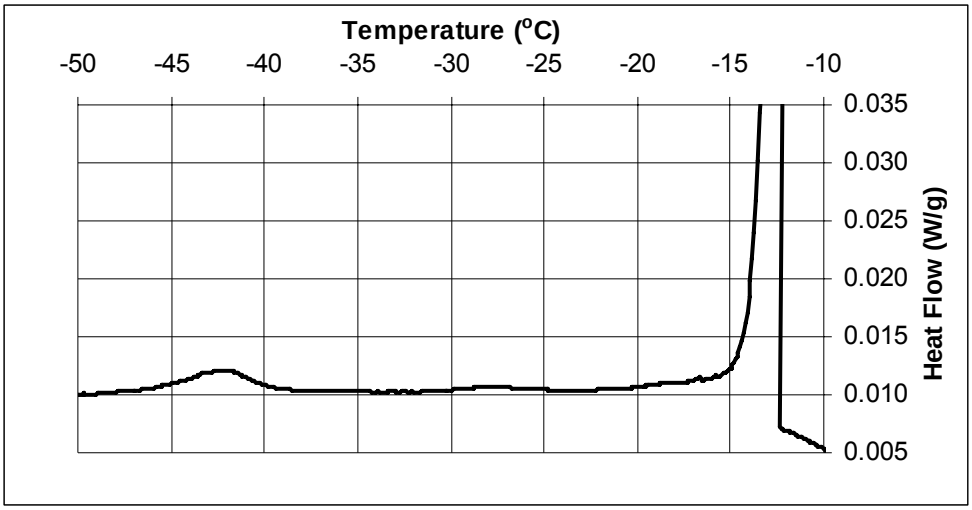

Figure 105 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 8 h under saturated conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 40 °C
Degree of hydration: 0.516

Curing: Saturated
Age when tested: 1 d
Sample mass: 56.8 mg
Filename: c152w025T40Csat1d
Date tested: June 1, 2005

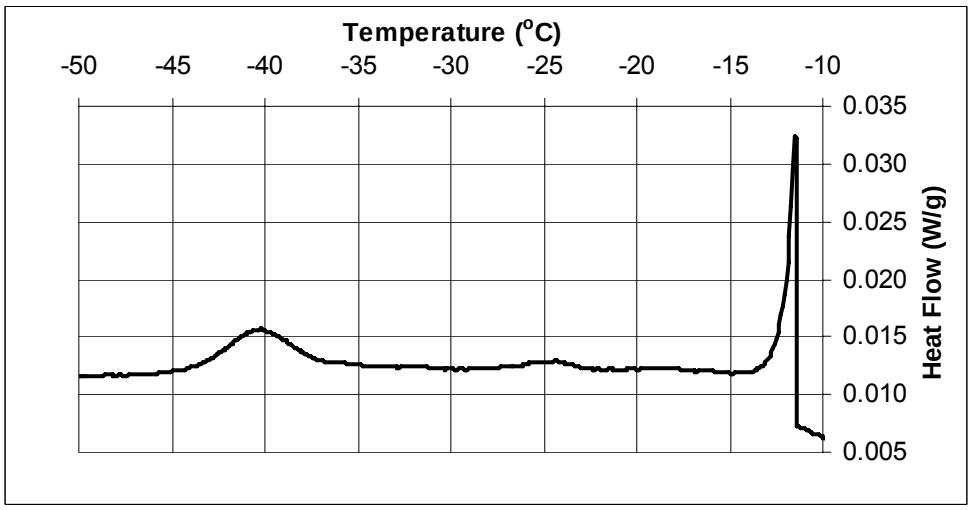

Figure 106 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 1 d under saturated conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 40 °C
Degree of hydration: 0.439

Curing: Sealed
Age when tested: 1 d
Sample mass: 55.5 mg
Filename: c152w025T40Cseal1d
Date tested: June 1, 2005

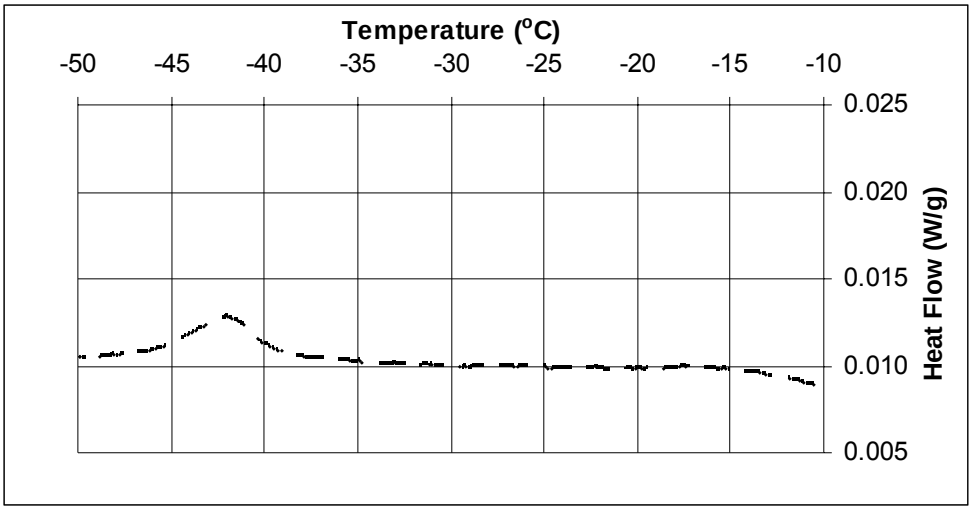

Figure 107 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 1 d under sealed conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 40 °C
Degree of hydration: 0.596

Curing: Saturated
Age when tested: 2 d
Sample mass: 56.3 mg
Filename: c152w025T40Csat2d
Date tested: June 2, 2005

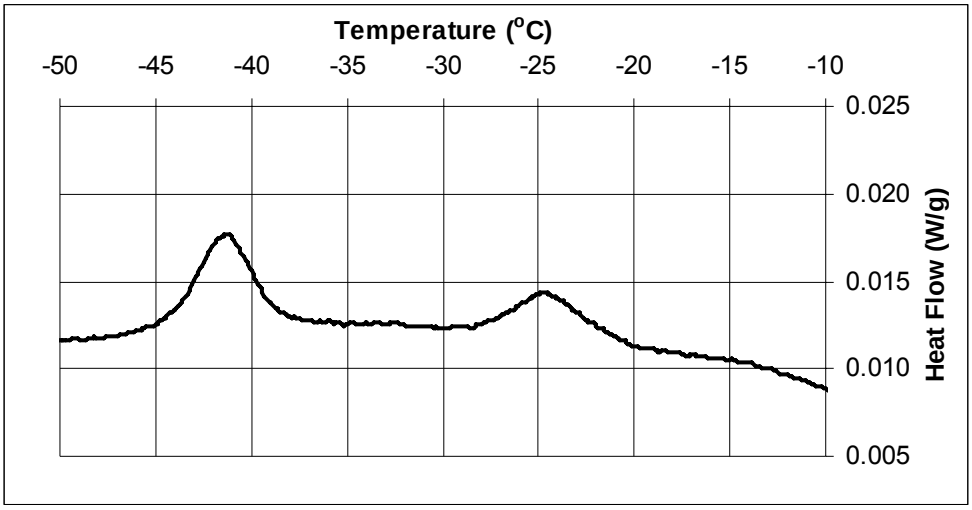

Figure 108 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 2 d under saturated conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 40 °C
Degree of hydration: 0.451

Curing: Sealed
Age when tested: 2 d
Sample mass: 32.4 mg
Filename: c152w025T40Cseal2d
Date tested: June 2, 2005

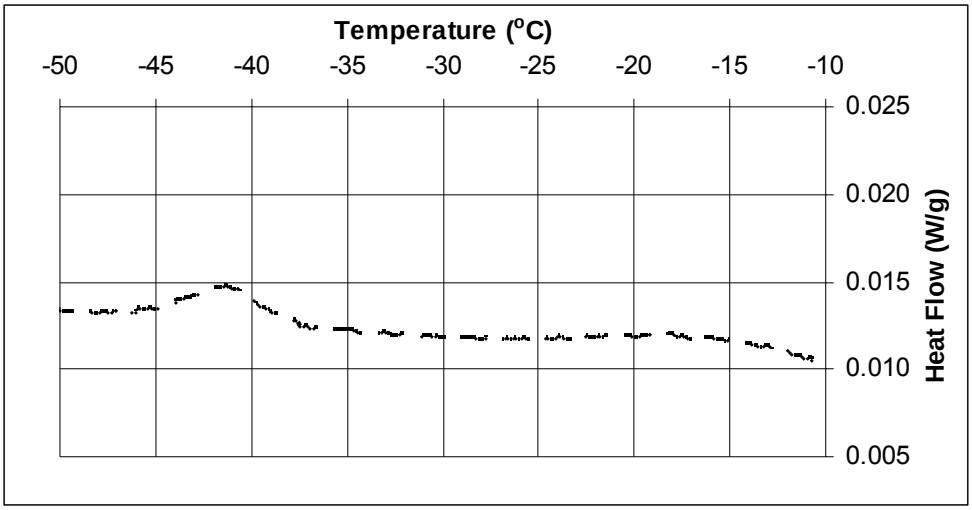

Figure 109 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 2 d under sealed conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 40 °C
Degree of hydration: N/A

Curing: Sealed 1 d/resaturated
Age when tested: 2 d
Sample mass: 50.5 mg
Filename: c152w025T40Csealresat1t2d
Date tested: June 2, 2005

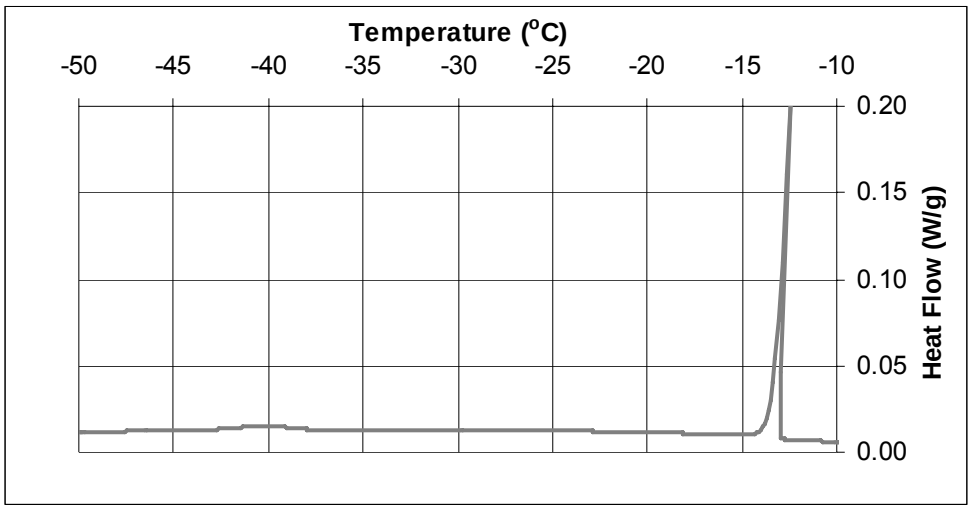

Figure 110 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 1 d at 40 °C under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 40 °C
Degree of hydration: 0.620

Curing: Saturated
Age when tested: 3 d
Sample mass: 44.0 mg
Filename: c152w025T40Csat3d
Date tested: June 3, 2005

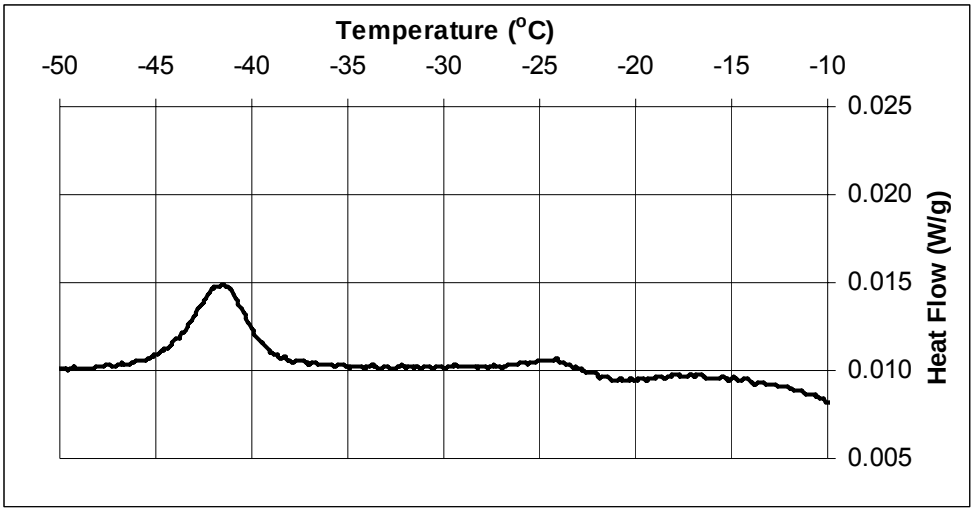

Figure 111 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 3 d under saturated conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 40 °C
Degree of hydration: 0.467

Curing: Sealed
Age when tested: 3 d
Sample mass: 40.0 mg
Filename: c152w025T40Cseal3d
Date tested: June 3, 2005

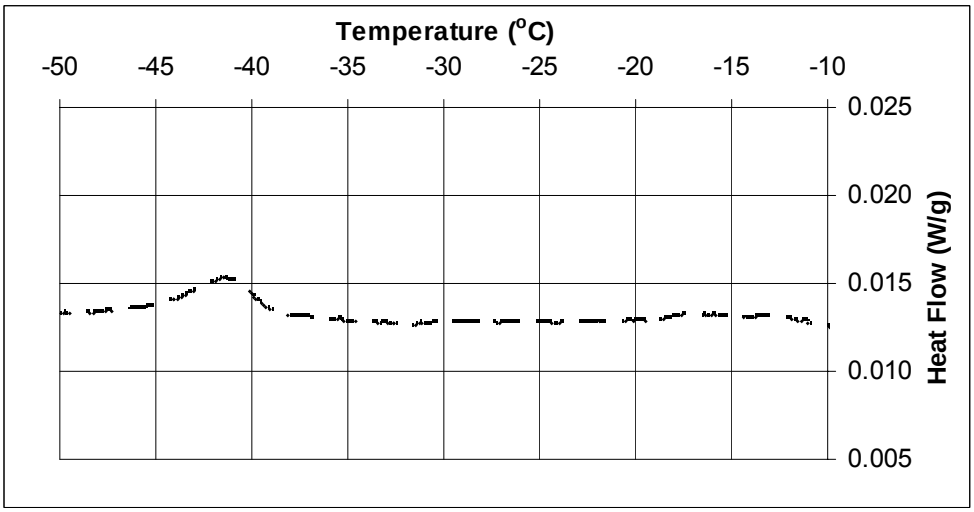

Figure 112 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 3 d under sealed conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 40 °C
Degree of hydration: N/A

Curing: Sealed 2 d/resaturated
Age when tested: 3 d
Sample mass: 40.3 mg
Filename: c152w025T40Csealresat2t3d
Date tested: June 3, 2005

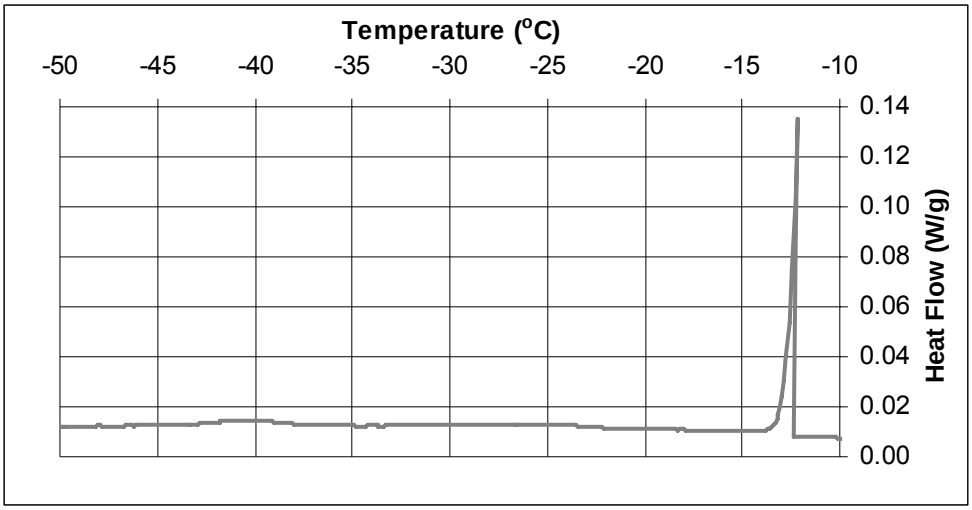

Figure 113 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 2 d at 40 °C under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 40 °C
Degree of hydration: N/A

Curing: Sealed 3 d/resaturated
Age when tested: 4 d
Sample mass: 35.2 mg
Filename: c152w025T40Csealresat3t4d
Date tested: June 4, 2005

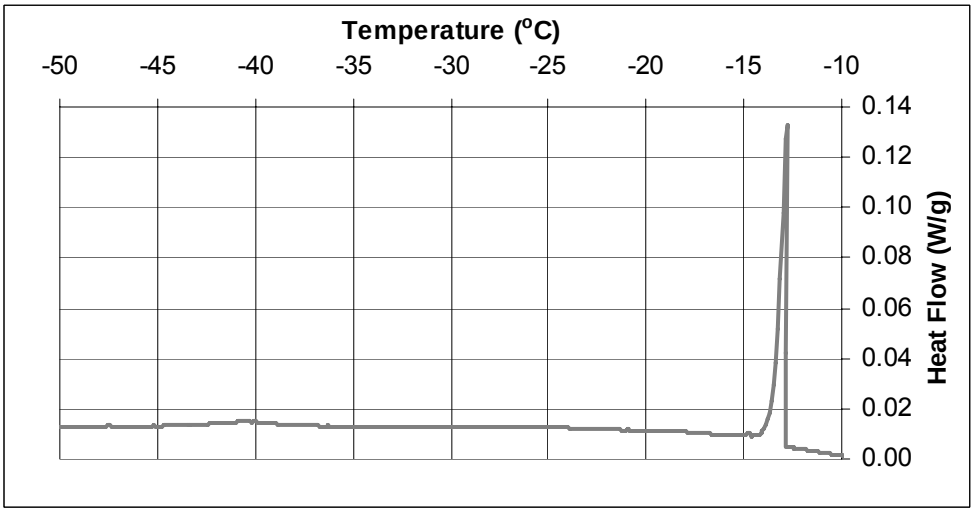

Figure 114 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 3 d at 40 °C under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 40 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 14 d
Sample mass: 48.9 mg
Filename: c152w025T40Csat14d
Date tested: June 22, 2005

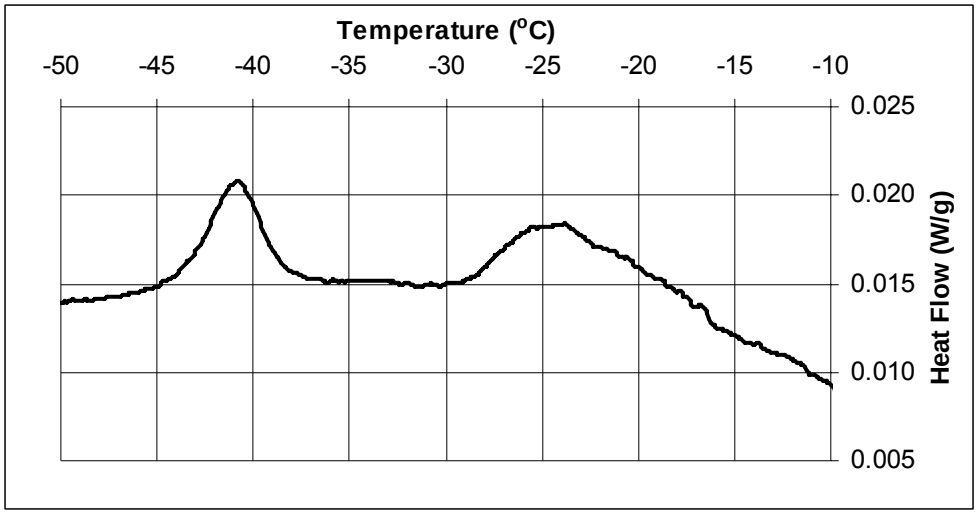

Figure 115 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 14 d under saturated conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 40 °C
Degree of hydration: N/A

Curing: Sealed
Age when tested: 14 d
Sample mass: 55.0 mg
Filename: c152w025T40Cseal14d
Date tested: June 22, 2005

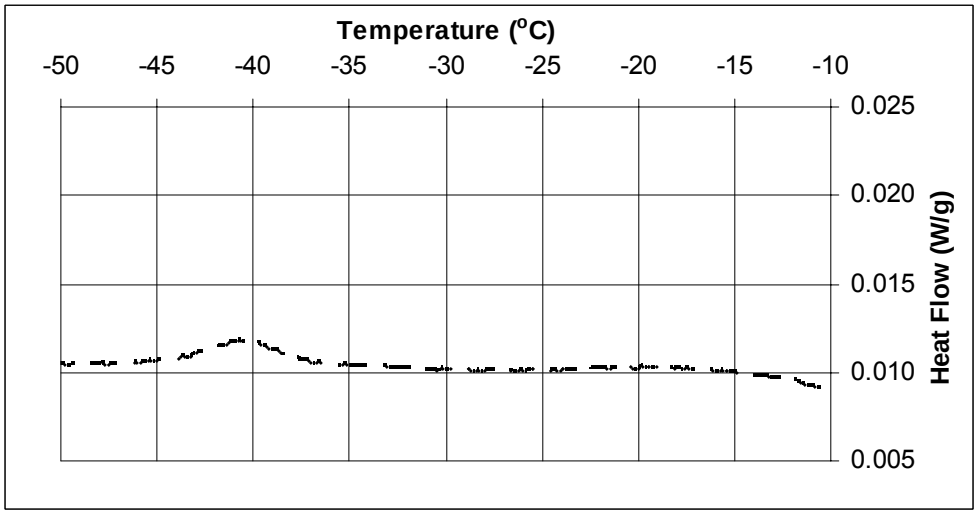

Figure 116 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 14 d under sealed conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 40 °C
Degree of hydration: N/A

Curing: Sealed 14 d/resaturated
Age when tested: 15 d
Sample mass: 58.7 mg
Filename: c152w025T40Csealresat14t15d
Date tested: June 23, 2005

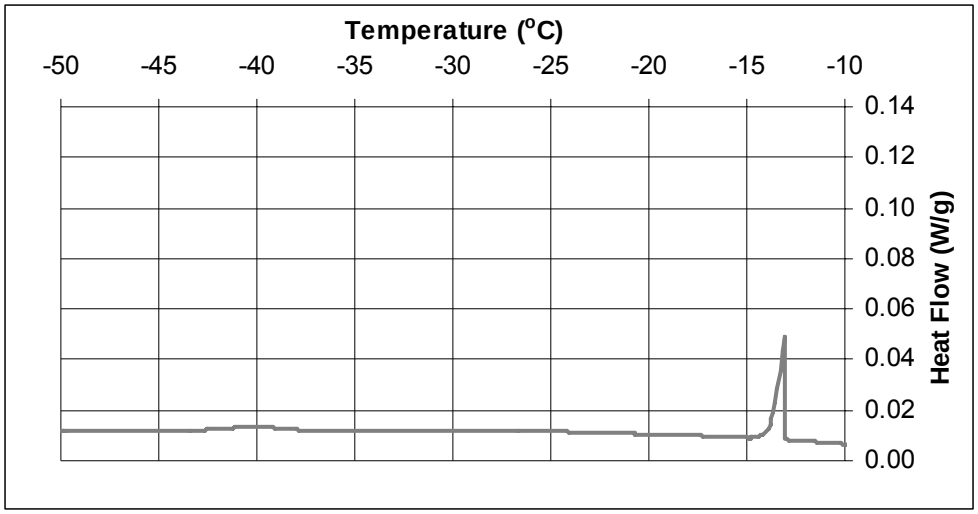

Figure 117 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 14 d at 40 °C under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 40 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 28 d
Sample mass: 61.8 mg
Filename: c152w025T40Csat28d
Date tested: July 6, 2005

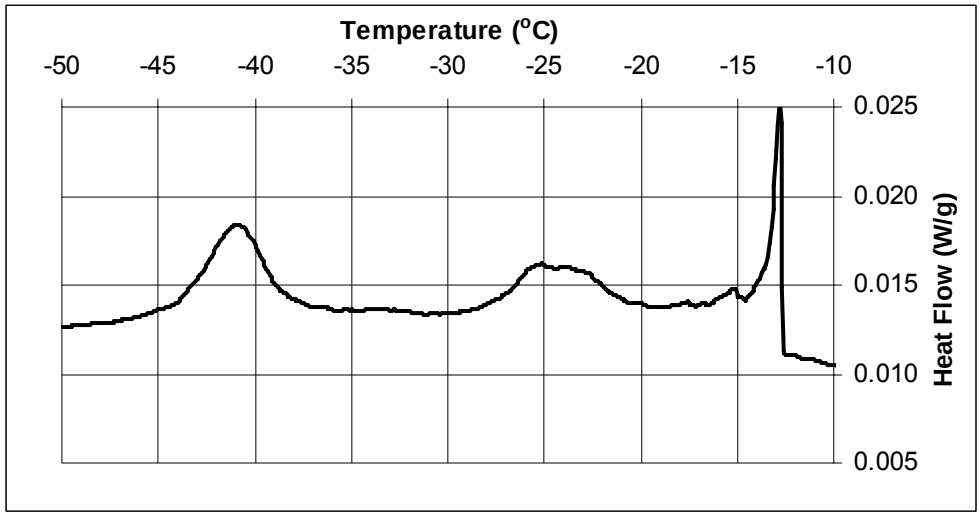

Figure 118 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 28 d under saturated conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 40 °C
Degree of hydration: N/A

Curing: Sealed
Age when tested: 28 d
Sample mass: 43.4 mg
Filename: c152w025T40Cseal28d
Date tested: July 6, 2005

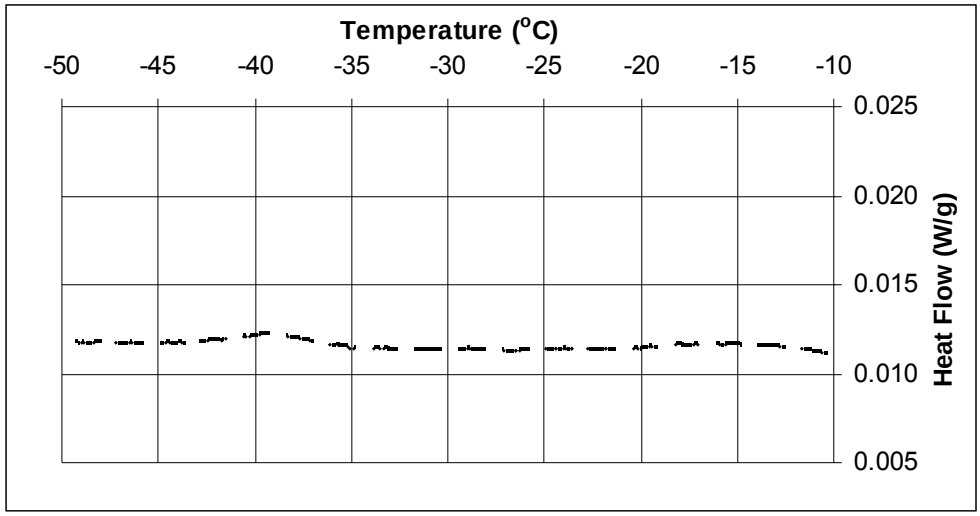

Figure 119 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 28 d under sealed conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.25
Temperature: 40 °C
Degree of hydration: N/A

Curing: Sealed 28 d/resaturated
Age when tested: 29 d
Sample mass: 59.8 mg
Filename: c152w025T40Csealresat28t29d
Date tested: July 7, 2005

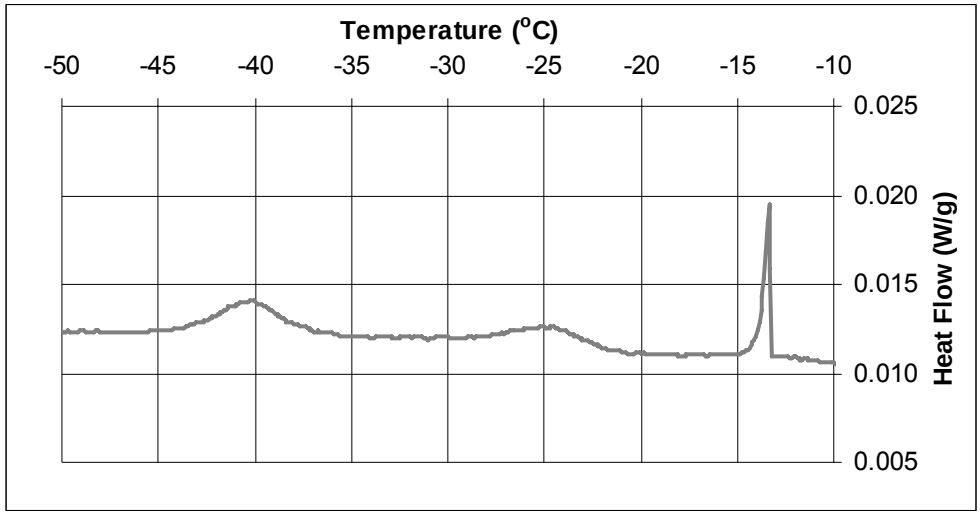

Figure 120 LTC scan for CCRL Cement 152, *w/c*=0.25, cured for 28 d at 40 °C under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 40 °C
Degree of hydration: 0.516

Curing: Saturated
Age when tested: 1 d
Sample mass: 70.0 mg
Filename: c152w35T40sat1d
Date tested: Jan. 12, 2005

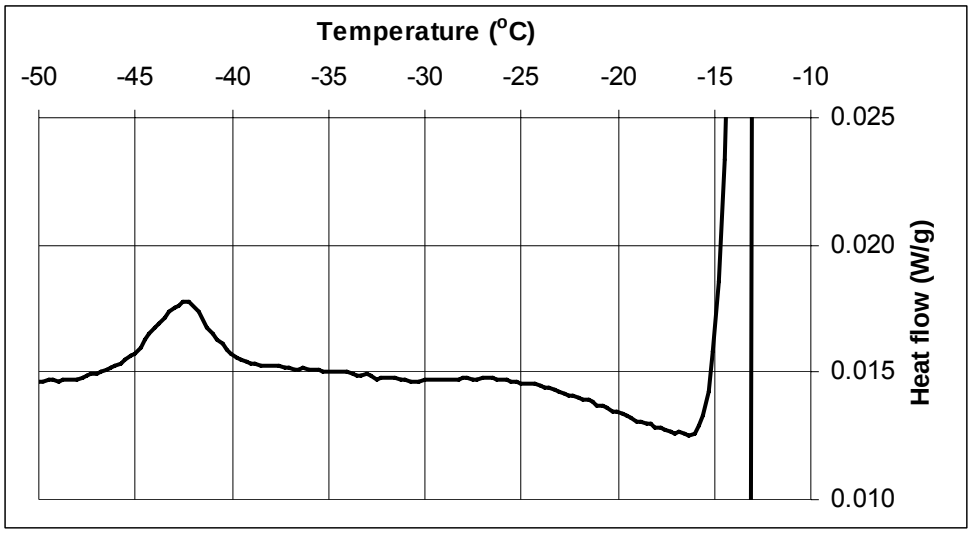

Figure 121 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 1 d under saturated conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 40 °C
Degree of hydration: 0.504

Curing: Sealed
Age when tested: 1 d
Sample mass: 43.5 mg
Filename: c152w35T40seal1d
Date tested: Jan. 12, 2005

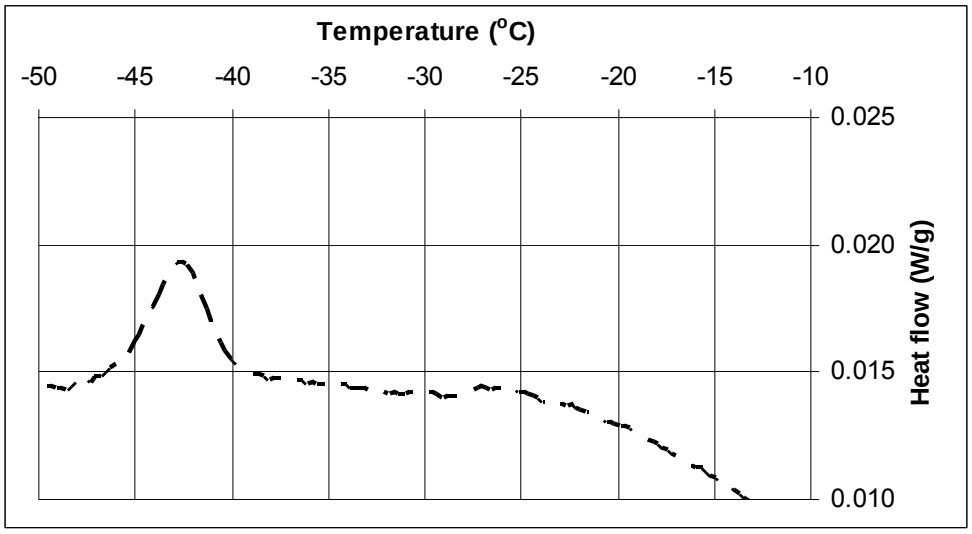

Figure 122 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 1 d under sealed conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 40 °C
Degree of hydration: N/A

Curing: Sealed 1 d/resaturated
Age when tested: 2 d
Sample mass: 38.3 mg
Filename: c152w35T40sealresat1d
Date tested: Jan. 13, 2005

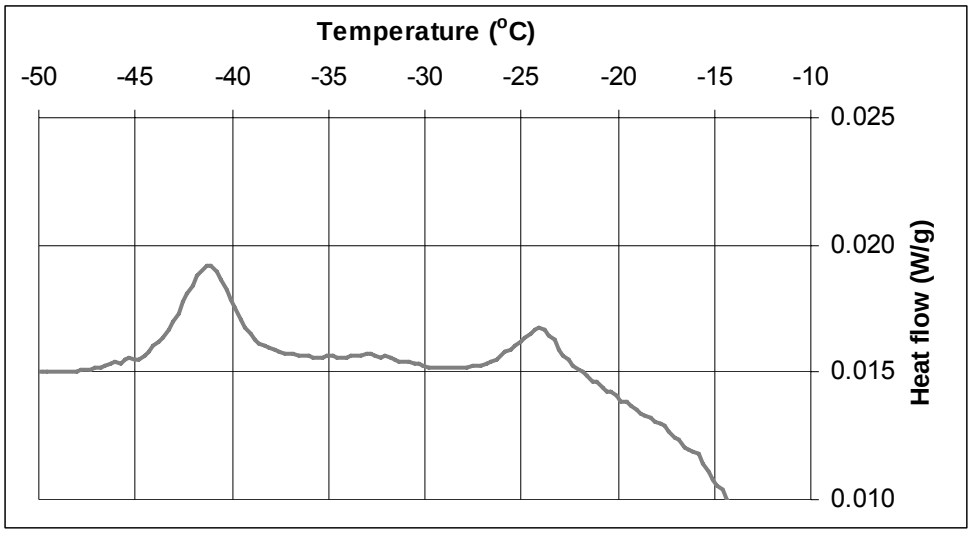

Figure 123 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 1 d at 40 °C under sealed conditions, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 40 °C
Degree of hydration: N/A

Curing: Sealed 1 d/resaturated
Age when tested: 3 d
Sample mass: 85.7 mg
Filename: c152w35T40sealresatb1d
Date tested: Jan. 14, 2005

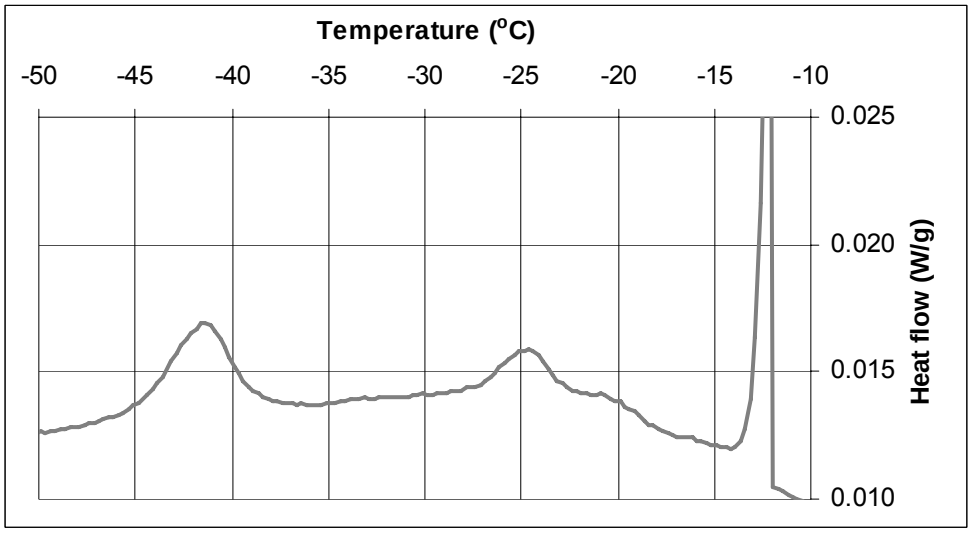

Figure 124 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 1 d at 40 °C under sealed conditions, then resaturated for 2 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 40 °C
Degree of hydration: 0.655

Curing: Saturated
Age when tested: 2 d
Sample mass: 52.8 mg
Filename: c152w35T40sat2d
Date tested: Jan. 13, 2005

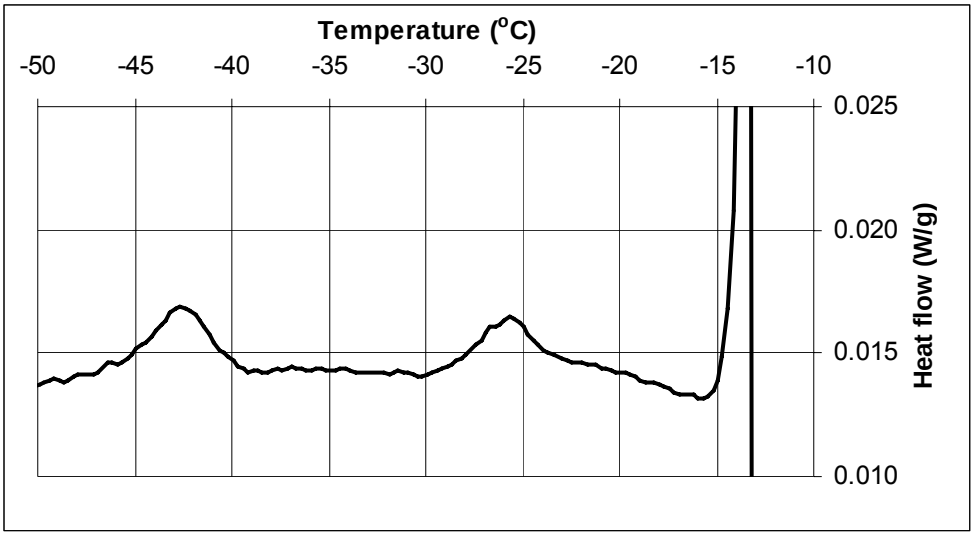

Figure 125 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 2 d under saturated conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 40 °C
Degree of hydration: 0.589

Curing: Sealed
Age when tested: 2 d
Sample mass: 77.3 mg
Filename: c152w35T40seal2d
Date tested: Jan. 13, 2005

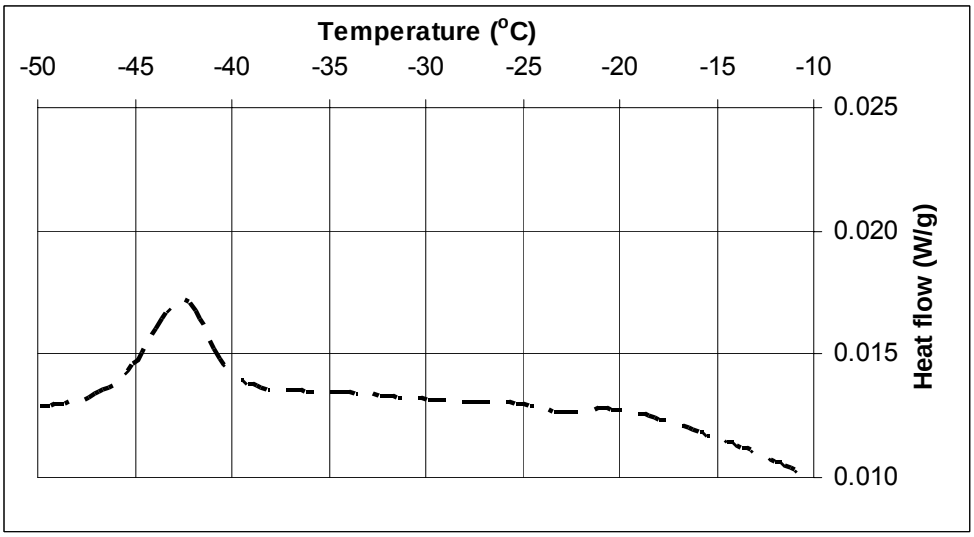

Figure 126 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 2 d under sealed conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 40 °C
Degree of hydration: 0.738

Curing: Saturated
Age when tested: 7 d
Sample mass: 77.3 mg
Filename: c152w35T40sat7d
Date tested: Jan. 18, 2005

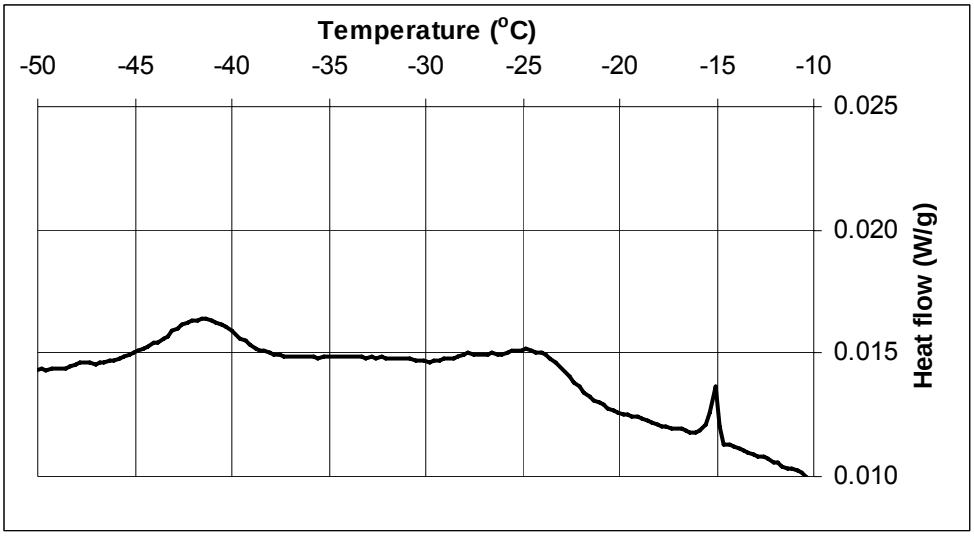

Figure 127 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 7 d under saturated conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 40 °C
Degree of hydration: 0.642

Curing: Sealed
Age when tested: 7 d
Sample mass: 50.9 mg
Filename: c152w35T40seal7d
Date tested: Jan. 18, 2005

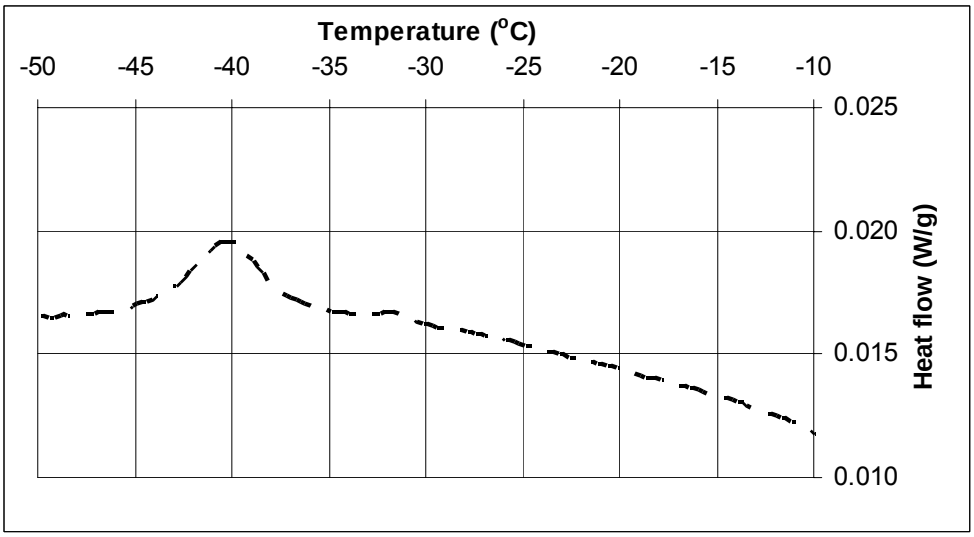

Figure 128 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 7 d under sealed conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 40 °C
Degree of hydration: N/A

Curing: Sealed 2 d/resaturated
Age when tested: 7 d
Sample mass: 76.8 mg
Filename: c152w35T40sealresat2t7d
Date tested: Jan. 18, 2005

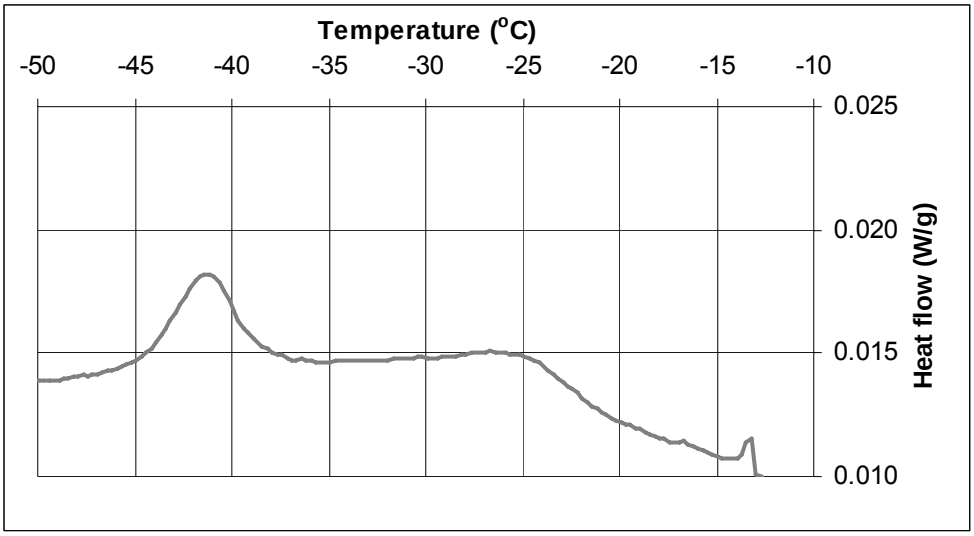

Figure 129 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 2 d under sealed conditions at 40 °C, then resaturated for 5 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 40 °C
Degree of hydration: N/A

Curing: Sealed 7 d/resaturated
Age when tested: 13 d
Sample mass: 52.7 mg
Filename: c152w35T40sealresat7t13d
Date tested: Jan. 24, 2005

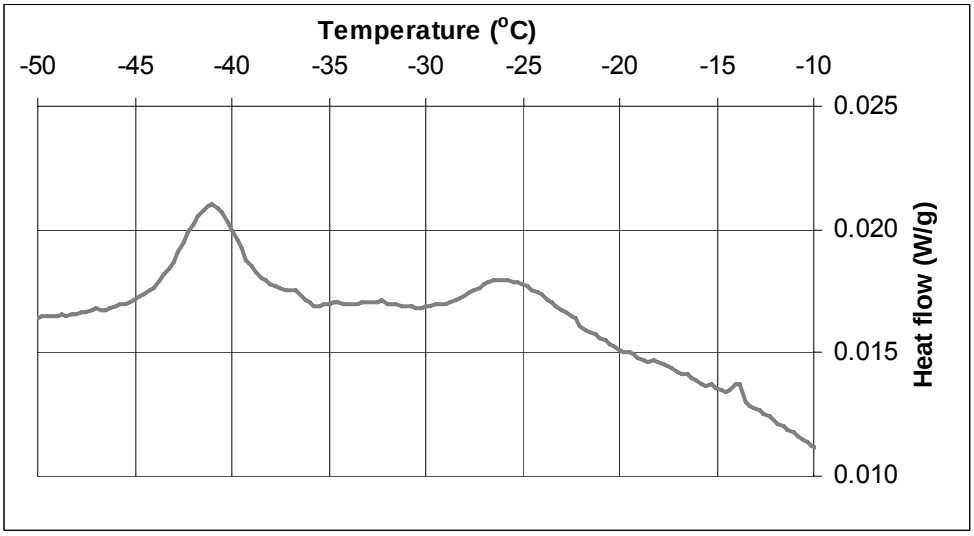

Figure 130 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 7 d under sealed conditions at 40 °C, then resaturated for 6 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 40 °C
Degree of hydration: 0.761

Curing: Saturated
Age when tested: 14 d
Sample mass: 60.8 mg
Filename: c152w35T40sat14d
Date tested: Jan. 25, 2005

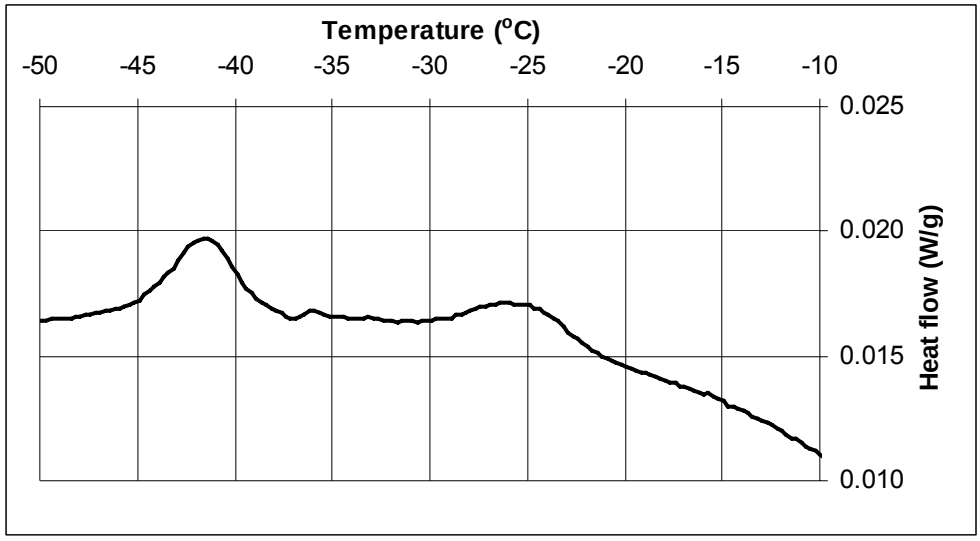

Figure 131 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 14 d under saturated conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 40 °C
Degree of hydration: 0.645

Curing: Sealed
Age when tested: 14 d
Sample mass: 62.7 mg
Filename: c152w35T40seal14d
Date tested: Jan. 25, 2005

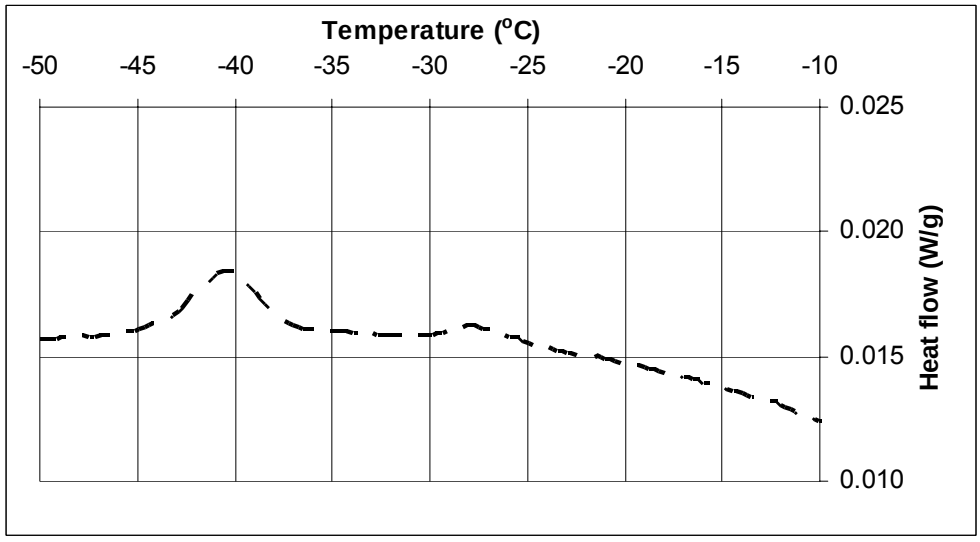

Figure 132 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 14 d under sealed conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 40 °C
Degree of hydration: 0.824

Curing: Saturated
Age when tested: 28 d
Sample mass: 97.0 mg
Filename: c152w35T40sat28d
Date tested: Feb. 8, 2005

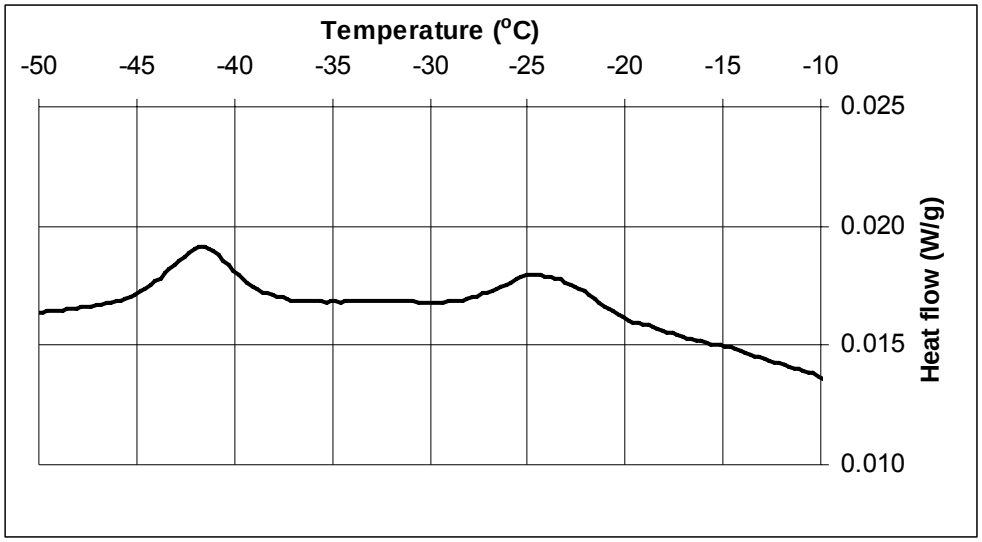

Figure 133 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 28 d under saturated conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 40 °C
Degree of hydration: 0.681

Curing: Sealed
Age when tested: 28 d
Sample mass: 80.2 mg
Filename: c152w035a40Cseal28d
Date tested: Feb. 8, 2005

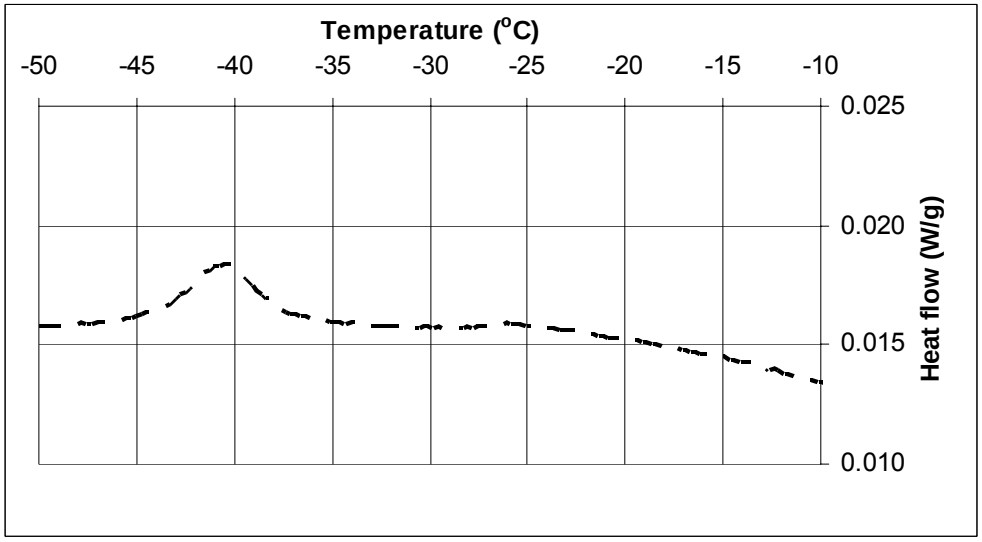

Figure 134 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 28 d under sealed conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 40 °C
Degree of hydration: N/A

Curing: Sealed 14 d/resaturated
Age when tested: 29 d
Sample mass: 51.3 mg
Filename: c152w35T40seal14resat29d
Date tested: Feb. 9, 2005

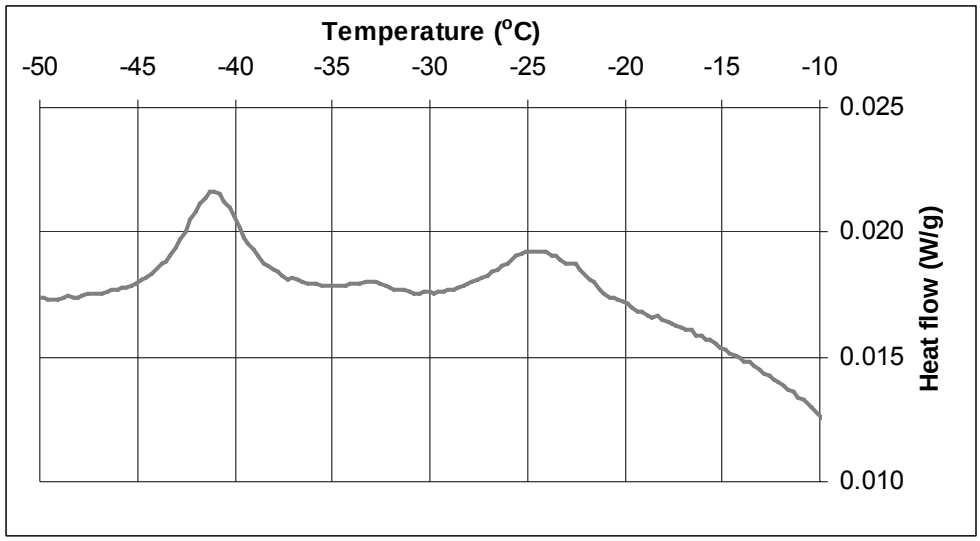

Figure 135 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 14 d under sealed conditions at 40 °C, then resaturated for 15 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 40 °C
Degree of hydration: N/A

Curing: Sealed 28 d/resaturated
Age when tested: 29 d
Sample mass: 61.5 mg
Filename: c152w35T40Csealresat28d
Date tested: Feb. 9, 2005

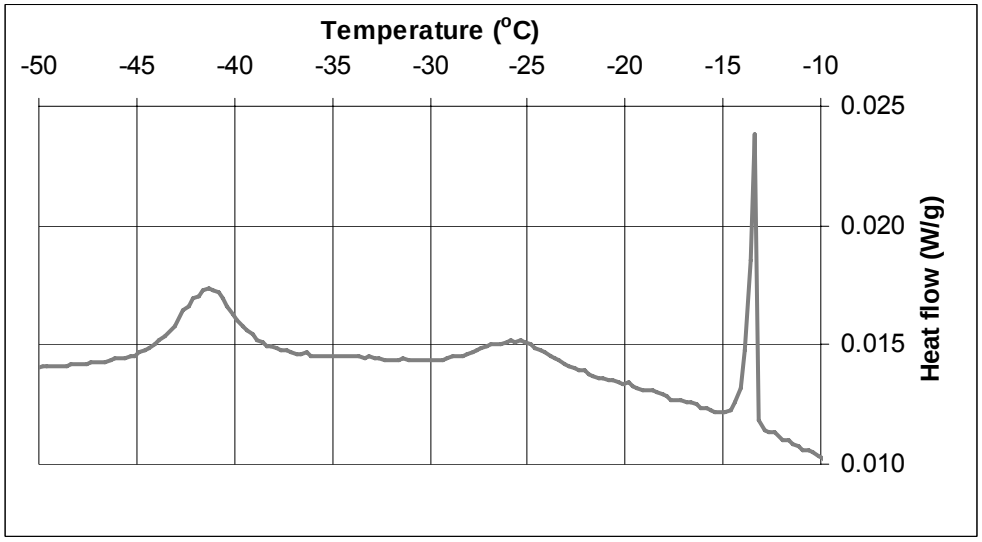

Figure 136 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 28 d under sealed conditions at 40 °C, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 40 °C
Degree of hydration: 0.794

Curing: Saturated
Age when tested: 58 d
Sample mass: 57.3 mg
Filename: c152w035T40Csat58d
Date tested: March 10, 2005

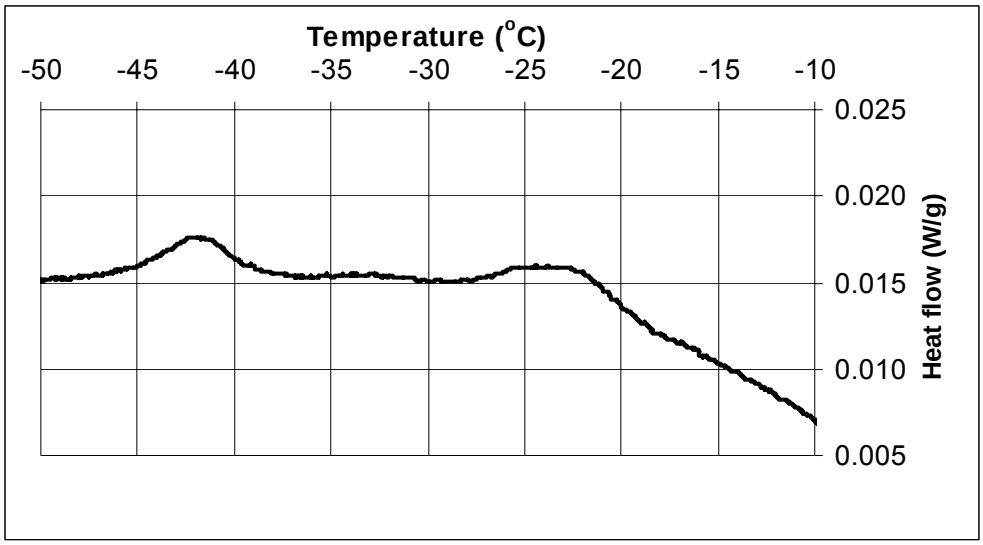

Figure 137 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 58 d under saturated conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 40 °C
Degree of hydration: 0.743

Curing: Sealed
Age when tested: 58 d
Sample mass: 51.3 mg
Filename: c152w035T40Cseal58d
Date tested: March 10, 2005

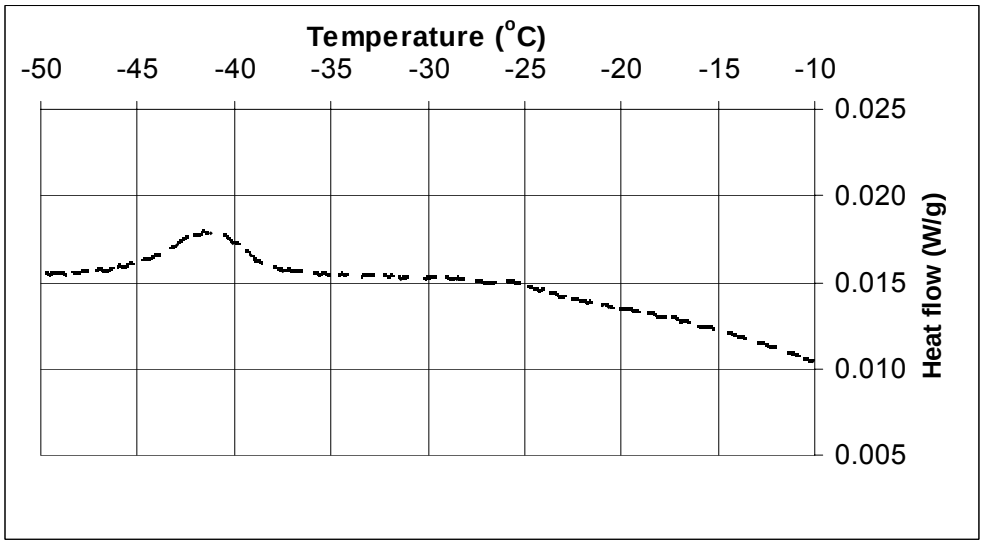

Figure 138 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 58 d under sealed conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 40 °C
Degree of hydration: N/A

Curing: Sealed 57 d/resaturated
Age when tested: 58 d
Sample mass: 62.1 mg
Filename: c152w035T40Csealresat58d
Date tested: March 10, 2005

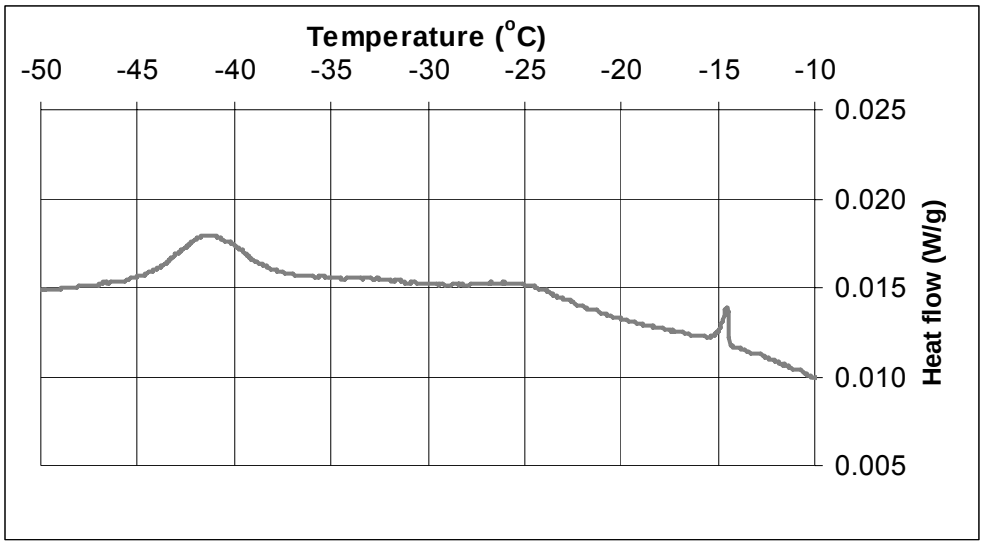

Figure 139 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 57 d under sealed conditions at 40 °C, then resaturated for 1 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.35
Temperature: 40 °C
Degree of hydration: N/A

Curing: Sealed 57 d/resaturated
Age when tested: 63 d
Sample mass: 71.5 mg
Filename: c152w035T40Cresat58t63d
Date tested: March 15, 2005

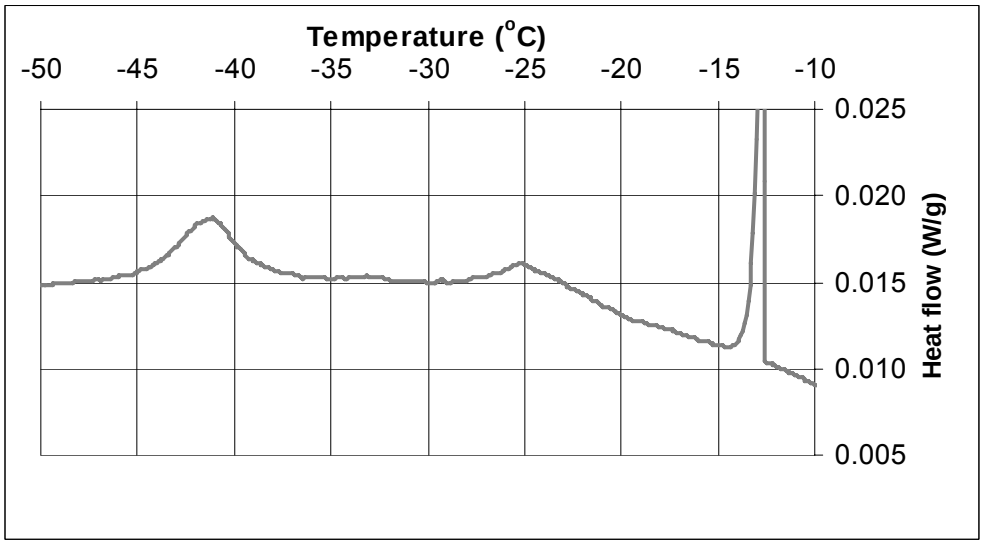

Figure 140 LTC scan for CCRL Cement 152, *w/c*=0.35, cured for 57 d under sealed conditions at 40 °C, then resaturated for 6 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.45
Temperature: 40 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 3 d
Sample mass: 55.2 mg
Filename: c152w45T40Csat3d
Date tested: Feb. 17, 2005

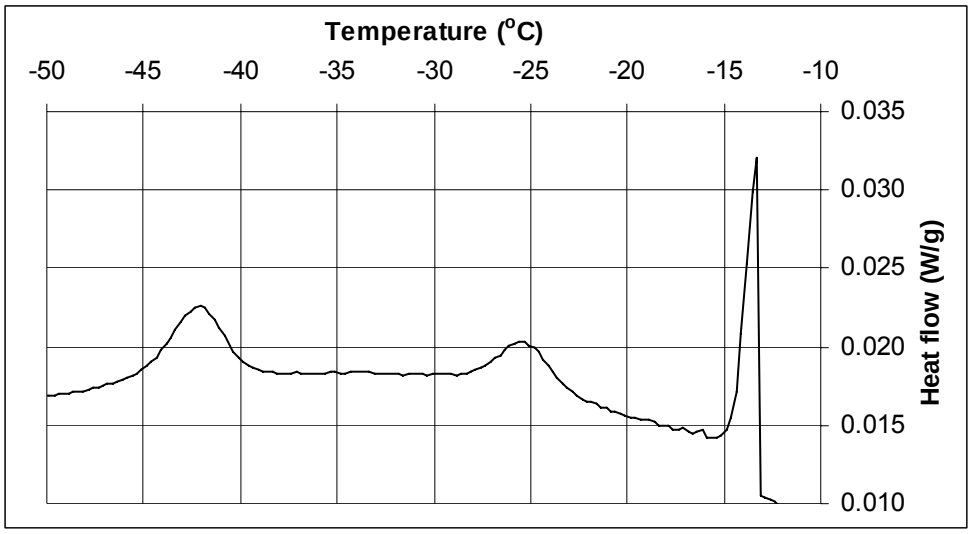

Figure 141 LTC scan for CCRL Cement 152, *w/c*=0.45, cured for 3 d under saturated conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.45
Temperature: 40 °C
Degree of hydration: N/A

Curing: Sealed
Age when tested: 3 d
Sample mass: 55.2 mg
Filename: c152w45T40Cseal3d
Date tested: Feb. 17, 2005

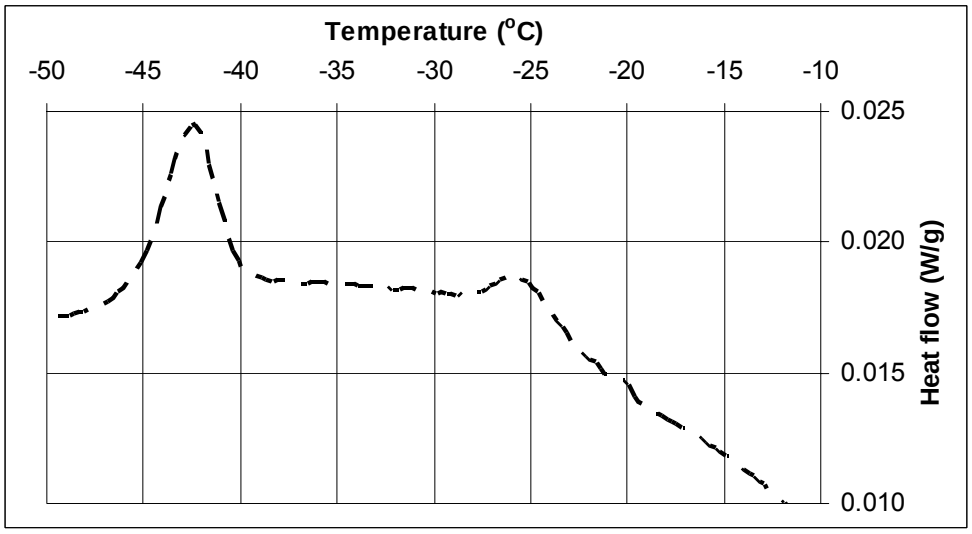

Figure 142 LTC scan for CCRL Cement 152, *w/c*=0.45, cured for 3 d under sealed conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.45
Temperature: 40 °C
Degree of hydration: 0.822

Curing: Saturated
Age when tested: 8 d
Sample mass: 69.1 mg
Filename: c152w45T40Csat8d
Date tested: Feb. 22, 2005

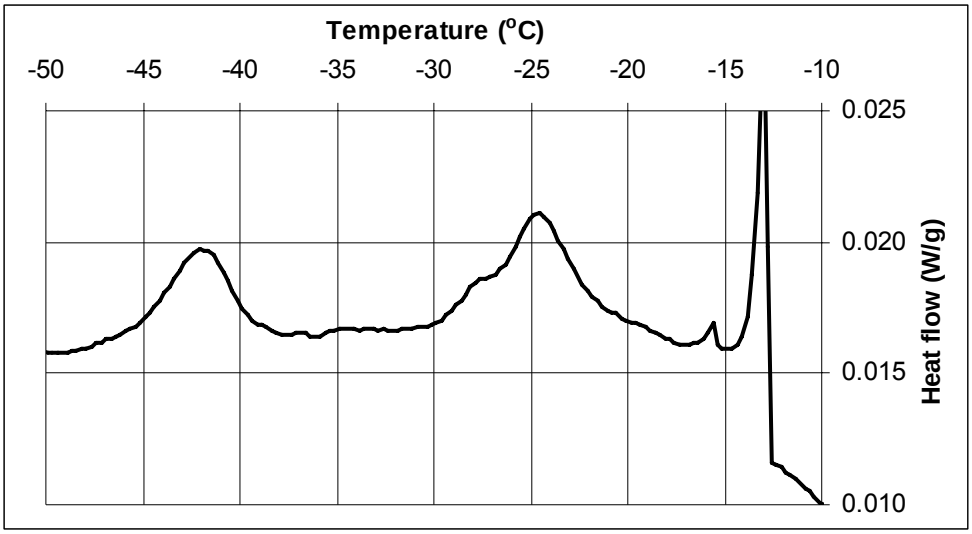

Figure 143 LTC scan for CCRL Cement 152, *w/c*=0.45, cured for 8 d under saturated conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.45
Temperature: 40 °C
Degree of hydration: 0.786

Curing: Sealed
Age when tested: 8 d
Sample mass: 51.4 mg
Filename: c152w45T40Cseal8d
Date tested: Feb. 22, 2005

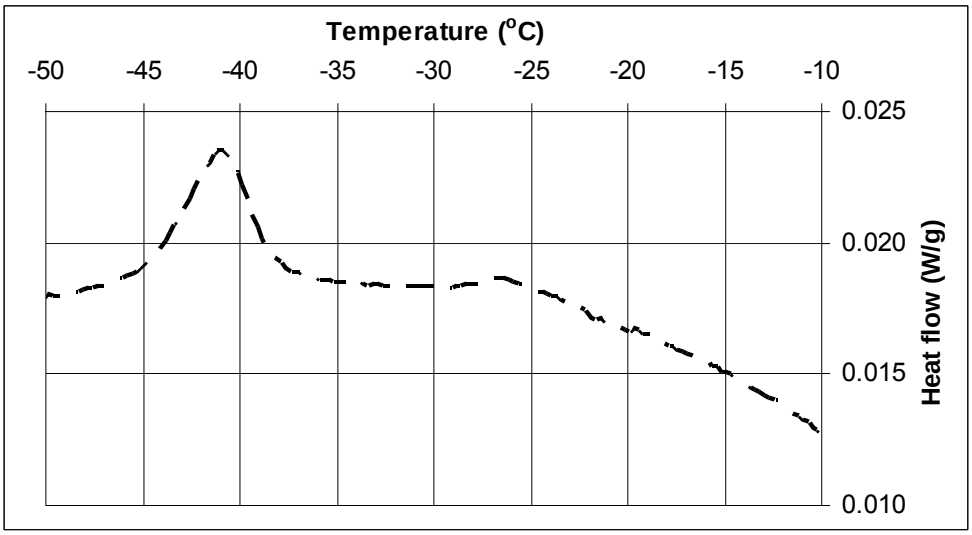

Figure 144 LTC scan for CCRL Cement 152, *w/c*=0.45, cured for 8 d under sealed conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.45
Temperature: 40 °C
Degree of hydration: N/A

Curing: Sealed 3 d/resaturated
Age when tested: 8 d
Sample mass: 45.2 mg
Filename: c152w45T40sealresat3t8d
Date tested: Feb. 22, 2005

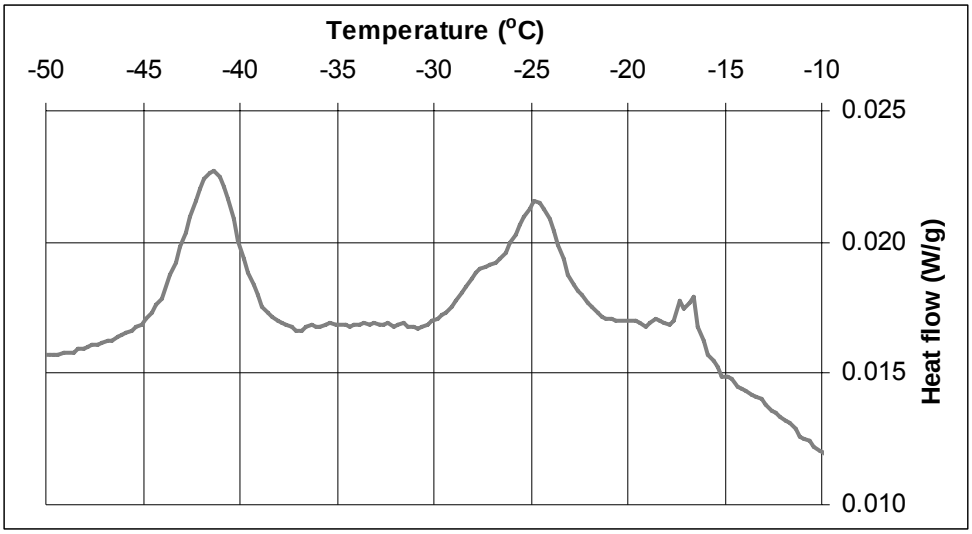

Figure 145 LTC scan for CCRL Cement 152, *w/c*=0.45, cured for 3 d under sealed conditions at 40 °C, then resaturated for 5 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.45
Temperature: 40 °C
Degree of hydration: 0.883

Curing: Saturated
Age when tested: 14 d
Sample mass: 58.3 mg
Filename: c152w45T40Csat14d
Date tested: Feb. 28, 2005

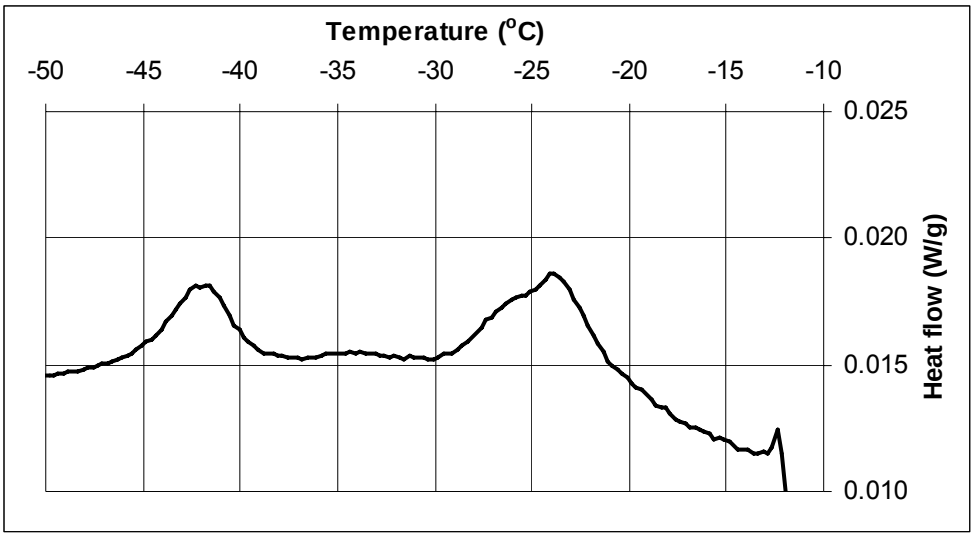

Figure 146 LTC scan for CCRL Cement 152, *w/c*=0.45, cured for 14 d under saturated conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.45
Temperature: 40 °C
Degree of hydration: 0.799

Curing: Sealed
Age when tested: 14 d
Sample mass: 44.7 mg
Filename: c152w45T40Cseal14d
Date tested: Feb. 28, 2005

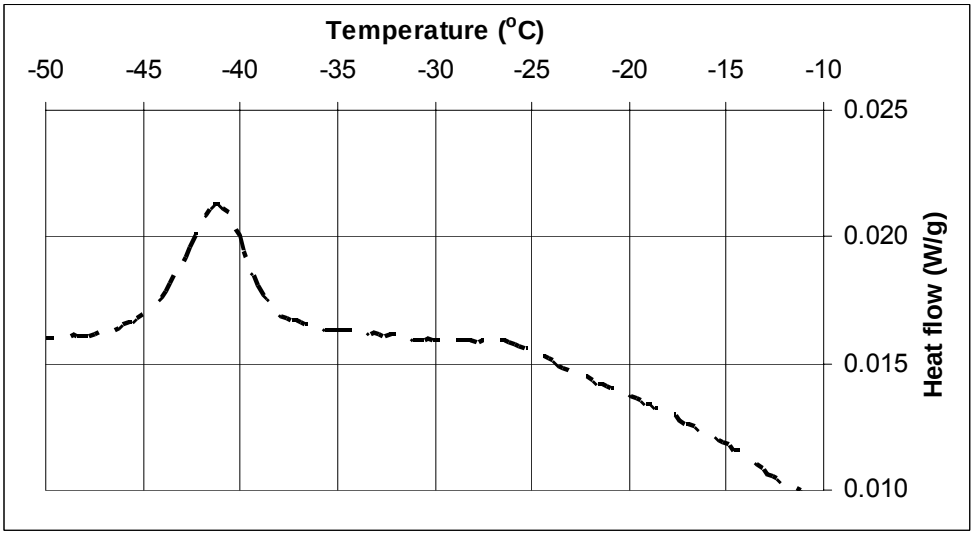

Figure 147 LTC scan for CCRL Cement 152, *w/c*=0.45, cured for 14 d under sealed conditions at 40 °C.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.45
Temperature: 40 °C
Degree of hydration: N/A

Curing: Sealed 3 d/resaturated
Age when tested: 14 d
Sample mass: 61.8 mg
Filename: c152w45T40sealres3t14d
Date tested: Feb. 28, 2005

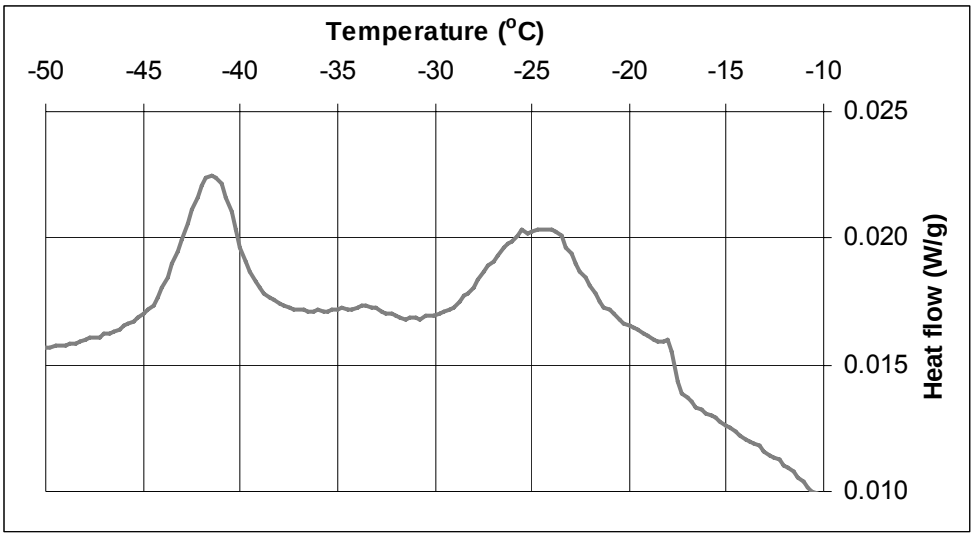

Figure 148 LTC scan for CCRL Cement 152, *w/c*=0.45, cured for 3 d under sealed conditions at 40 °C, then resaturated for 11 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.45
Temperature: 40 °C
Degree of hydration: N/A

Curing: Sealed 8 d/resaturated
Age when tested: 14 d
Sample mass: 68.6 mg
Filename: c152w45T40sealres8t14d
Date tested: Feb. 28, 2005

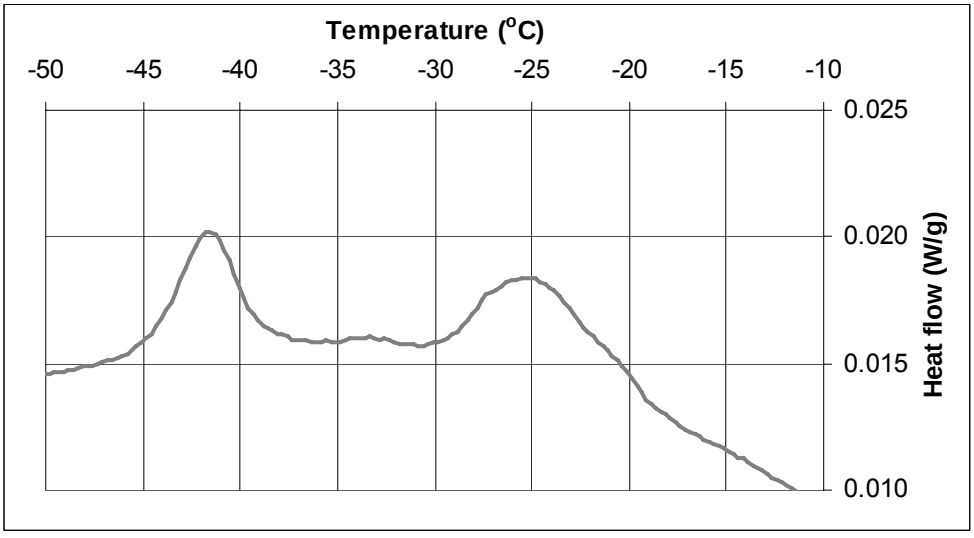

Figure 149 LTC scan for CCRL Cement 152, *w/c*=0.45, cured for 8 d under sealed conditions at 40 °C, then resaturated for 6 d.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.45
Temperature: 40 °C
Degree of hydration: 0.890

Curing: Saturated
Age when tested: 29 d
Sample mass: 56.8 mg
Filename: c152w045T40Csat28d
Date tested: March 15, 2005

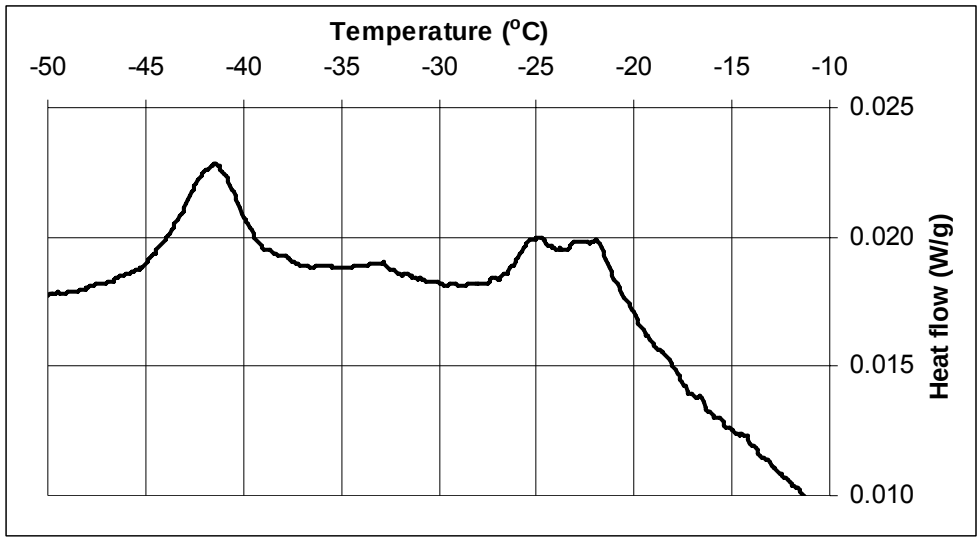

Figure 150 LTC scan for CCRL Cement 152, *w/c*=0.45, cured for 29 d at 40 °C under saturated conditions.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.45
Temperature: 40 °C
Degree of hydration: 0.826

Curing: Sealed
Age when tested: 29 d
Sample mass: 56.7 mg
Filename: c152w045T40Cseal28d
Date tested: March 15, 2005

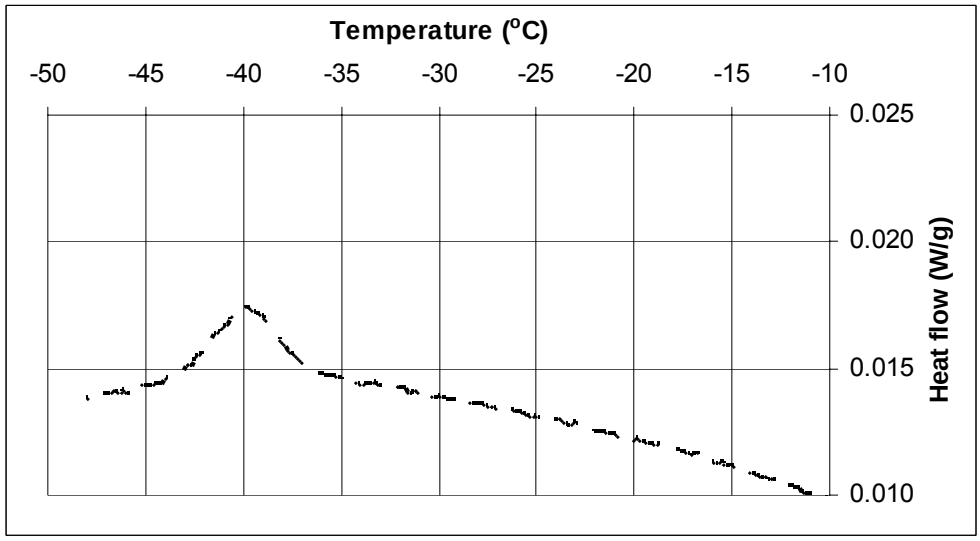

Figure 151 LTC scan for CCRL Cement 152, *w/c*=0.45, cured for 29 d at 40 °C under sealed conditions.

Cement: CCRL Cement 152
Solution: Distilled water
w/c: 0.45
Temperature: 40 °C
Degree of hydration: N/A

Curing: Sealed 28 d/resaturated
Age when tested: 29 d
Sample mass: 52.2 mg
Filename: c152w045T40Cresat28t29d
Date tested: March 15, 2005

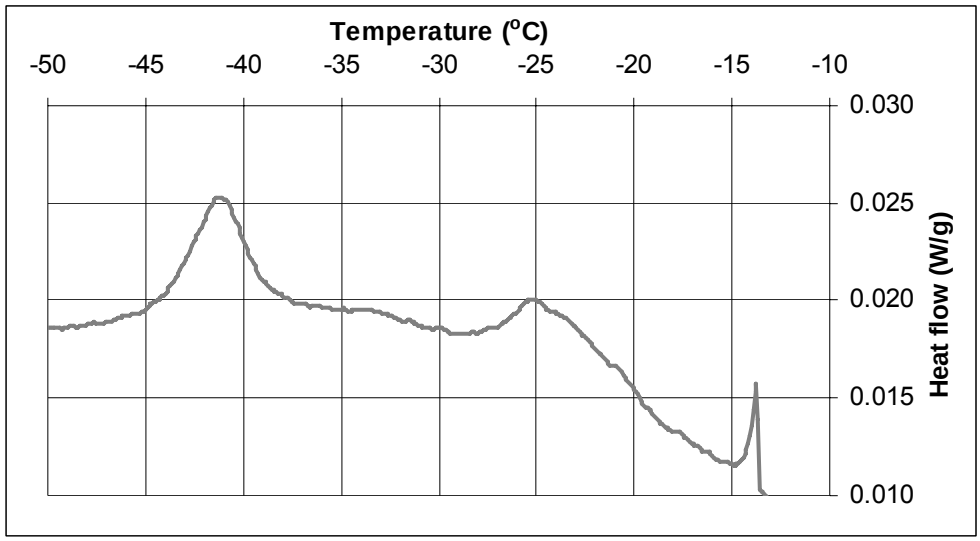

Figure 152 LTC scan for CCRL Cement 152, *w/c*=0.45, cured for 28 d under sealed conditions at 40 °C, then resaturated for 1 d.

CCRL Cement 140

Cement: CCRL Cement 140
Solution: Distilled water
w/c: 0.40
Temperature: 20 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 2 d
Sample mass: 64.7 mg
Filename: c140w4nalk2d
Date tested: Dec. 30, 2004

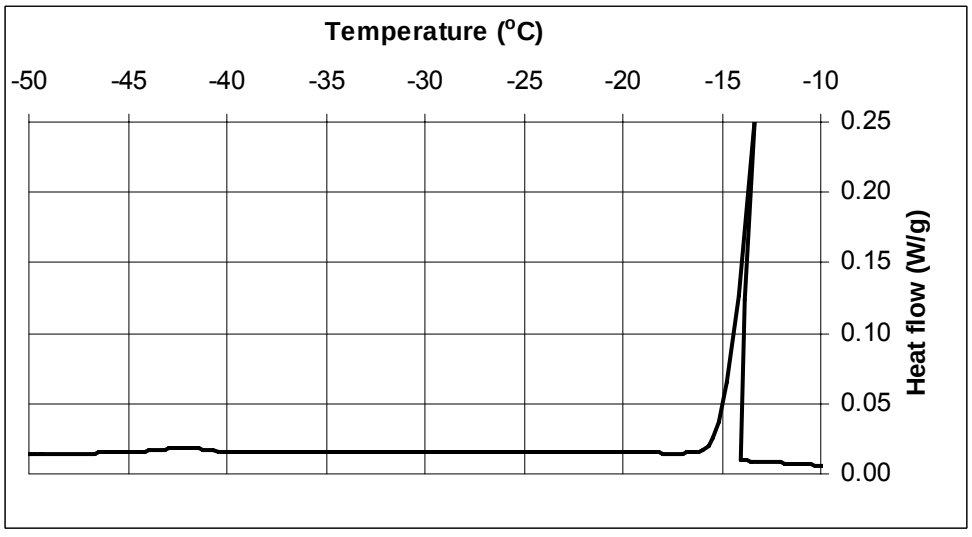

Figure 153 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with distilled water and cured for 2 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: Alkali sulfate solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 2 d
Sample mass: 64.1 mg
Filename: c140w4walk2d
Date tested: Dec. 30, 2004

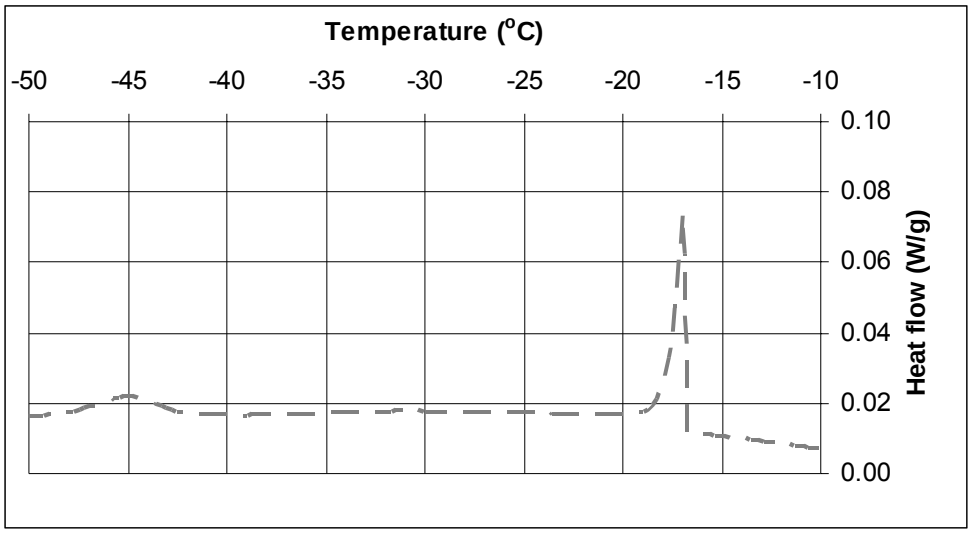

Figure 154 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of alkali sulfates and cured for 2 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: Alkali hydroxide solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 2 d
Sample mass: 62.8 mg
Filename: c140w4walkoh2d
Date tested: Dec. 30, 2004

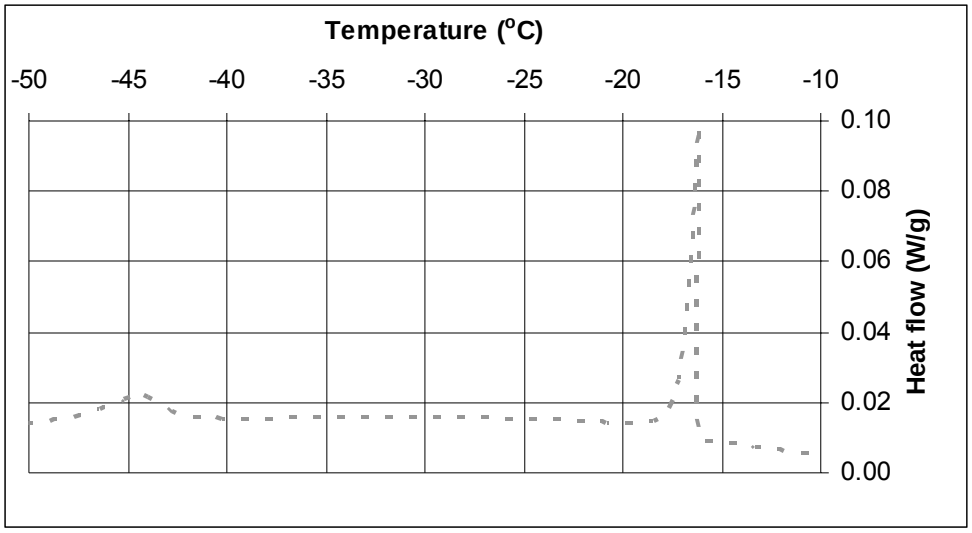

Figure 155 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of alkali hydroxides and cured for 2 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: LiOH solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.499

Curing: Saturated
Age when tested: 2 d
Sample mass: 66.6 mg
Filename: c140wlioh2d
Date tested: Feb. 3, 2005

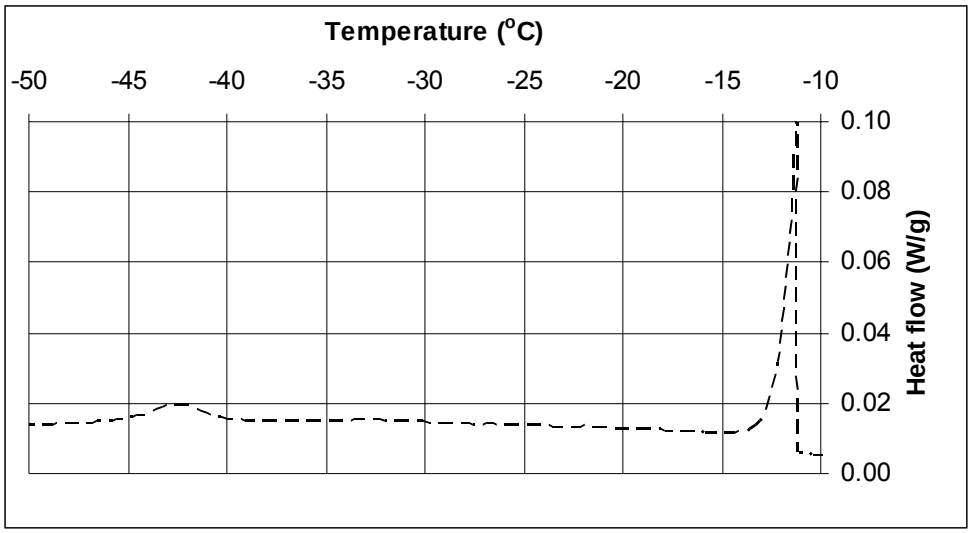

Figure 156 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a LiOH solution and cured for 2 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: $LiNO_3$ solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.472

Curing: Saturated
Age when tested: 2 d
Sample mass: 48.0 mg
Filename: c140wlino3a2d
Date tested: Feb. 3, 2005

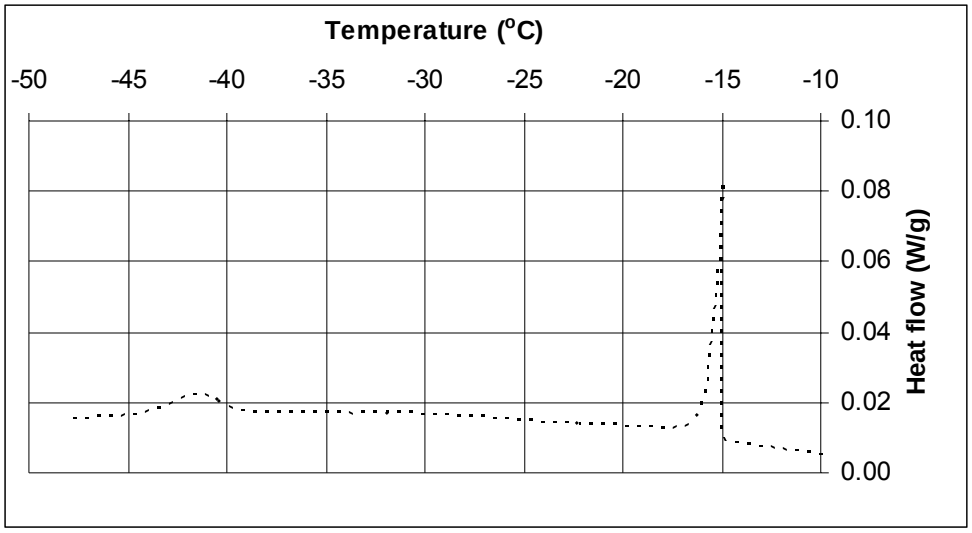

Figure 157 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a $LiNO_3$ solution and cured for 2 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: LiOH solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 4 d
Sample mass: 88.0 mg
Filename: c140w04lioh4d
Date tested: Feb. 5, 2005

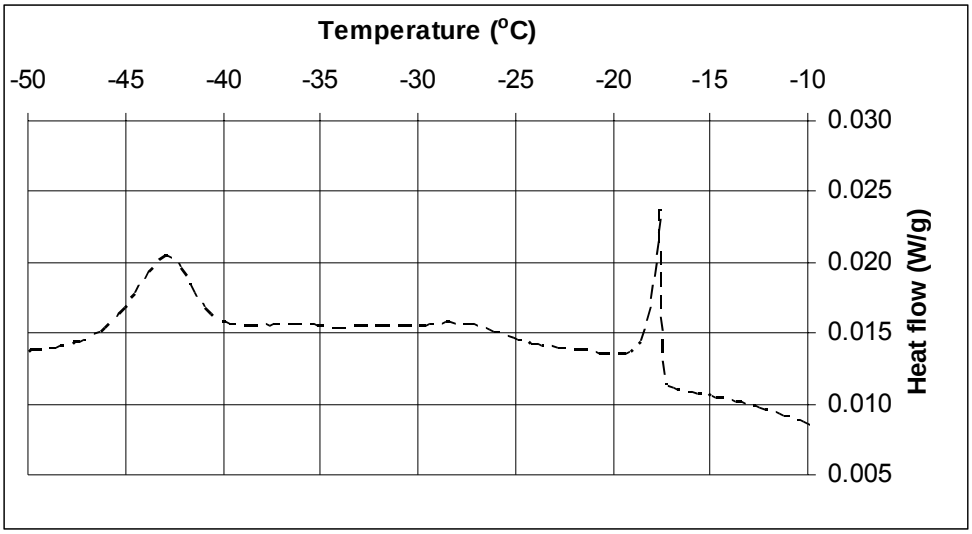

Figure 158 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a LiOH solution and cured for 4 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: $LiNO_3$ solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 4 d
Sample mass: 81.0 mg
Filename: c140w04lino3a4d
Date tested: Feb. 5, 2005

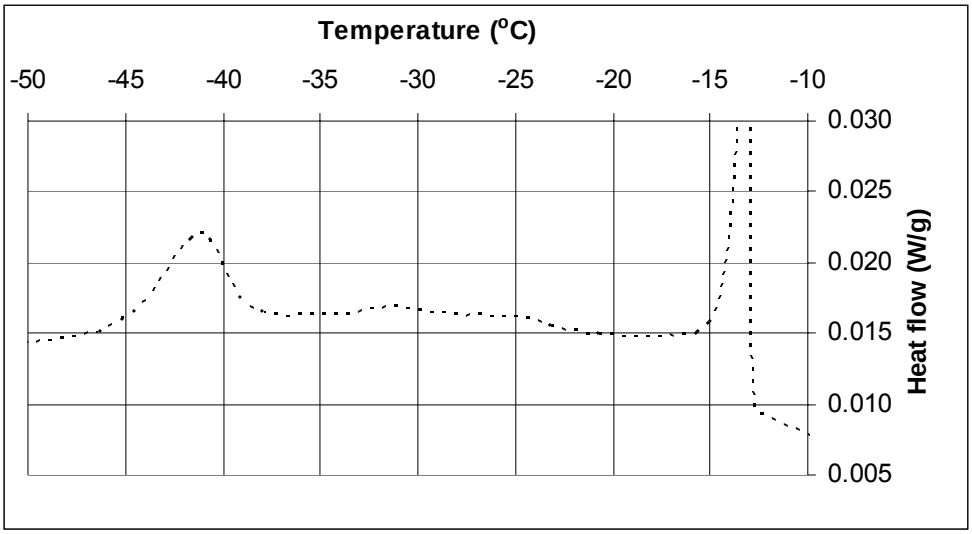

Figure 159 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a $LiNO_3$ solution and cured for 4 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: LiOH solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.664

Curing: Saturated
Age when tested: 7 d
Sample mass: 97.8 mg
Filename: c140w04lioh7d
Date tested: Feb. 8, 2005

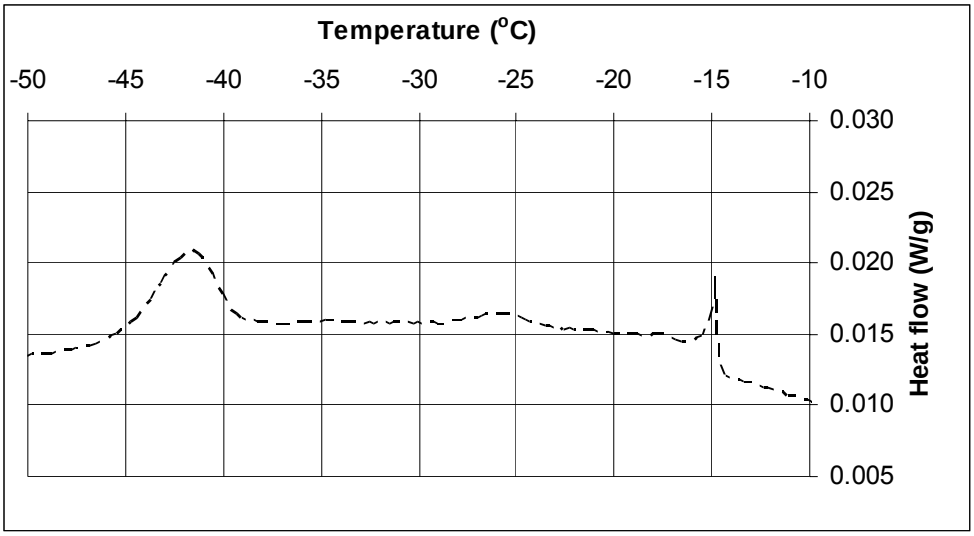

Figure 160 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a LiOH solution and cured for 7 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: $LiNO_3$ solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.686

Curing: Saturated
Age when tested: 7 d
Sample mass: 67.3 mg
Filename: c140w04lino3a7d
Date tested: Feb. 8, 2005

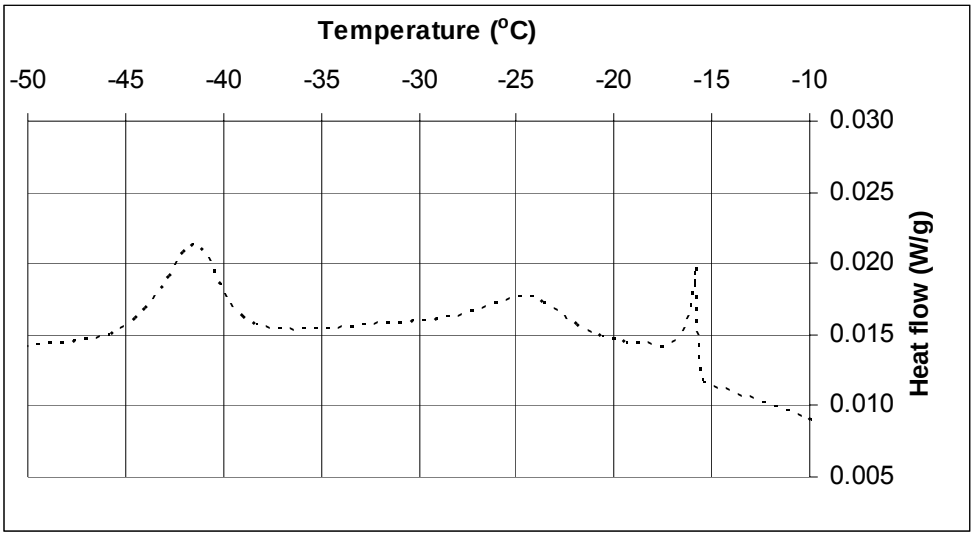

Figure 161 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a $LiNO_3$ solution and cured for 7 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: Distilled water
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.667

Curing: Saturated
Age when tested: 8 d
Sample mass: 62.3 mg
Filename: c140w4nalk8d
Date tested: Jan. 5, 2005

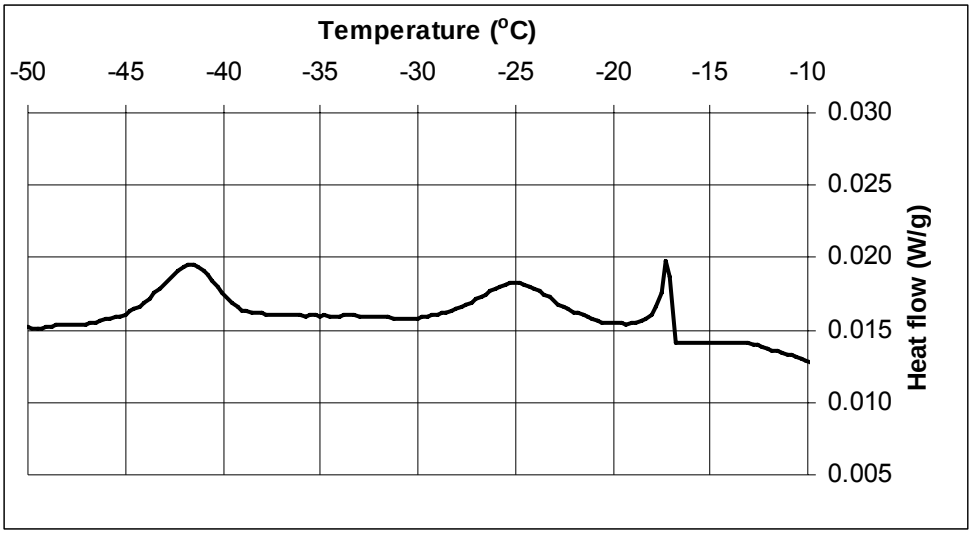

Figure 162 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with distilled water and cured for 8 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: Alkali sulfate solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.631

Curing: Saturated
Age when tested: 8 d
Sample mass: 42.5 mg
Filename: c140w4walk8d
Date tested: Jan. 5, 2005

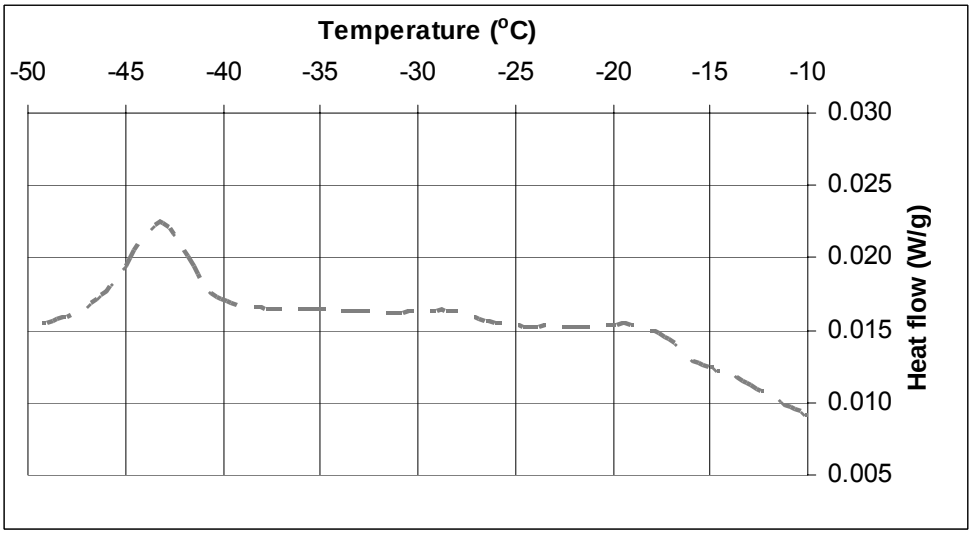

Figure 163 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of alkali sulfates and cured for 8 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: Alkali hydroxide solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.661

Curing: Saturated
Age when tested: 8 d
Sample mass: 61.0 mg
Filename: c140w4walkoh8d
Date tested: Jan. 5, 2005

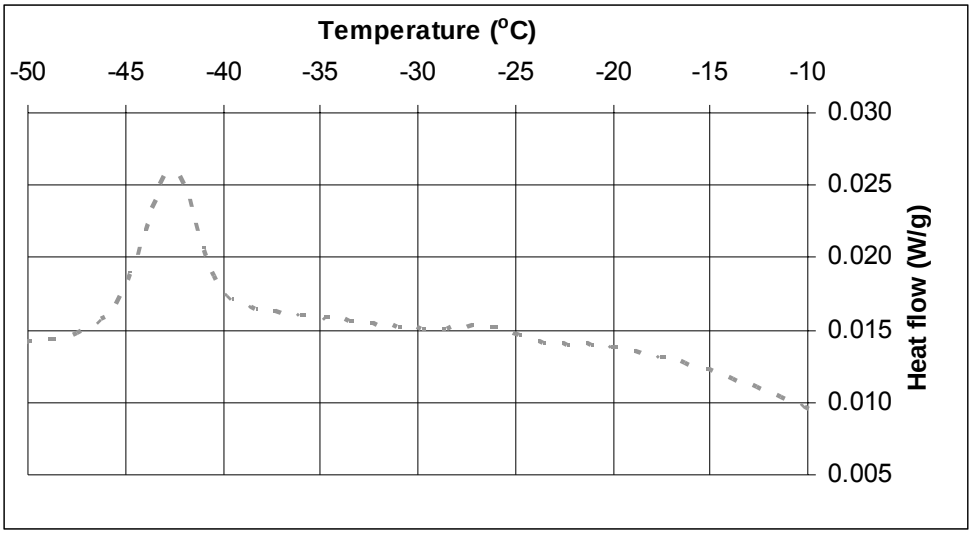

Figure 164 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of alkali hydroxides and cured for 8 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: LiOH solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.692

Curing: Saturated
Age when tested: 8 d
Sample mass: 64.0 mg
Filename: c140w04lioh8d
Date tested: Feb. 9, 2005

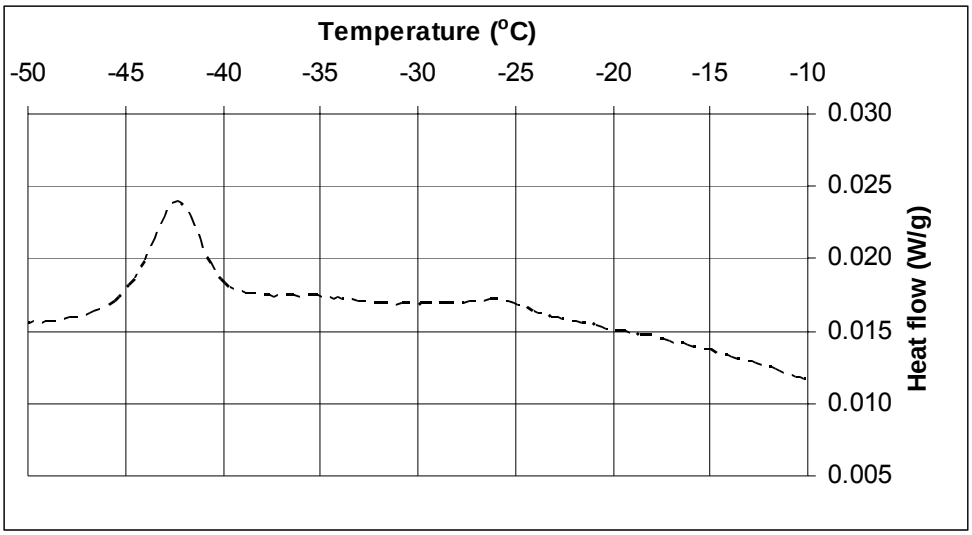

Figure 165 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of LiOH and cured for 8 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: $LiNO_3$ solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.699

Curing: Saturated
Age when tested: 8 d
Sample mass: 59.8 mg
Filename: c140w04lino3a8d
Date tested: Feb. 9, 2005

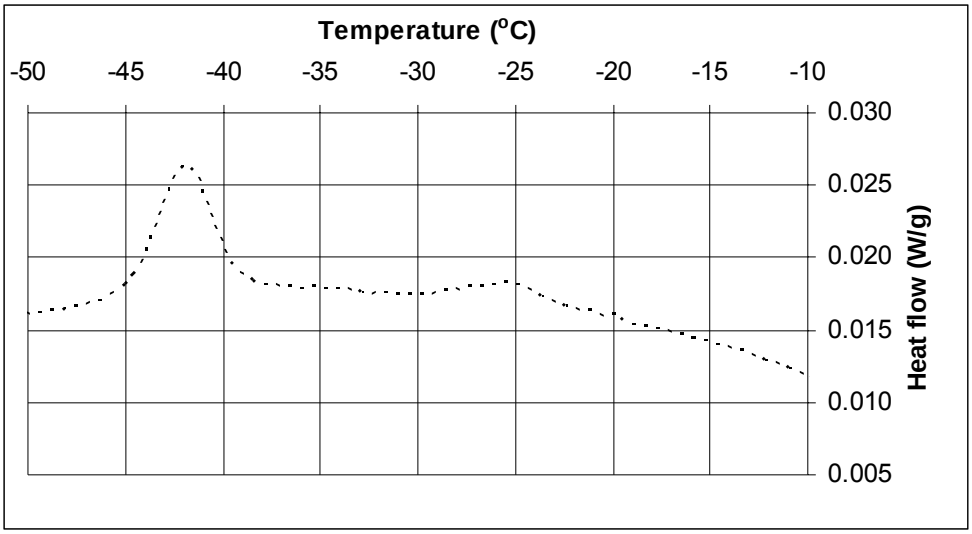

Figure 166 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of $LiNO_3$ and cured for 8 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: Distilled water
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.732

Curing: Saturated
Age when tested: 14 d
Sample mass: 58.9 mg
Filename: c140w04nalk14d
Date tested: Jan. 11, 2005

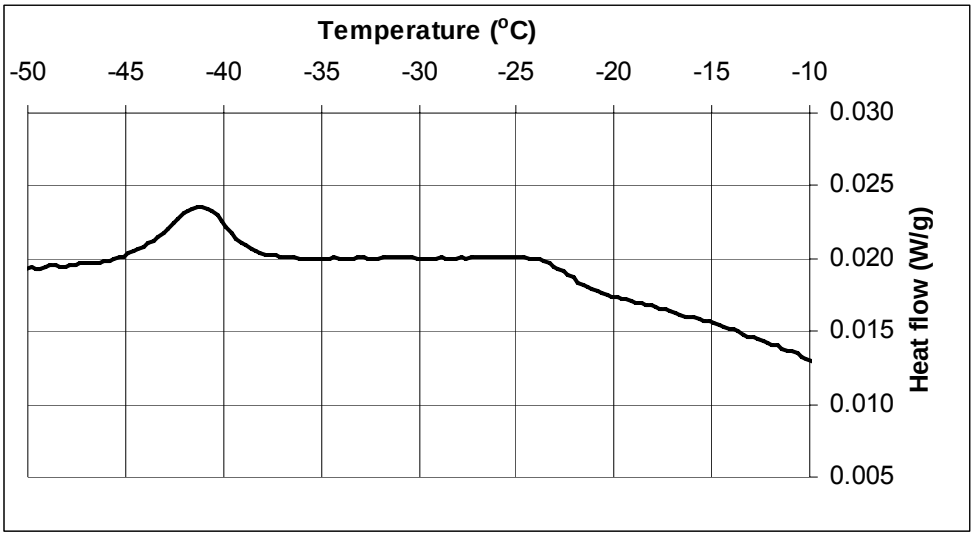

Figure 167 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with distilled water and cured for 14 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: Alkali sulfate solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.655

Curing: Saturated
Age when tested: 14 d
Sample mass: 48.7 mg
Filename: c140w04walk14d
Date tested: Jan. 11, 2005

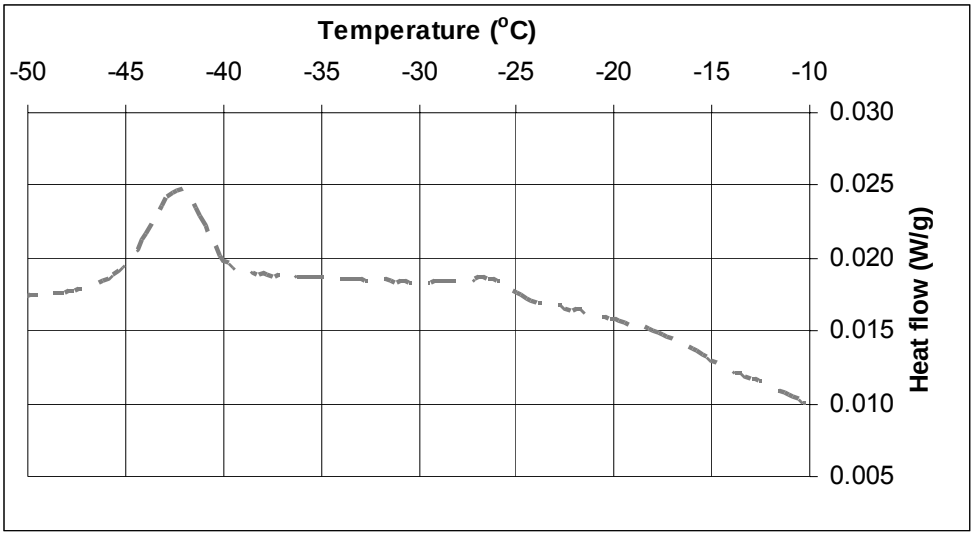

Figure 168 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of alkali sulfates and cured for 14 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: Alkali hydroxide solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.698

Curing: Saturated
Age when tested: 14 d
Sample mass: 43.9 mg
Filename: c140w04walkoh14d
Date tested: Jan. 11, 2005

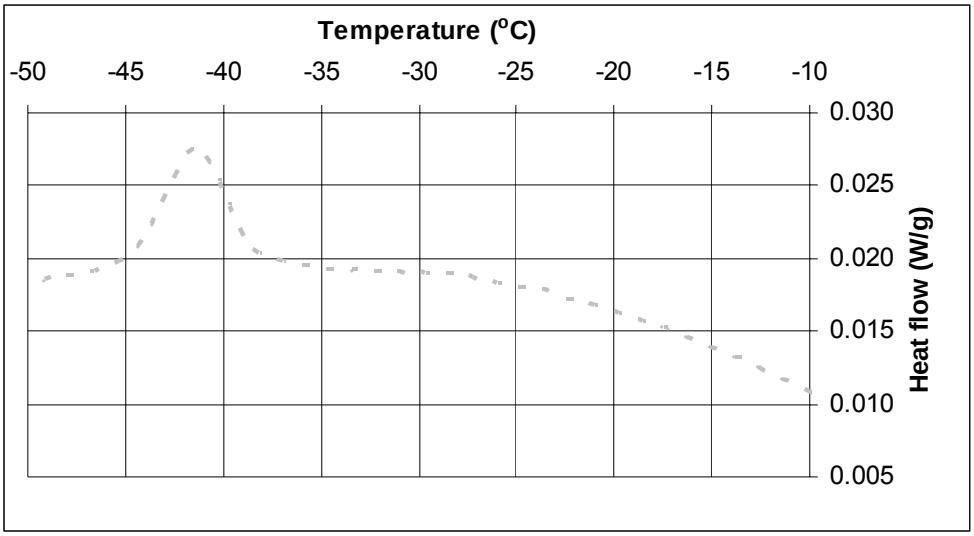

Figure 169 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of alkali hydroxides and cured for 14 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: LiOH solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.736

Curing: Saturated
Age when tested: 14 d
Sample mass: 95.7 mg
Filename: c140w04lioha14d
Date tested: Feb. 15, 2005

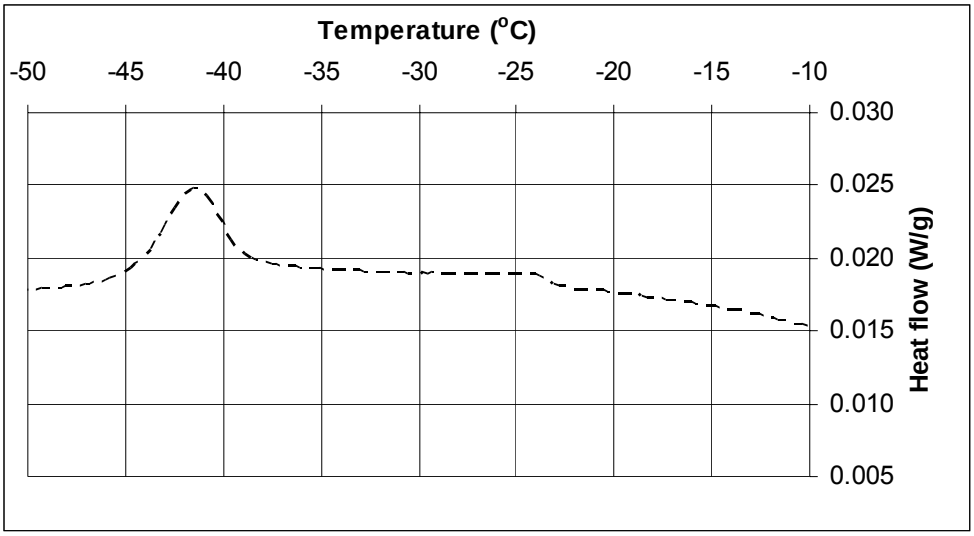

Figure 170 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of LiOH and cured for 14 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: $LiNO_3$ solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.736

Curing: Saturated
Age when tested: 14 d
Sample mass: 53.1 mg
Filename: c140w04lino3a14d
Date tested: Feb. 15, 2005

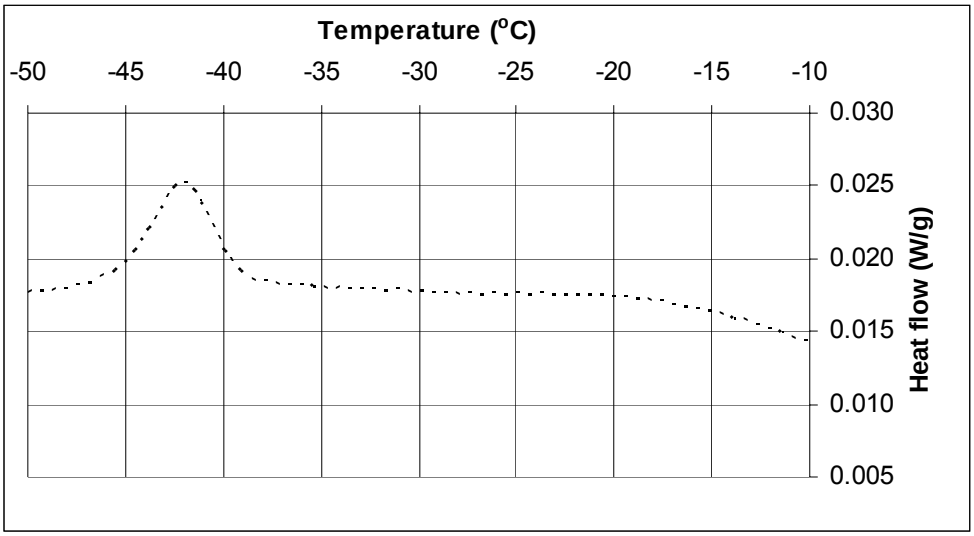

Figure 171 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of $LiNO_3$ and cured for 14 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: Distilled water
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.764

Curing: Saturated
Age when tested: 30 d
Sample mass: 59.1 mg
Filename: c140w04nalk30d
Date tested: Jan. 27, 2005

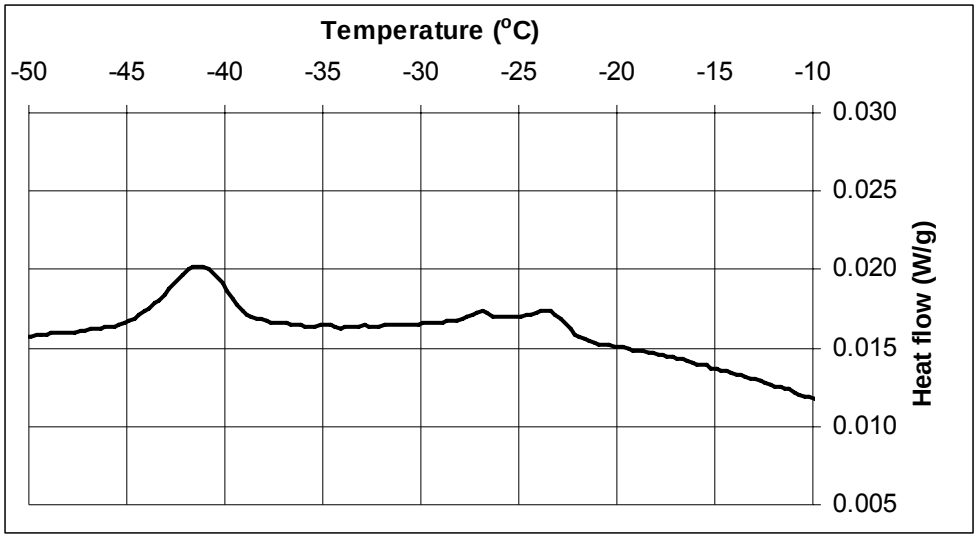

Figure 172 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with distilled water and cured for 30 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: Alkali sulfate solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.671

Curing: Saturated
Age when tested: 30 d
Sample mass: 60.4 mg
Filename: c140w04walk30d
Date tested: Jan. 27, 2005

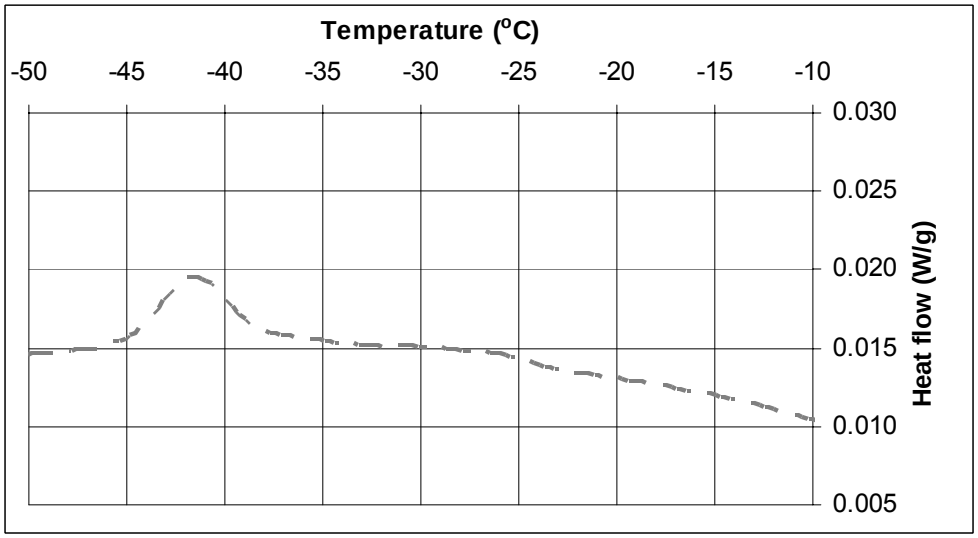

Figure 173 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of alkali sulfates and cured for 30 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: Alkali hydroxide solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.738

Curing: Saturated
Age when tested: 30 d
Sample mass: 75.5 mg
Filename: c140w04walkoh30d
Date tested: Jan. 27, 2005

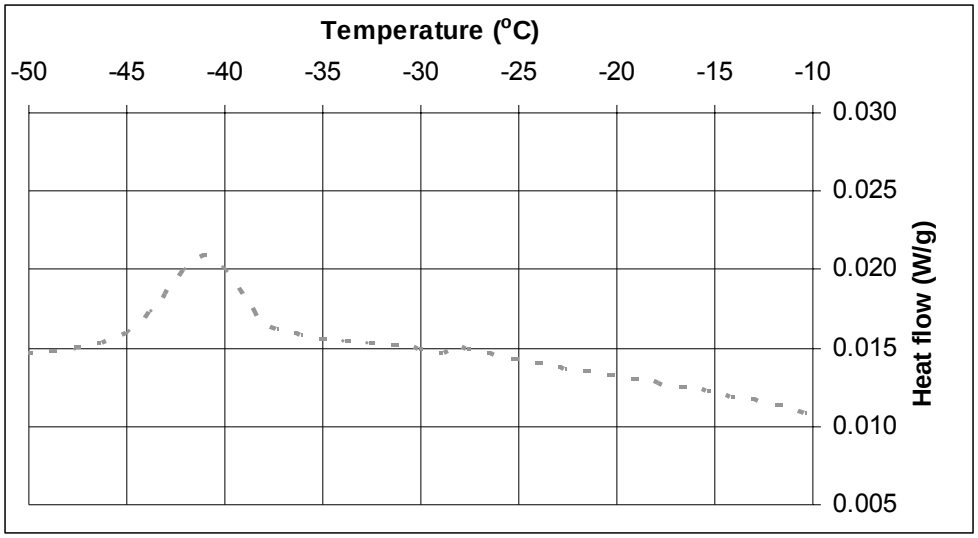

Figure 174 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of alkali hydroxides and cured for 30 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: LiOH solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.761

Curing: Saturated
Age when tested: 30 d
Sample mass: 57.9 mg
Filename: c140w04lioh30d
Date tested: March 3, 2005

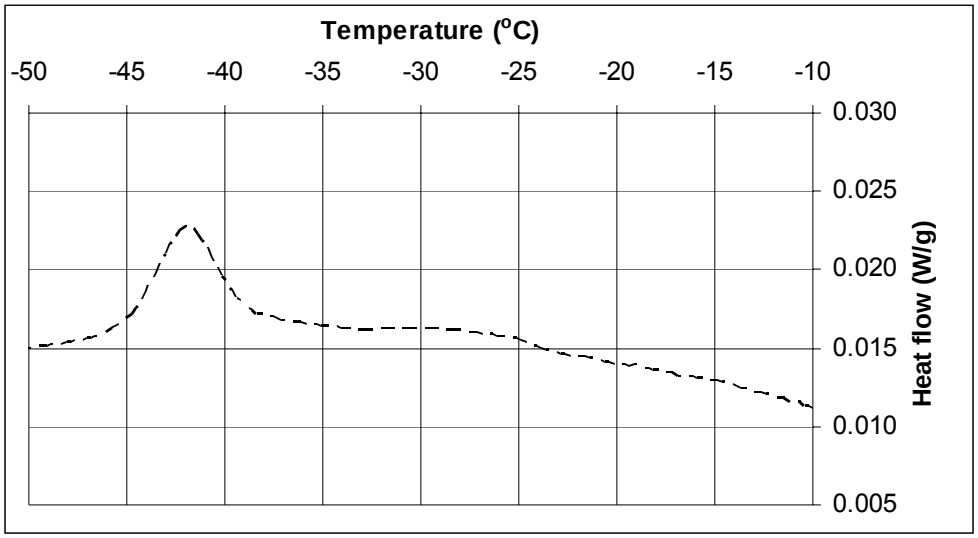

Figure 175 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of LiOH and cured for 30 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: $LiNO_3$ solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.764

Curing: Saturated
Age when tested: 30 d
Sample mass: 65.8 mg
Filename: c140w04lino3a30d
Date tested: March 3, 2005

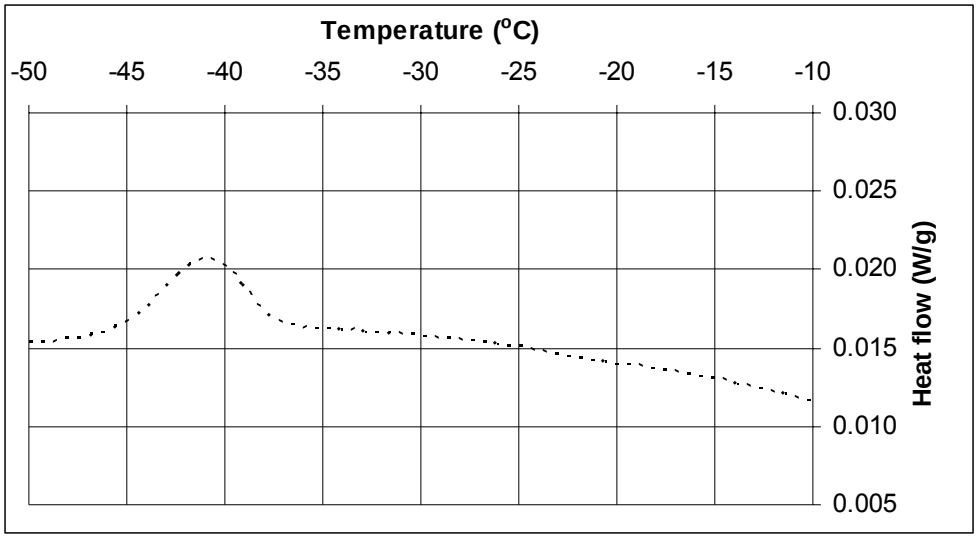

Figure 176 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of $LiNO_3$ and cured for 30 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: Distilled water
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.82

Curing: Saturated
Age when tested: 63 d
Sample mass: 66.8 mg
Filename: C140w4nalksat63d
Date tested: March 1, 2005

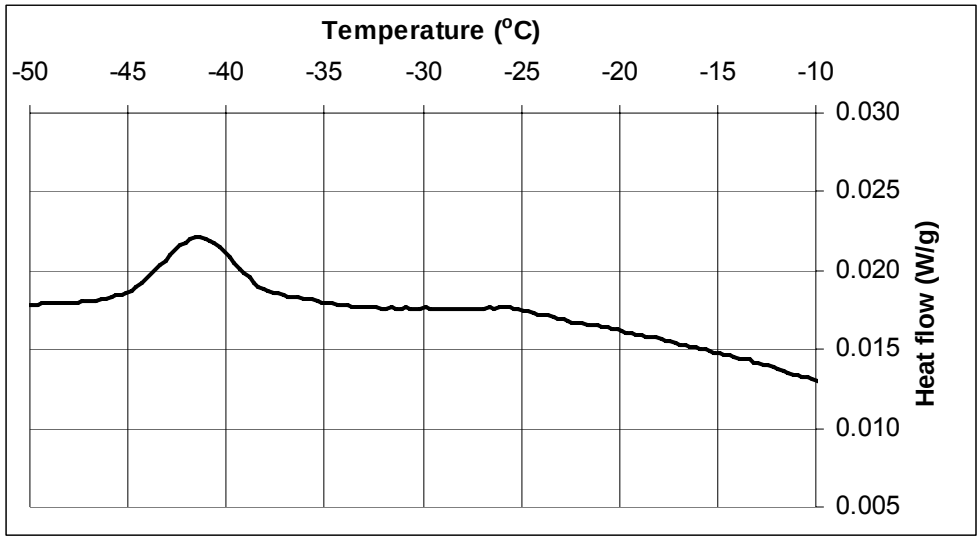

Figure 177 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with distilled water and cured for 63 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: Alkali sulfate solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.737

Curing: Saturated
Age when tested: 63 d
Sample mass: 47.2 mg
Filename: C140w4walksat63d
Date tested: March 1, 2005

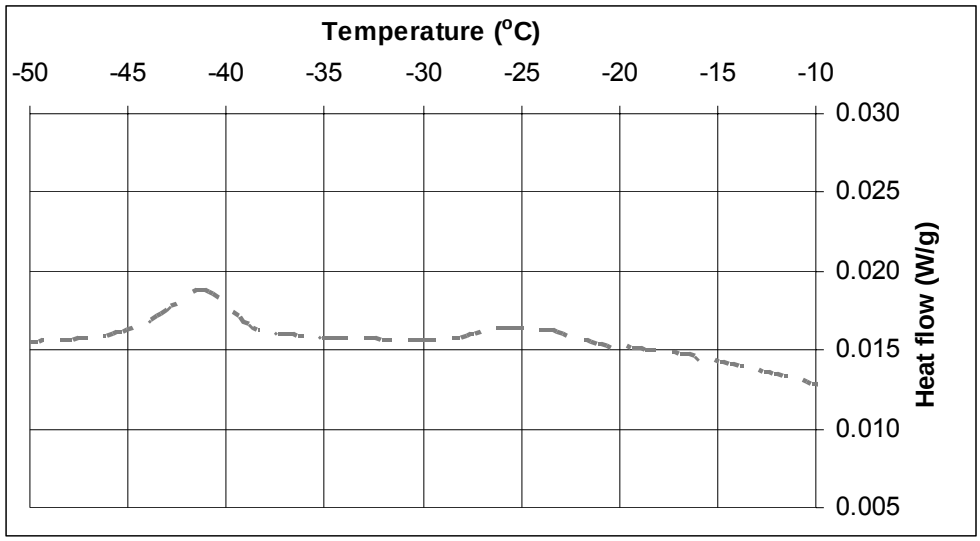

Figure 178 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of alkali sulfates and cured for 63 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: Alkali hydroxide solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.815

Curing: Saturated
Age when tested: 63 d
Sample mass: 48.5 mg
Filename: C140w4walkohsat63d
Date tested: March 1, 2005

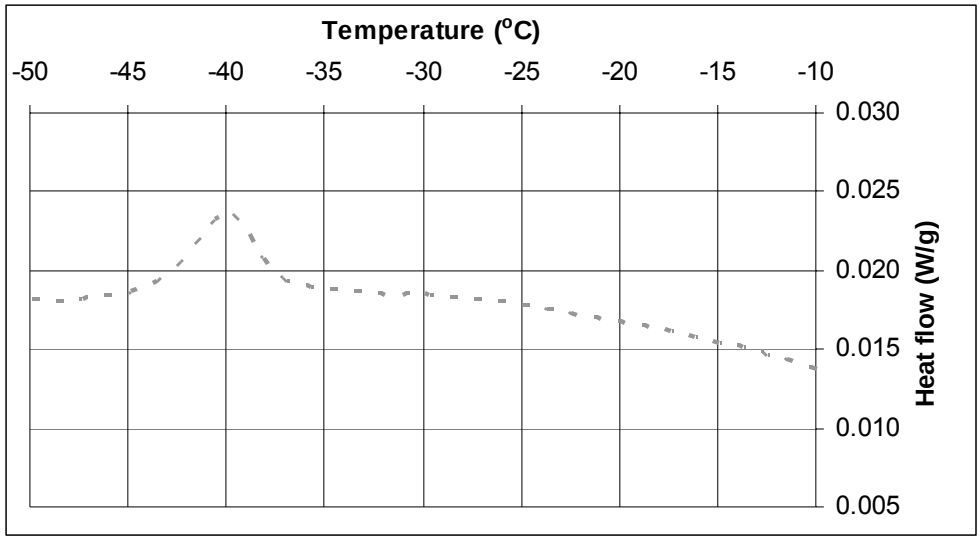

Figure 179 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of alkali hydroxides and cured for 63 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: LiOH solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.812

Curing: Saturated
Age when tested: 63 d
Sample mass: 53.7 mg
Filename: c140w04lioh63d
Date tested: April 5, 2005

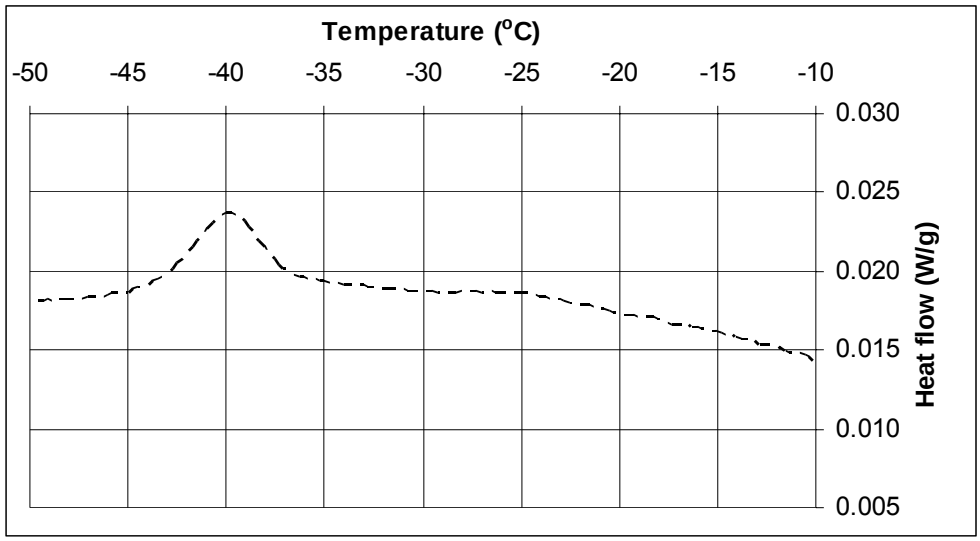

Figure 180 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of LiOH and cured for 63 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: $LiNO_3$ solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.804

Curing: Saturated
Age when tested: 63 d
Sample mass: 56.2 mg
Filename: c140w04lino3a63d
Date tested: April 5, 2005

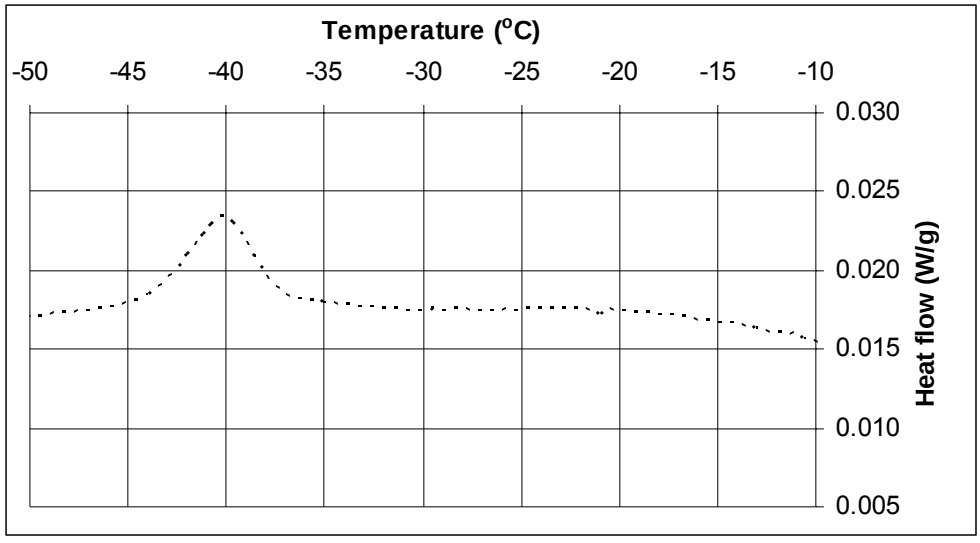

Figure 181 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of $LiNO_3$ and cured for 63 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: Distilled water
w/c: 0.40
Temperature: 20 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 90 d
Sample mass: 54.7 mg
Filename: c140w04nalk90d
Date tested: March 28, 2005

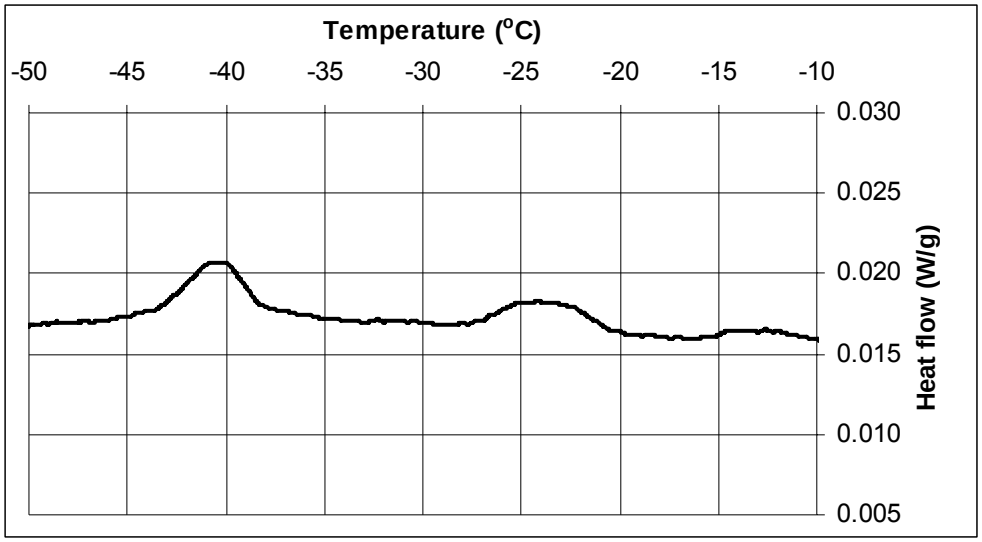

Figure 182 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with distilled water and cured for 90 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: Distilled water
w/c: 0.40
Temperature: 20 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 91 d
Sample mass: 56.4 mg
Filename: c140w04nalk91d
Date tested: March 29, 2005

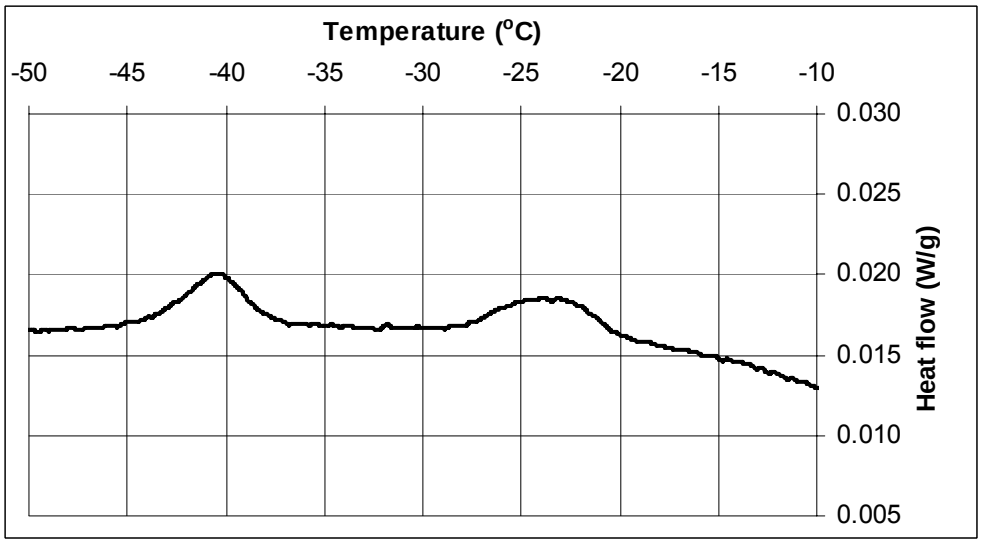

Figure 183 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with distilled water and cured for 91 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: Alkali sulfate solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 90 d
Sample mass: 65.2 mg
Filename: c140w04walk90d
Date tested: March 28, 2005

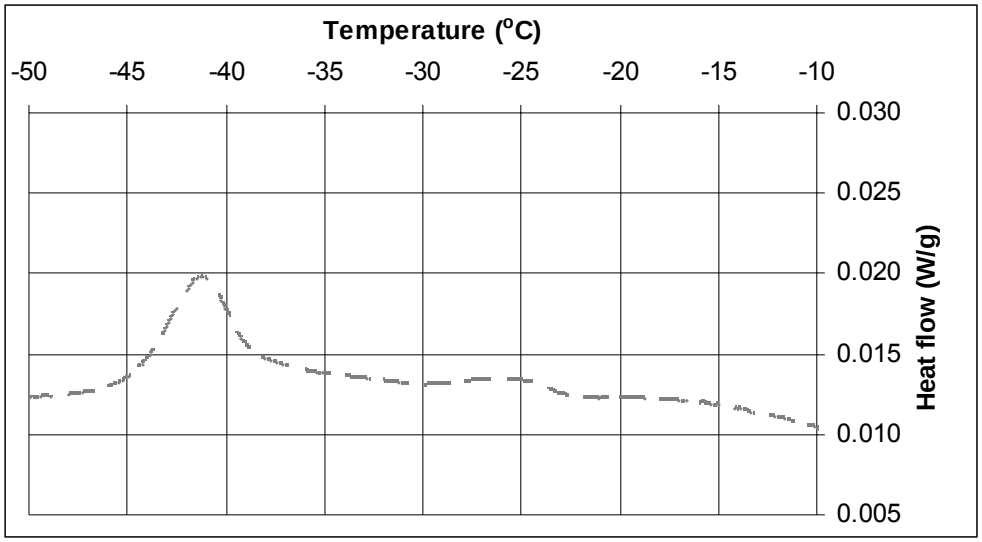

Figure 184 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of alkali sulfates and cured for 90 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: Alkali sulfate solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 91 d
Sample mass: 74.6 mg
Filename: c140w04walk91d
Date tested: March 29, 2005

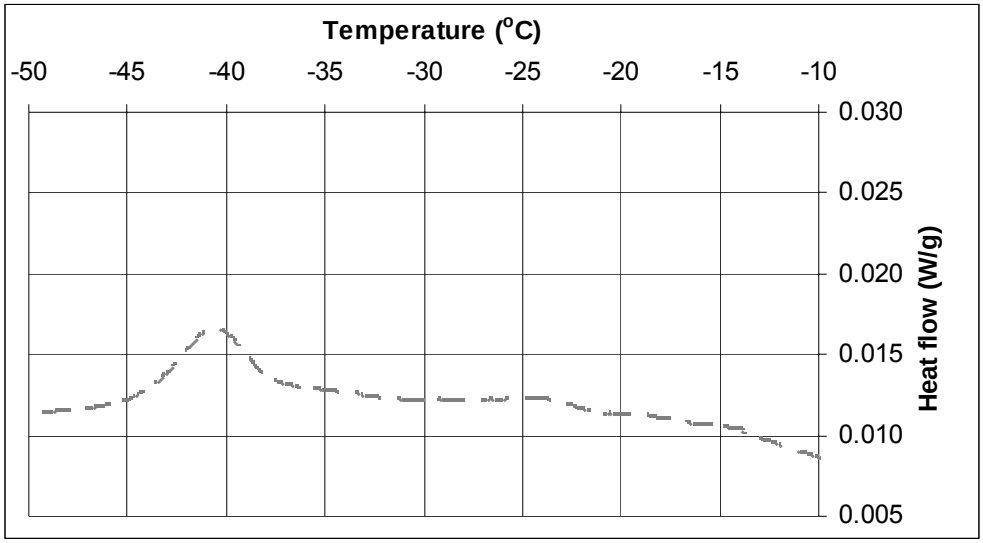

Figure 185 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of alkali sulfates and cured for 91 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140 Curing: Saturated
Solution: Alkali hydroxide solution Age when tested: 90 d
w/c: 0.40 Sample mass: 59.8 mg
Temperature: 20 °C Filename: c140w04walkoh90d
Degree of hydration: N/A Date tested: March 28, 2005

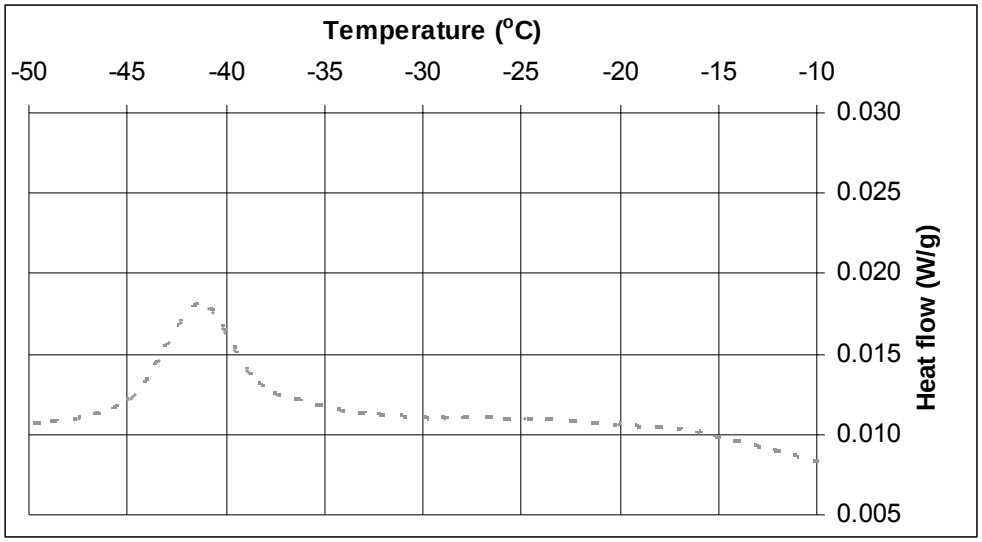

Figure 186 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of alkali hydroxides and cured for 90 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140 Curing: Saturated
Solution: LiOH solution Age when tested: 90 d
w/c: 0.40 Sample mass: 41.0 mg
Temperature: 20 °C Filename: c140w04lioh90d
Degree of hydration: 0.831 Date tested: May 2, 2005

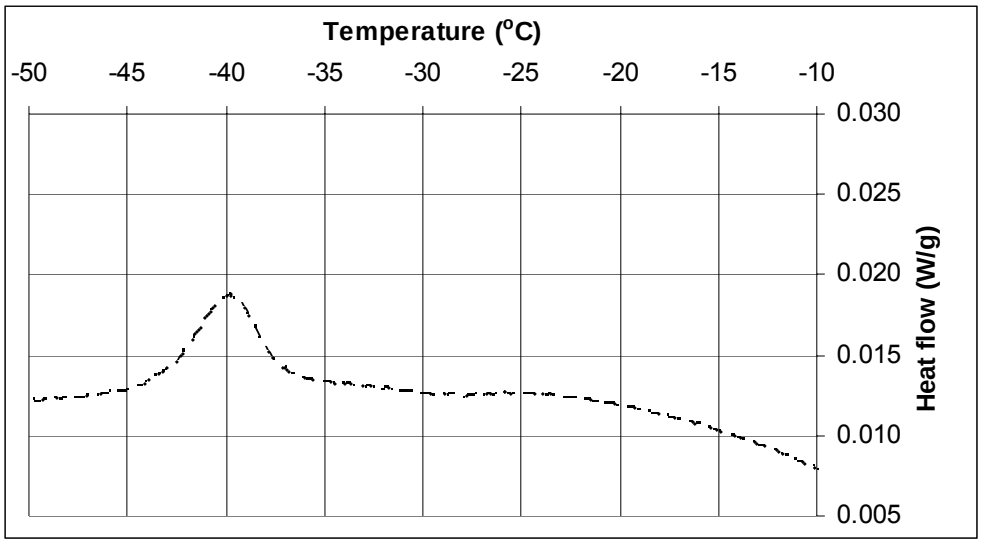

Figure 187 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of LiOH and cured for 90 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: $LiNO_3$ solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: 0.834

Curing: Saturated
Age when tested: 90 d
Sample mass: 54.5 mg
Filename: c140w04lino3a90d
Date tested: May 2, 2005

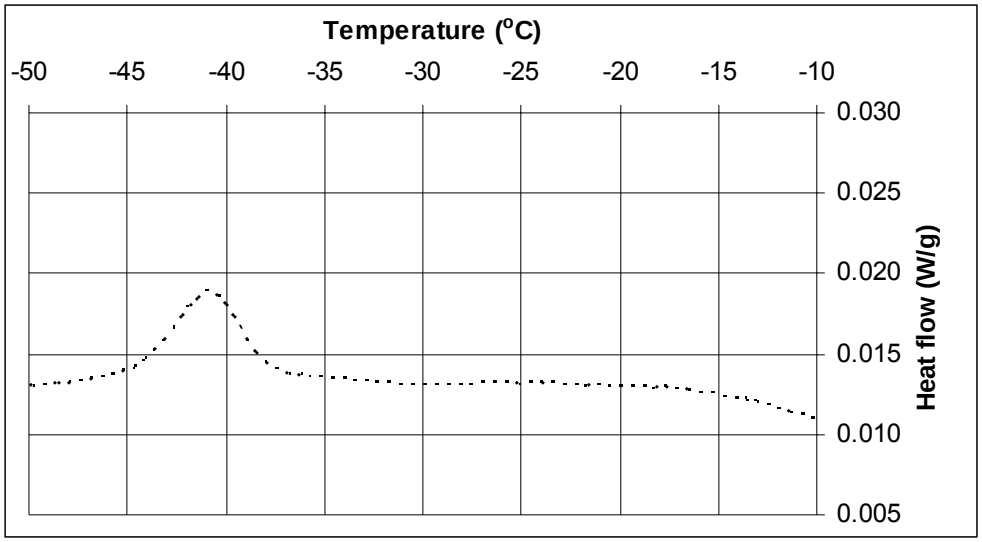

Figure 188 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of $LiNO_3$ and cured for 90 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: Distilled water
w/c: 0.40
Temperature: 20 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 101 d
Sample mass: 56.4 mg
Filename: c140p101d
Date tested: July 18, 2002

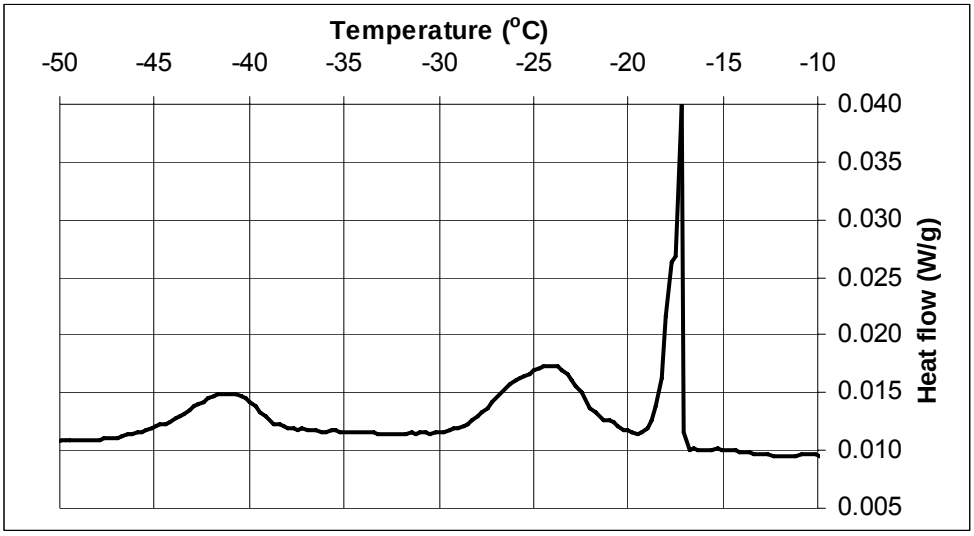

Figure 189 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with distilled water and cured for 101 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: Distilled water
w/c: 0.40
Temperature: 20 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 105 d
Sample mass: 49.8 mg
Filename: c140p105d
Date tested: July 22, 2002

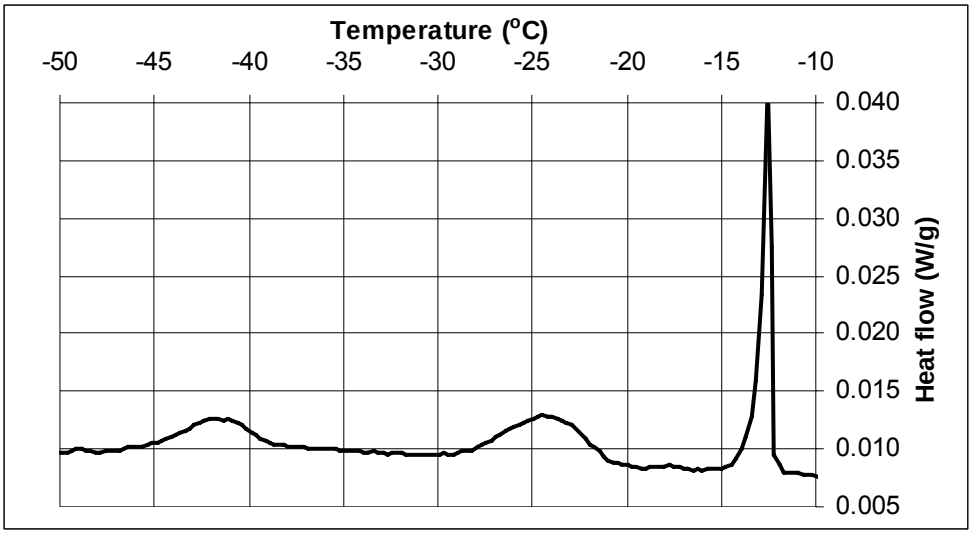

Figure 190 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with distilled water and cured for 105 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140
Solution: Alkali sulfate solution
w/c: 0.40
Temperature: 20 °C
Degree of hydration: N/A

Curing: Saturated
Age when tested: 101 d
Sample mass: 64.2 mg
Filename: c140walk101d
Date tested: July 18, 2002

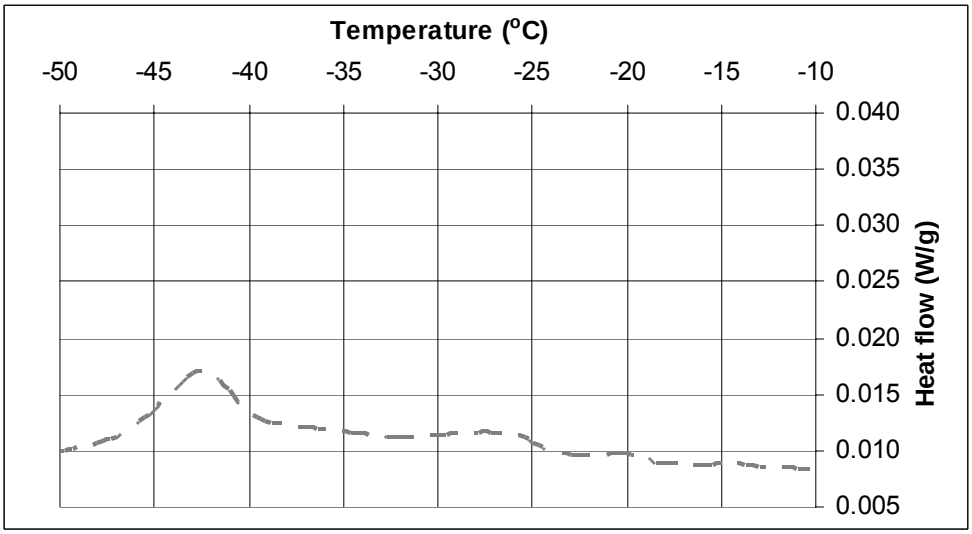

Figure 191 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of alkali sulfates and cured for 101 d at 20 °C under saturated conditions.

Cement: CCRL Cement 140	Curing: Saturated
Solution: Alkali sulfate solution	Age when tested: 110 d
w/c: 0.40	Sample mass: 60.6 mg
Temperature: 20 °C	Filename: c140walk110d
Degree of hydration: N/A	Date tested: July 29, 2002

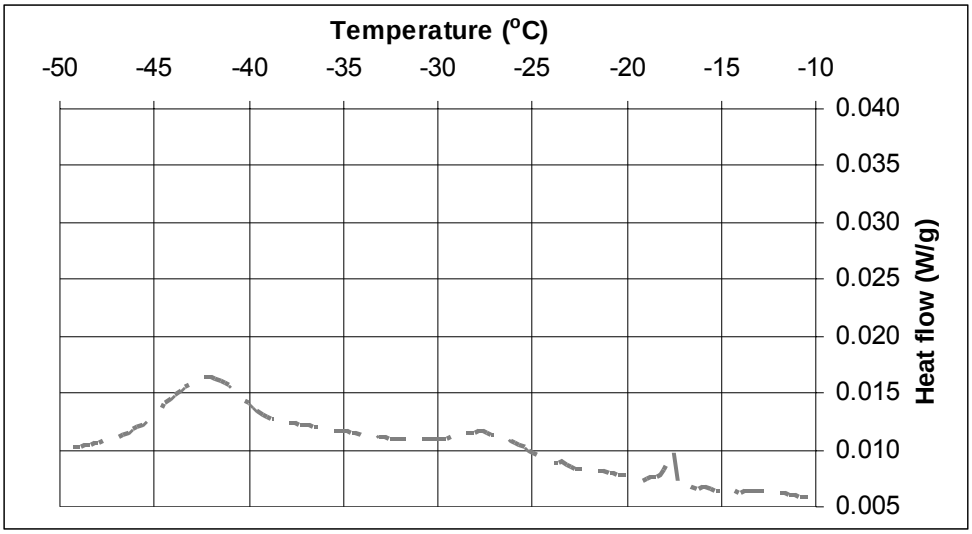

Figure 192 LTC scan for CCRL Cement 140, *w/c*=0.40, prepared with a solution of alkali sulfates and cured for 110 d at 20 °C under saturated conditions.

Observations

1) For low *w/c*, sealed curing first depercolates capillary pores, but then later repercolates them due to self-desiccation stresses, internal shrinkage, and possibly microcrack formation [2]. The sealed/resaturated scans for cement 152, *w/c* = 0.35 in Figures 39, 42, 43, 48, 49, 55, 59, 64, 71, 73, 79, and 81 illustrate this process for curing at 20 ^{o}C. For the small cement paste specimens employed in these studies, continuing resaturation of the specimens cured first under sealed conditions did result in a second depercolation of the repercolated capillary (size) pores; this is illustrated in Figures 67, 72, and 83. In Figures 83 and 84, however, the repercolated open gel (size) pores did not exhibit a second depercolation upon extended resaturation from 204 d to 224 d or 238 d. For curing at 40 ^{o}C, equivalent depercolation/repercolation behavior is indicated in Figures 124, 130, 135, 136, and 140. For cement pastes with a 20 % by mass fraction limestone substitution, equivalent repercolation behavior was observed (Figures 97 and 101), but without any evidence of a subsequent second depercolation of the capillary pores (Figure 98), perhaps due to the higher effective *w/c* in the specimens with the limestone substitution.

2) For extremely low *w/c* = 0.25 at 20 ^{o}C, this repercolation was observed both for specimens cured under sealed conditions and then resaturated (Figures 8, 11, 15, 18, 21, 24, 27, and 30) and for specimens cured under nominally "saturated" (water ponded on top) conditions (Figures 4, 6, 9, 13, 16, 19, 22, 25, and 28). Most likely, for this extremely low *w/c*, it was not possible to maintain saturated conditions using the techniques employed in this study. Similar repercolation observations apply for the 40 ^{o}C curing for the *w/c* = 0.25 cement pastes, as indicated in Figures 117, 118, and 120.

3) For saturated curing, **more** time (and hydration) is required to depercolate the pores in a *w/c* = 0.35 cement 152 paste when cured at 40 ^{o}C, as opposed to at 20 ^{o}C, in spite of the fact that the higher temperature curing significantly accelerates the cement hydration reactions. This suggests the formation of a coarser capillary pore structure when curing at higher temperatures in agreement with conventional wisdom [9]. For 20 ^{o}C curing under saturated conditions, depercolation of the capillary size pores occurred between 3 d (Figure 37) and 4 d (Figure 40) of curing. Conversely, for 40 ^{o}C saturated curing, this same depercolation occurred between 7 d (Figure 127) and 14 d (Figure 131).

4) For intermediate *w/c* (e.g., 0.40 to 0.45), it appears that some length of sealed curing followed by resaturation may be superior to saturated curing from the time of initial casting, in terms of providing an earlier depercolation of the capillary pores. Evidence for this can be found in Figures 146, 148, and 149 for the cement 152 *w/c*=0.45 cement pastes cured at 40 ^{o}C for 14 d and in Figures 87, 89, and 90 for the cement 152 *w/c*=0.435 cement pastes cured at 20 ^{o}C. This effect could be due to the fact that under the initial sealed curing conditions, cement hydration will be localized in the pore entryways and smaller pores and will not be occurring in the larger pores that are emptying due to self-desiccation (from the chemical shrinkage accompanying the hydration reactions). Figure 193 provides a simple 4-particle model of cement hydration illustrating this hypothesis.

5) For the low-alkali cement 140 pastes with *w/c* = 0.40, repercolation of the capillary and open gel pores was observed to occur at later ages even under saturated curing conditions, as exemplified by the LTC scans in Figures 172, 177, 182, 183, 189, and 190. It is likely that the C-S-H gel formed in this hydrating low-alkali cement paste is very amorphous with a highly random morphology; thus, subsequent rearrangement to a more ordered (nano)structure could be responsible for local shrinkage and the observed repercolation of the open gel and capillary (size) pores [3, 4]. Conversely, the addition of alkalis (lithium, sodium, or potassium) results in an earlier depercolation of the capillary pores as indicated by comparing Figures 162 to 166 for specimens cured for 8 d under saturated conditions. Furthermore, limited evidence of a later age repercolation is observed only for the specimens with potassium and sodium sulfate additions, as shown in Figures 191 and 192. The specimens with alkali hydroxide or lithium nitrate additions cured for 90 d under saturated conditions exhibited no evidence of either an open gel or capillary pore repercolation (Figures 186, 187, and 188).

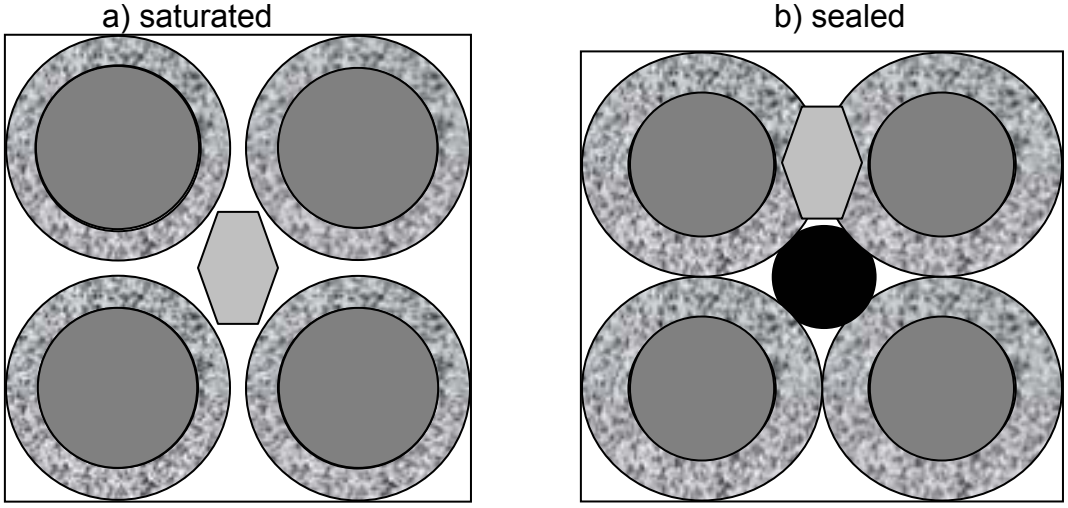

Figure 193 Four particle model for hydrating cement paste microstructure, indicating hydration under saturated and sealed curing conditions. Dark grey is unhydrated cement grains, textured material and light grey are hydration products, white is water-filled porosity, and black is empty porosity, from reference [2].

Conclusions and Future Research

Low temperature calorimetry has been shown to be a valuable tool for characterizing the porosity of hydrating cement pastes, both in terms of the presence/absence of freezable water as a function of temperature and the percolation state of pore networks with various size entryways (dense gel, open gel, and capillary). Numerous examples of the influences of cement type, *w/c*, curing temperature, curing time, curing saturation conditions, and the additions of alkali compounds or limestone fillers have been presented in this report. Future efforts will focus on extending these LTC and hydration studies to blended cements to examine the influence of additions of silica fume, slag, fly ash, and the like on the developing porosity. In addition, studies are also underway on the influence of several different shrinkage-reducing admixture (SRA) types and dosages on the freezable water content of hydrating cement pastes.

References

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