Low Temperature Calorimetry and Alkali-Activated Slags

By

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Abstract

The American Society of Civil Engineers' (ASCE's) "2013 Report Card for America's Infrastructure" estimated that "32% of America's major roads are in poor or mediocre condition." An estimated $100 billion dollars are needed to maintain that condition, and an additional $79 billion is needed to improve the quality of American roadways to an acceptable level. In many regions around the US, the service lives of concrete pavements are limited by the damage caused by freezing and thawing of pore solution inside the pavements. Alkali-activated slags (AAS) are produced from ground granulated blast furnace slag (GGBFS), a byproduct of iron production, and exhibit cementitious properties. AAS concretes have been shown to have improved corrosion and freeze/thaw resistance compared to traditional cement-based concretes. A Guarded Longitudinal Comparative Calorimeter (GLCC) was used to determine when the freezing and thawing of internal water occurs in three AAS mortars using solutions of NaOH, Na_2CO_3, or waterglass compared to a control Ordinary Portland Cement (OPC) mortar. AAS mortars using NaOH and Na2CO3 showed comparable thermal properties to the OPC mortar using the GLCC, and the AAS mortar using waterglass was shown to have higher heat capacity compared to the other AAS mixes. The compressive strengths varied by the alkaline solution used, with AAS with Na2CO3 showing inferior compressive strength to OPC, AAS with NaOH showing similar compressive strength to OPC, and AAS with waterglass showing superior compressive strength to OPC, but poor workability. A computer model of the GLCC testing procedure was created and showed good agreement with the experimental data. The GLCC model can be modified to approximate the results of the GLCC using a wider range of materials and internal solutions, like PCMs.

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1 Introduction

In 2009 the American Society of Civil Engineers (ASCE) released a "Report Card for America's Infrastructure" and gave U.S. infrastructure a D grade [1]. The ASCE recently released their "2013 Report Card for America's Infrastructure" and increased that score to D+ [2]. An estimated $3.6 trillion will be needed by 2020 to improve American infrastructure over all of the 16 categories studied [2]. Such a large investment would improve the quality and safety of American infrastructure. The ASCE states that "32% of America's major roads are in poor or mediocre condition" as of 2013 [2]. American roads also received a grade of D in 2013, which was a slight improvement to the 2009 grade of D- [1, 2]. An estimated $100 billion is needed annually to maintain the current roadway conditions, and an additional $79 billion annually is needed to improve the quality of the roads [2].

It is clear that improvements need to be made in roadway infrastructure in the US, so research into new technologies and new materials for pavements are increasingly becoming more important. One way to increase the performance of roadways and decrease the economic burden of pavement rehabilitation and replacement is to use more durable materials. Durability is defined as the ability of a material to resist damage. This damage can come from many sources, but this thesis focuses on the damage from freeze/thaw cycling.

Concrete is a common paving material and a mixture of Ordinary Portland Cement (OPC), water, aggregate, and admixtures. The water allows for hydration reactions to occur with the OPC creating a cementitious paste that binds the aggregates together. However, not all of the water is used in the hydration reaction, and some is left behind in the pore solution of the concrete. Additionally, the concrete can become further saturated by ground- or storm- water. A saturated concrete can be damaged if exposed to cold temperatures where the freezing point of the pore solution is reached. The pore solution (mostly water) can freeze and expand, which creates and expands cracks in the microstructure of the concrete.

This damage to the microstructure accumulates over multiple freeze/thaw cycles, decreasing the effectiveness of a concrete over the course of its service life, eventually leading to failure. Freeze/thaw cycles have been shown to cause D-cracking, scaling, and internal paste cracking. This can only happen to concrete that is saturated in wet environments and also subjected to freezing temperatures. Because of these specific conditions, concrete pavements in many locations do not experience significant freeze/thaw damage. Places that are too warm year round, like the American South, or too dry to reach critical saturation, like the Great Plains, do not experience freeze/thaw damage as a major degradation mechanism. Places like New England, on the other hand, are wet and cold climates where freeze/thaw damage is a significant problem. For places like New England, a new, more durable pavement material could be used to replace cement-based concretes and reduce the economic burden of roadway maintenance.

One possible alternative material to cement-based concrete is alkali-activated slag-based concrete. Alkali activated slags (AAS) are made from Ground Granulated Blast Furnace Slag (GGBFS) and an alkaline solution. GGBFS is a waste product from iron production. This recycled material (GGBFS) has been used as an additive in "blended cements" and has been shown to increase durability against other forms of damage [3]. It can also be activated by an alkali solution to completely replace OPC as the cementitious material in concrete. The reaction that produces an AAS binder requires alkali solutions to occur. Solutions such as sodium hydroxide, sodium carbonate, and waterglass have been used to activate AAS, each resulting in different properties.

Since each activating solution results in a different set of properties, multiple mixes of AAS are used for research purposes. This thesis used three activating solutions (sodium hydroxide, sodium carbonate, and waterglass) and compares the properties of the resulting 100% AAS mortars to standard OPC-based mortars. By studying the compressive strength and behavior in freezing and thawing cycles, this thesis aimed to further research into using AAS as a durable alternative to current OPC pavements. Also developing a computer model of concretes undergoing freeze/thaw cycling, this thesis allowed research to be performed at a faster rate than current long-term testing.

2 Background

2.1 Freeze/Thaw effects on OPC

Over the course of a concrete's service cycle, the concrete can be exposed to wetting events, such as rainfall, flooding, etc. During these wetting events, water enters the pores of the concrete. The water in the pore structure then freezes which can cause damage to the concrete. The mechanism for the damage of concrete is not fully known, but there are two accepted theories: hydraulic pressure theory and osmotic pressure theory.

Hydraulic pressure theory is based on the understanding that the phase change of water from liquid to solid causes an increase in volume of 9%. In this theory, when the internal water begins to freeze, the unfrozen water is pushed out of large voids into the smaller capillary voids. This movement creates hydraulic pressure that can eventually create internal tensile stress failure. These tensile failures accumulate over a number of freeze/thaw cycles until the degradation eventually reaches failure level [4] .

The osmotic pressure theory is based on the understanding that when freezing occurs, the unfrozen water at the freezing site has a higher concentration of ions than the original solution. In this theory, the higher concentration of ions in the unfrozen solution creates an osmotic potential between the unfrozen solution in the capillaries and gel voids, and the unfrozen solution at the freezing site. This osmotic potential drives the movement of the lower concentration solution into the freeing site void. This creates osmotic pressure, which can cause the cementitious binder to fail locally [4]. As in the hydraulic pressure theory, the damage is cumulative over a number of freeze/thaw cycles until a failure level is reached. How the failure level is defined varies by locality, research group, and agencies, but ASTM C666 defines concrete failure when the transverse elastic modulus has fallen to 60% of the original measured value.

Freeze/thaw degradation is not a significant degradation mechanism in all locations because it only exists in certain environmental conditions. Both theories discussed above require the saturation of concrete in water and for the water to reach freezing temperature. Therefore, only locations that have sufficiently wet climates and that reach freezing temperatures regularly are subject to significant freeze/thaw degradation. In the United States, locations that meet these criteria are parts of the Northwest including California, parts of the Southeast, most of the Midwest and Mid-Atlantic, and the entire Northeast.

Deicing salts are a mainstay of wet and cold climates in which freeze/thaw is most likely to occur. They are chemicals used to lower the freezing point of water and ice on roadways in the hopes that it will cause the ice to melt, thus making the roadways safer. Deicing salts have been shown to reduce the service life of concrete pavements.

Cai *et al.* found that the final temperature of saturated concrete significantly affects the freeze/thaw resistance of concrete. The studied concrete mix failed at 133 freeze/thaw cycles at 23°F (-5°C), 12 freeze/thaw cycles at 14°F(-10°C), and 7 freeze/thaw cycles at 1.4°F(-17°C) [5].

2.2 Freeze/Thaw Mitigation

Both the hydraulic pressure theory and osmotic pressure theory relate the damage caused by the freeze/thaw cycle to the water stored in the pores of concrete. In addition, in both theories the stresses produced are a function of the volume of the pores in the concrete matrix. Based on this observation, the resistance of concrete to freeze/thaw damage is considered to be a function of the material properties related to the air voids in concrete, such as porosity, sorptivity, and critical saturation. A number of environmental conditions factor into the service life of concrete, such as the total length of wetting events over the nickpoint and number of freeze/thaw cycles. Nickpoint is defined as the time between the start of wetting of the concrete and the change from initial sorptivity to secondary sorptivity. Research into improving freeze/thaw resistance focuses on adjusting these material properties, although some research has been done in adjusting the local environmental factors.

Internationally entraining air voids into concrete is the primary method of improving freeze/thaw resistance in concretes. The air voids created by air entrainment provide room for the expansion of freezing water outside of the capillary pores, which reduces the internal stresses. Air entrainment agents are admixtures that provide a uniform distribution of air voids for internal stress relief. Intentional air entrainment has been used in concretes for over 45 years and is the standard technique for increasing durability of concrete.

Normal strength concrete requires 4 % to 7% air content to be considered frost resistant [6]. 2% comes from the entrapped air in the concrete, and the rest comes from air entrainment. High strength concrete requires only the entrapped air for mixtures with water to cement ratios less than 0.36, and only an additional 2% air entrainment for high strength mixes with water to cement ratios between 0.36 and 0.50 [7].

Environmental conditions are largely outside the control of designers, but the development of Phase Changing Materials (PCM) has opened up a method of mitigating the number of freeze/thaw cycles that concrete undergoes. PCM are materials engineered to undergo phase changes at a specified temperature. The energy used or released by the PCM during phase change is then used to regulate the temperature of whatever material it is used with. Concrete using PCMs were first used to mitigate high temperature effects in concrete, lessen the temperature rise in early age curing of large concrete structures, and regulate the overheating of livable concrete structures in hot environments.

PCM in concrete has been used to delay, and in some cases, completely avoid the onset of freezing in concrete. Using the CONTEMP computer model, Bentz and Turpin were able to simulate the effects of a 5°C PCM in concrete bridge decks in 12 American cities, and found that the PCM had reduced the number of freeze/thaw cycles undergone by at least 19.1% [8]. A similar study found that PCMs could increase the service life of concrete bridge decks in the American Northwest, Southeast, and parts of the Mid-Atlantic by at least 1 year [9].

Though PCM increases the service life of concrete due to freeze/thaw, PCMs have also been found to decrease the compressive strength of concrete.

2.3 Alkali-Activated Slags

Alkali-activated slags (AAS) are made from ground granulated blast furnace slag (GGBFS), which are the by-product of iron production, which exhibit cementitious properties when exposed to alkaline solutions. AAS concretes are made of ground granulated blast furnace slag, aggregates, and an alkali activator solution. The activators are generally alkali hydroxides, non-silicic salts of weak acids, or silicic salts of the form $R_2O \cdot (n)SiO_2$. The alkali metal ions (R) are generally Na, K, or Li [10]. Out of all the studied activator solutions, waterglass is consistently found to be the most effective activator [10-16]. Waterglass solutions have a higher pH compared to other solutions, resulting in a more complete reaction [17]. In other words, when the waterglass solutions are mixed with AAS, more hydration products are produced. Several studies have shown that waterglass solutions produce early strength gain and can cause setting times to be within 15 minutes [12, 18-20].

The possibility of using alkali solutions to activate slag from industrial processes was discussed as early as the 1940s. The first use of Alkali Activated Slag binder in concrete was by Glukhovsky in the USSR in 1957 [21, 22]. Much of the original research on AAS was done in the USSR, and did not garner interest in Europe or the East Asia until the 1970s [10].

Though the various activators produce some differences, C-S-H with a C/S of ratio of 1-1.2 and some substitution by other elements, such as Na and Al, has always been found to be the primary hydration product of AAS pastes. C-S-H is also the primary hydration product of OPC pastes, but with a C/S ratio of 1.7 [23-25]. AAS mortars show a denser microstructure than typical OPC mortars [18, 26, 27]. Hardened AAS show a lower number of capillary pores and a higher number of gel pores than OPC, making the structure of AAS more impermeable than OPC [14, 28-31]. Capillary pores larger than 50 µm have been shown to be detrimental to the impermeability and strength [32]. Higher impermeablility of a concrete has been shown to correlate with higher corrosion resistance.[33-36]. Higher impermeability has also been shown to be related to higher resistance to freeze/thaw damage [37, 38].

2.4 Freeze/Thaw effects on Alkali-Activated Slag

AAS have shown much promise in increased durability over OPC. AAS concretes have been found to resist anywhere from 300-1150 freeze/thaw cycles compared to OPC concretes, which typically fail below 300 cycles [18, 26, 39, 40]. This increased benefit of freeze/thaw durability has translated into real world gains. Case studies performed on structures using AAS have found that the AAS concretes of varied starting strengths show increased strength over the service life of the structures and over hundreds of freeze/thaw cycles (Table 1) [10, 18, 41-43]. These case studies show that freeze/thaw cycling does not have an overall detrimental effect in real world water saturated conditions, like canals, water ponds, road surfaces, and dams. Table 1 also shows that the strength of AAS concrete can increase by almost 200% over a service life even when undergoing freeze/thaw cycling.

Table 1 Results of case studies performed on AAS concrete structures [10, 18, 41-43]

Application	Service years	Aggregate type	Original strength: MPa	After service		Strength increase: %
				Frost-resistance cycles	Strength: MPa	
Canal surface (under water)	11	Secondary sand rock	15	900	42·6	184
Canal surface (in air)	11	Secondary sand rock	15	900	40·0	167
Water pond	9	Sea sand	25	700	59·5	138
Pile	9	Sea sand	30	600	71·8	139
Road surface	8	Sea sand	16	250	47·6	198
Dam	8	Sea sand	30	570	62·0	107
Pipe	7	River sand	30	—	83·0	177
Floor member	2	Carbonate	90	1115	101·0	11
Floor member	2	Granite	96	1115	122·0	27
Floor member	2	Carbonate	70	1000	110·0	57

As mentioned in section 2.3 of this report, AAS mortars have a higher impermeability than OPC. This impermeability has been shown to increase over the service life of structures using AAS concretes (Table 2).This increased impermeability means that as an AAS structure ages it becomes more resistant to corrosion and freeze/thaw degradation.

Table 2 Results of case studies of impermeability of AAS concretes over a service life [10, 18, 41-43]

Application	Service years	Impermeability: MPa		Increase: %
		Original	After service	
Canal surface	12	0·6	1·8	200
Water pond	9	1·0	2·0	100
Dam	8	0·8	2·0	150
Slab in biomaterial	8	0·8	2·0	150

3 Methods

In this section, the materials used in the research are described, followed by the mix design of the concrete. Three different test procedures were used: compressive strength testing, freeze/thaw testing, and Guarded Longitudinal Comparative Calorimetry (GLCC), each of which are described in detail. Finally, there is a discussion of a computer model created to simulate the GLCC testing procedure.

3.1 Materials[1]

The control mix was prepared using commercially ASTM C150 Type I/II cement and local sand. The test mixes used granulated ground blast furnace slag, local sand, and three different alkali solutions. Sand was sieved using #8, #16, #30, #50, and #100 sieves for 10 minutes of mechanical sieving. The alkali solutions used were 4M NaOH, 2M Na_2CO_3, or waterglass, and were created in the lab. The waterglass solution was 61.82% Na_2SiO_3, 28.18% 4M NaOH, and 10% potable tap water by mass.

3.2 Mix design

Each mortar was prepared with an activator-binder ratio of 0.45 by mass and contains 50 % aggregate by volume. Table 3 (overleaf) shows the proportions for each mix for a 61.02 in^3 (1000 cm^3) batch. During the mixing process, the dry binder was first added to the mixer and the mixing started. After 30 seconds of mixing to insure that all of the binder was being caught by the blades of the mixer, the activator was added. The activator and binder were mixed for 30 seconds. Mixing was then paused, in order scrape the binder/activator mix from the sides and blades to insure that all the binder and activator was being mixed. The mixing was then continued for 30 more seconds, and the fine aggregates were added and left to mix for 30 more seconds. The mixer was then stopped, and the mix was visually inspected to ensure that all the elements were properly mixed. If the elements were not properly mixed, the mix was manually manipulated and the mixing continued for another 30 seconds. After all the elements were confirmed to be properly mixed, the mix was placed into molds and then into plastic bags to prevent extra moisture entering the mixture. The molds in the bags were then placed in a curing room for 24 hours. The specimens were then removed from the molds and placed back into the curing room without the bag until their specified testing date.

[1]Certain commercial equipment, instruments, or materials are identified in this report in order to specify the experimental procedure adequately. Such identification is not intended to imply recommendation or endorsement, nor is it intended to imply that the materials or equipment identified are necessarily the best available for the purpose.

Table 3 Mix design materials and ratios. Masses are in grams (Volumes are in cm^3)

Mix Name	Control Mix	Mix 1	Mix 2	Mix 3
OPC	613.4 (194.4)			
Slag		573.9 (211.8)	573.9 (211.8)	573.9 (211.8)
Sand	1305 (500)	1305 (500)	1305 (500)	1305 (500)
Water	275.6 (275.6)			
NaOH		258.2 (258.2)		72.8 (72.8)
Na_2CO_3			258.2 (258.2)	
Waterglass				159.6 (159.6)

3.3 Compressive Strength

Compressive strength was determined in accordance with ASTM C109 using 2-inch (50.8 mm), concrete cubes. A load frame loaded the cubes at 2,000 psi (13,790 KPa) per minute, while recording the load and crosshead position until failure occurred. This testing was performed on specimens of each mix at ages of 3, 7, and 28 days in order to determine the strength gain over time. Each mix was tested using three cubes at each age.

3.4 Guarded Longitudinal Comparative Calorimetry (GLCC)

A Guarded Longitudinal Comparative Calorimeter (GLCC) was used to determine the specimen thermal properties. The GLCC consists of a cold plate, thermal insulation, thermocouples, two standard blocks of known thermal properties, and thermal contact media (Figures 1 and 2). By placing the concrete specimen between standards, the thermal properties of the concrete specimen can be determined over the course of a thermal cycle (Figure 3). The specimens were prepared for this testing by submerging them in water for at least 24 hours beforehand to saturate the specimen with water.

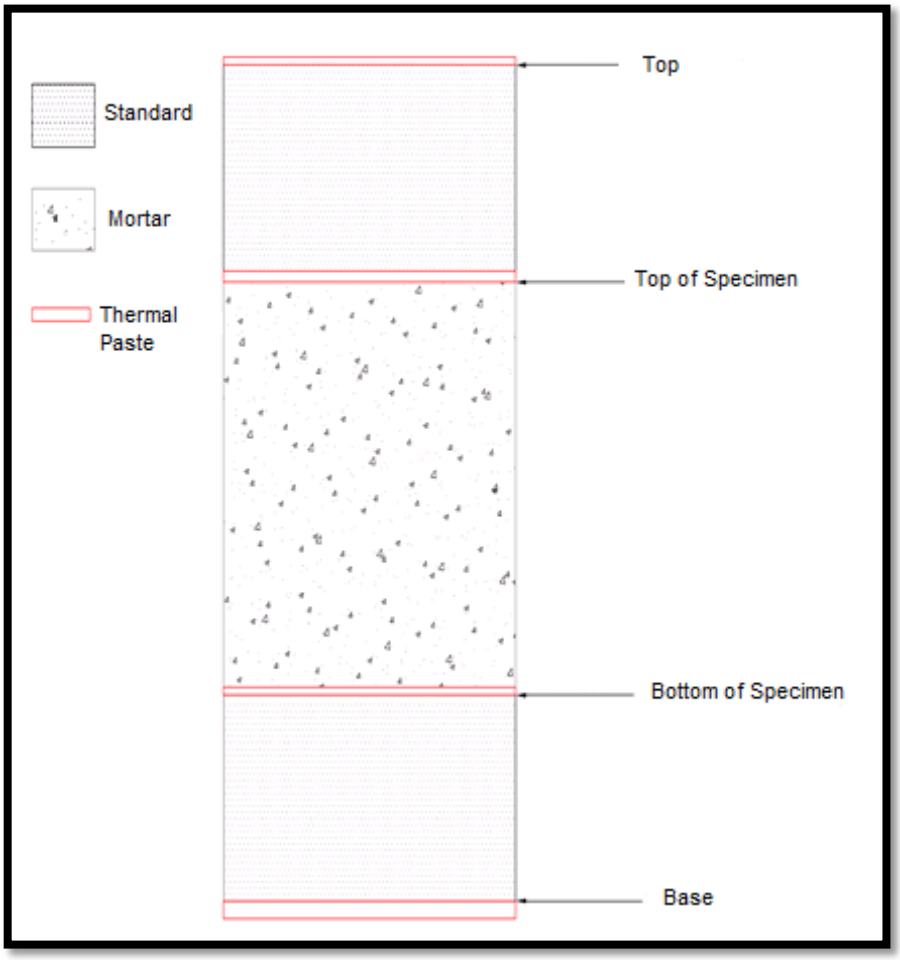

Figure 1 Drawing of GLCC experimental setup

The equation used to determine the unit heat flow through the standards was:

$$q_{standard} = \lambda_{standard} . \frac{T_{top\ of\ standard} - T_{bottom\ of\ standard}}{depth_{standard}}$$

Equation 1

Where q equals heat flow per unit area (W/m^2), λ is thermal conductivity of Pyroceram 9606 (W/m^2),T is temperature in °C, and depth is measured in meters. The standard blocks used in this experiment were Pryoceram 9606. The thermal conductivity of Pyroceram 9606 is calculated by [1]:

$$\lambda = -0.0061(T) + 4.2013$$

Equation 2

Where λ is thermal conductivity of Pyroceram 9606 (W/m^2) and T is temperature (°C). The equation used to find the average unit heat flow through the specimen was:

$$q_{Specimen} = \frac{q_{Top\ standard} + q_{bottom\ standard}}{2}$$

Equation 3

And the total heat flow change in the specimen was determined using the following equation:

$$\Delta Q_{Sample} = (q_{Bottom\ standard} - q_{top\ standard}) * A$$

Equation 4

Where ΔQ is the change in heat flow through the specimen. A graph of the average temperature of specimen versus ΔQ was then created. These graphs show the general heat flow trends and "spikes" in heat flow due to the energy released during the melting of frozen water or absorbed by the freezing of the water in the concrete samples. These spikes gave the average specimen temperature of the phase changes of the water. The average temperature of each specimen was determined by the following equation:

$$T_{avg} = \frac{(T_{bottom\ of\ concrete} + T_{top\ of\ concrete})}{2}$$

Equation 5

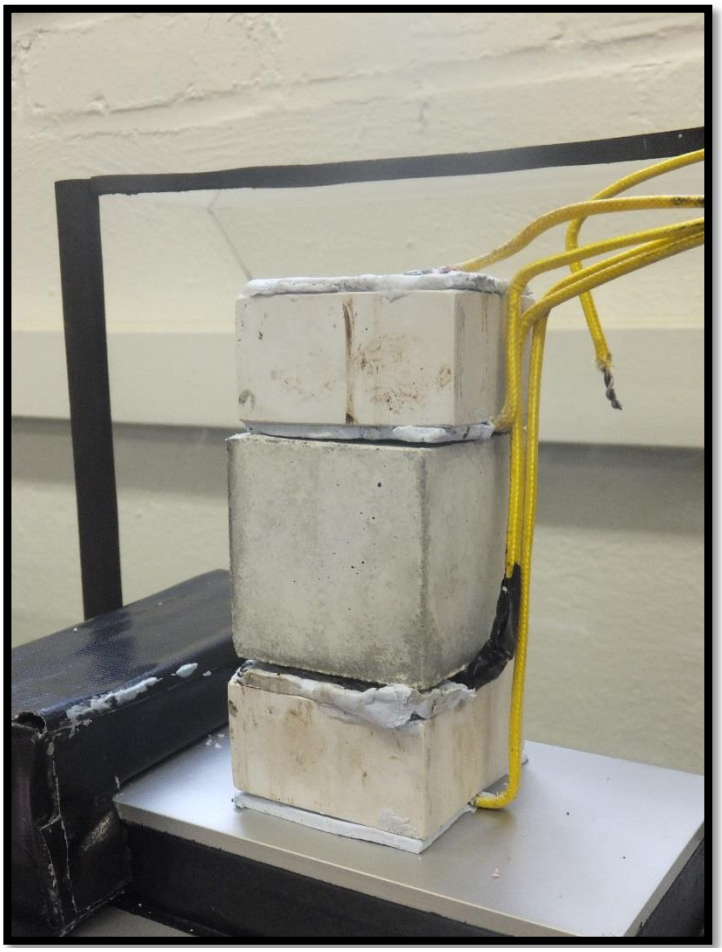

Figure 2 GLCC set-up without insulation. Standard blocks on the top and bottom of a concrete specimen, with thermal paste and thermocouples at each horizontal boundary.

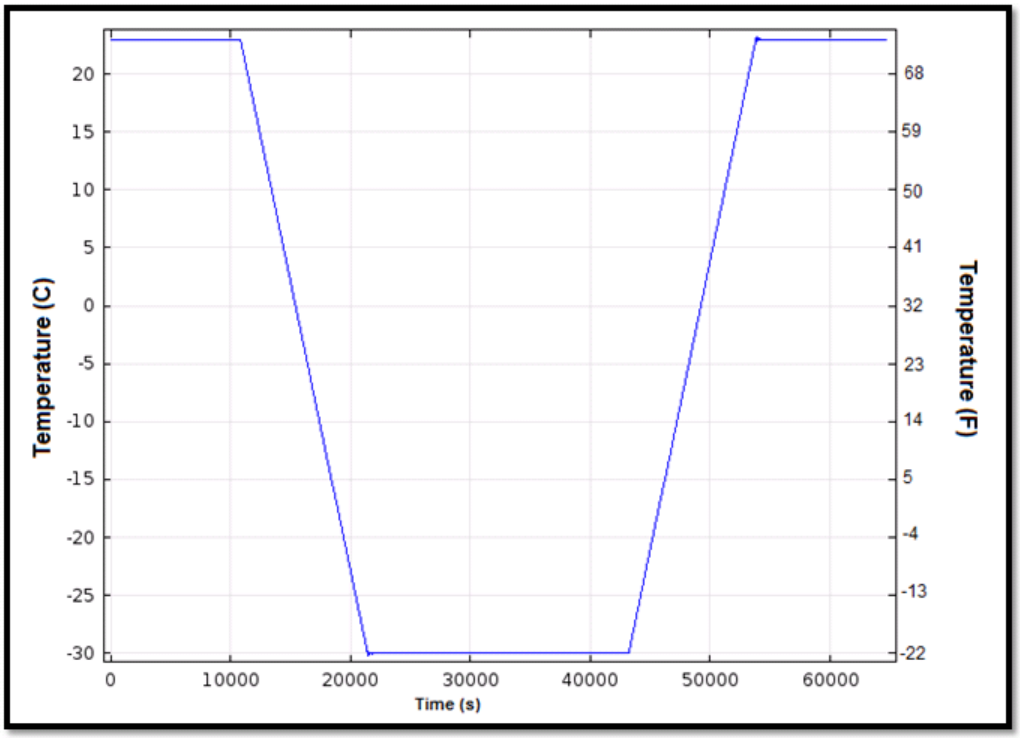

Figure 3 Programed thermal loading cycle of cold plate.

3.5 COMSOL Multiphysics Modeling

A 2D heat transfer computer model was produced to simulate the GLCC tests using the COMSOL multiphysics software package. The geometry of the model is a 2D cross sectional representation of the GLCC experiment with insulating material (Figure 4). The material Pryoceram 9606 was taken from the material browser within the COMSOL program and used for the standard material. The specimen material was a user-defined material to simulate a cement mortar saturated with water. The insulation material was also user-defined, the values were derived from the printed R value (Figure 5) on the material, calculating density from the weight, and taking the specific heat from literature. The top horizontal boundary is in contact with the ambient heat of the room which was assumed to be 73.4 °F (23 °C). The free air heat convection is described by this equation for every external boundary not in contact with the heat source:

$$\lambda \nabla T = h * (T_{external} - T_{surface})$$

Equation 6

Where λ is the thermal conductivity of the material (W/km), $T_{surface}$ is the temperature of the material surface (°K), $T_{external}$ is the outside temperature of the air (°K) which is assumed to be room temperature or 73.4 F (23°C), and h is the heat transfer coefficient (W/m^2K), which is assumed to be 5 W/m^2K for free air.

The same boundaries were also modeled to experience surface radiation, which is described by the equation:

$$\lambda \nabla T = \varepsilon \sigma (T_{ambient}^4 - T_{surface}^4)$$

Equation 7

Where ε is the surface emissivity, σ is the Stefan-Boltzmann constant, and $T_{ambient}$ is the ambient temperature which was set to 73.4 °F (23°C).

The specimen was defined as heat transfer with phase change, which is defined by the equations:

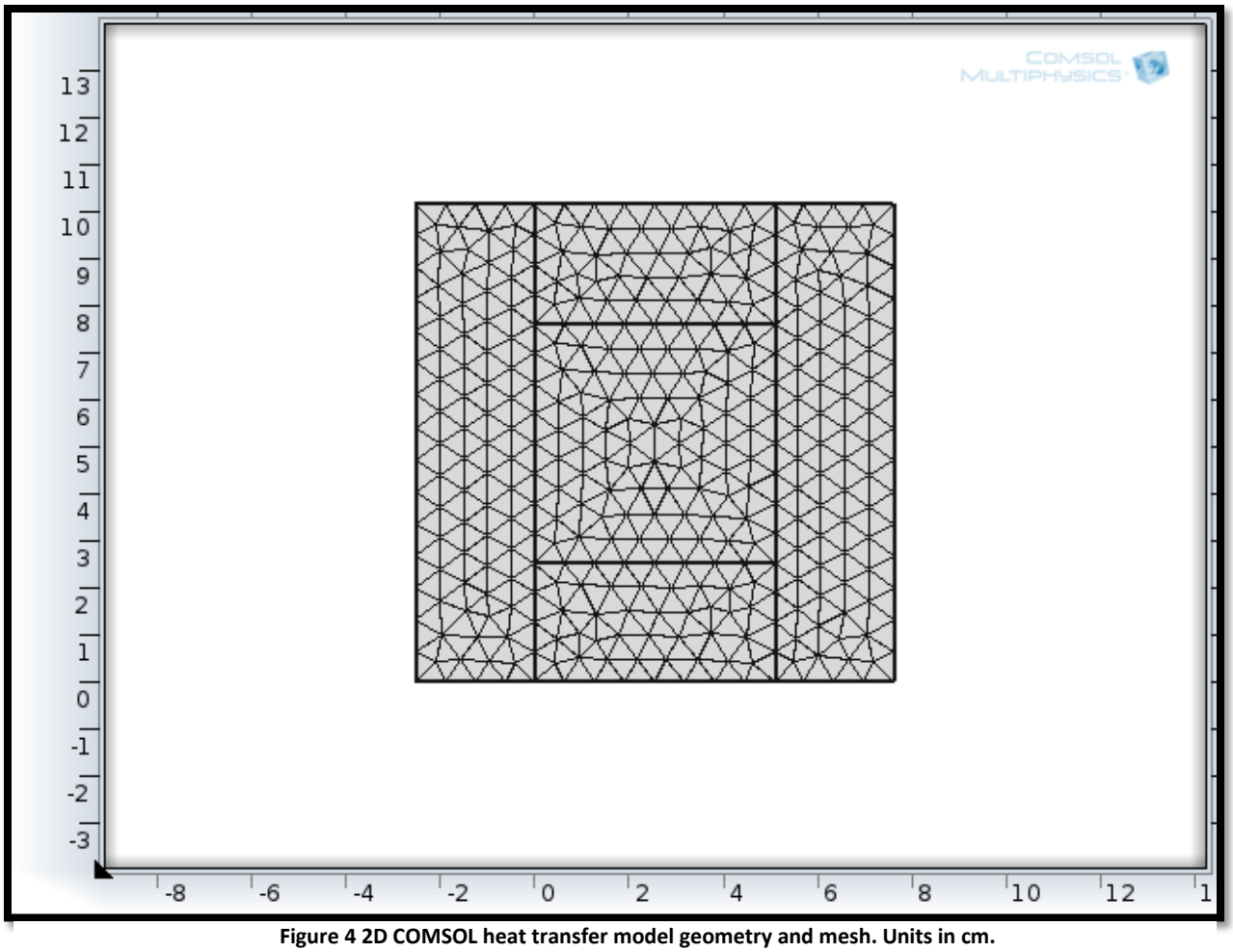

Figure 4 2D COMSOL heat transfer model geometry and mesh. Units in cm.

$$\left(\rho_{eq}C_{p,eq}\right)\frac{\partial T}{\partial t}+\rho C_p u\nabla T=\nabla\left(\lambda_{eq}\nabla T\right)+Q$$

Equation 8

$$C_{p,eq}=\theta_c\rho_c C_{\rho,c}+(1-\theta_c)\rho_w C_w+L\frac{d\alpha}{dT}$$

Equation 9

$$\lambda_{eq}=\theta_c\lambda_c+(1-\theta_c)\lambda_w$$

Equation 10

$$\rho_{eq}=\frac{\theta_c\rho_c C_{p,c}+(1-\theta_c)\rho_w C_{p,w}}{\theta_c C_{p,c}+(1-\theta_c)C_{p,w}}$$

Where $C_{p,c}$ is the specific heat of the mortar (J/kg K). u is the velocity field (m/s), which was assumed to be 0. λ_w is the thermal conductivity of the water, $C_{p,w}$ is the specific heat of the water(J/kgK), and ρ_w is the density of the water (kg/m^3). θ_p is the volume fraction of the mortar, which is set to 0.965 because voids are assumed to be 3.5% of the mortar. ρ_c is the density of the solid material (kg/m^3), $C_{p,w}$ is the specific heat of the mortar (J/kgK), and Q is the heat source or sink. L is the latent heat of fusion.

$\frac{d\alpha}{dT}$ is the Dirac pulse, which is the derivative of the Heaviside function. The Dirac pulse, or Dirac delta function, is a function that is equal to 0 at all places other than the origin, which can be infinitely high, an infinitely thin spike, or a thin distribution. The Heaviside function and the Dirac Pulse are used to indicate the change from one phase to another at the set phase change temperature (0°C).

The rest of the geometry was defined as heat transfer through solids, and it was defined by a simplified version of Equation 8:

$$\left(\rho C_p\right)_{eq}\frac{\partial T}{\partial t}+\rho C_p u\nabla T=\nabla(\lambda\nabla T)+Q$$

Equation 11

After the model was created, the resulting data was analyzed using the same equations as the experimental data (Equation 1-Equation 4). The results were then compared to one control sample. All the COMSOL material inputs can be found in Table 4.

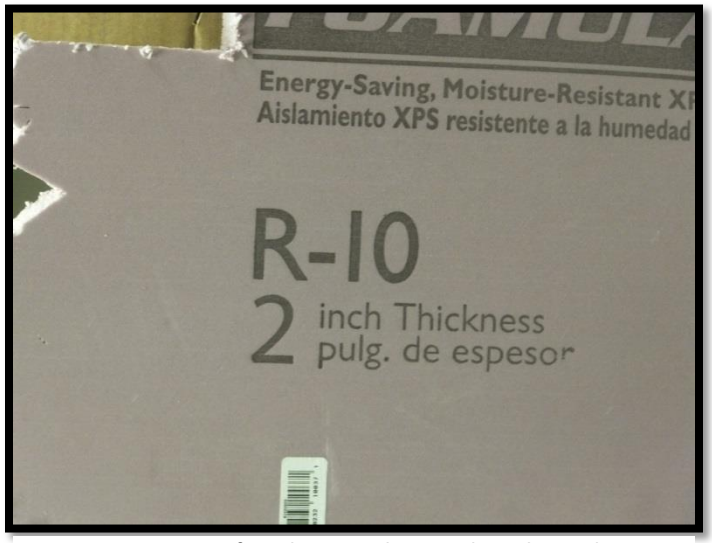

Figure 5 Picture of Insulation with printed R-value and thickness

Table 4 COMSOL material properties inputs

COMSOL material properties input							
	Volume Fraction	Density (kg/m^3)	Heat Capacity[1] (J/kgK)	Thermal Conductivity (W/mK)	Ratio of Specific Heats	Latent Heat of Fusion (J/kg)	Surface Emissivity
Cement Mortar	0.965	2200	750	1.78	NA	NA	NA
Water	0.035	997	4179	0.613	1	4179	NA
Ice		918	2052	2.31	1		NA
Pyroceram 9606	1	2600	From COMSOL material browser	From COMSOL material browser	NA	NA	0.85
Insulation	1	1050	1300	0.0285	NA	NA	0.95

1 - At constant pressure

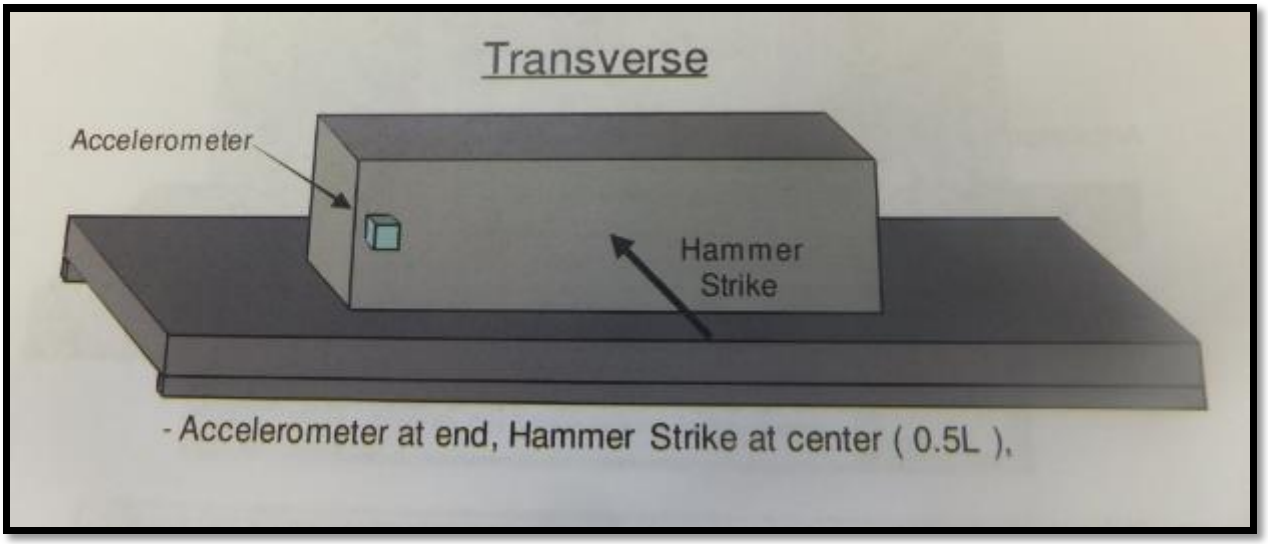

Figure 6 Resonant test setup up for determining transverse dynamic modulus (NDE 360 Platform Resonance Tester System Reference Manual.

3.6 ASTM C666/M and Wenner Probe

ASTM C666 is a standard test for measuring the effects of freeze-thaw cycling on concrete. After 14 days of curing, the mortar specimens were saturated in water and frozen for up to five hours so that the entire mortar specimen was below freezing temperature. Then it was thawed by submerging it in room temperature water for two hours. This cycle should be repeated for either 300 cycles or until the relative dynamic elastic modulus fell to 60%.

Resonant frequency tests (RTs) were performed before the first freezing cycle and after every 35th cycle. These RTs measure the transverse frequency of the specimen by placing an acoustic microphone at one end of the specimen and hitting the specimen lightly with a hammer (Figure 6). The microphone then measures the sounds waves caused by the hammer to give a resonance frequency for the specimen, (Figure 7). This frequency is then used to determine the relative dynamic transverse elastic modulus:

$$Pc = \left(\frac{{n_1}^2}{n^2}\right) x\ 100\%$$

Equation 12

Where;
P_c= the relative dynamic modulus of elasticity after *c* cycles
c= the number of freeze=thaw cycles
n_1=fundamental transverse frequency in Hz after *c* cycles
n= fundamental transverse frequency in Hz at 0 cycles

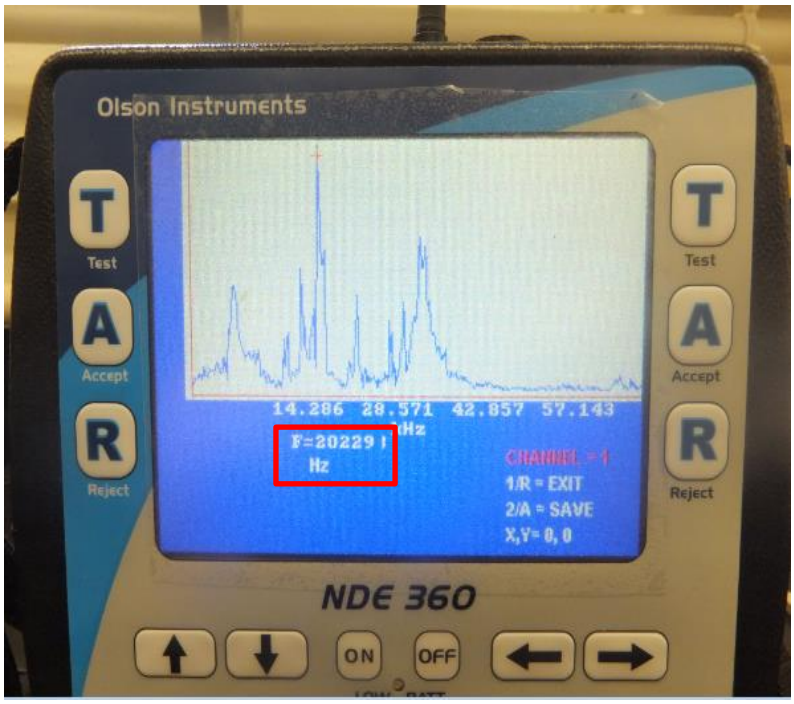

Figure 8 Resonant testing result, relevant result in red box.

The ASTM C666 modified test procedure was used due to storage space limitations. ASTM C666M requires 1 x 1 x 10 inch (25.4mm x 25.4mm x 254mm) prisms.

In addition to the resonance testing, the resistivity of each specimen was measured using a Wenner probe. A Wenner probe measures the resistivity of mortar by running a current between two outer probes spaced at 15 inches (380 mm), and then measuring the induced potential using two inner probes

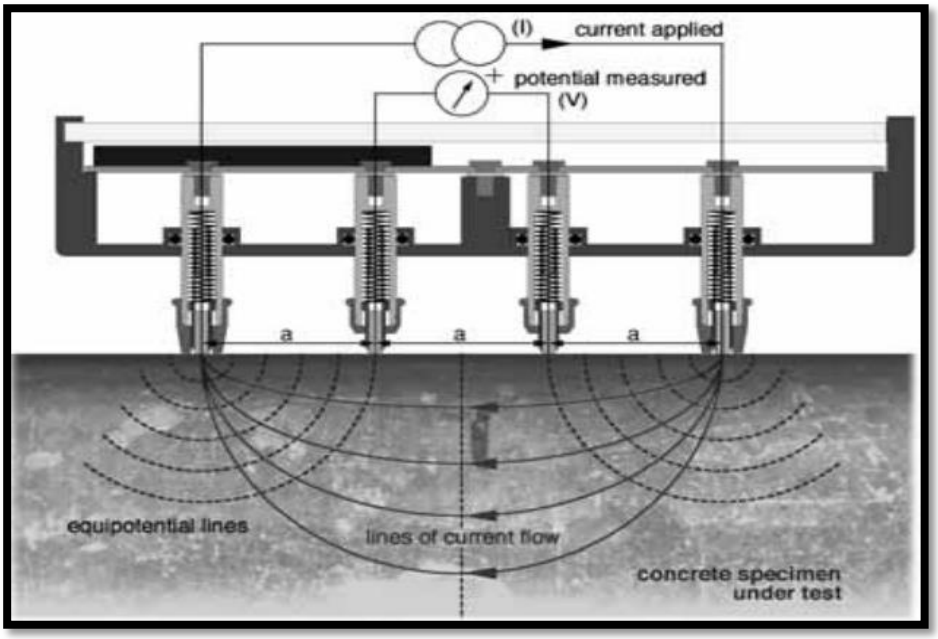

Figure 7 Operating schematic of a 4 probe Wenner probe, the Proceq Resipod Resistivity Meter. a=5inches (126.7mm) (Operating Manual Resipod Family)

spaced at 5 inches (126.7mm), as shown in Figure 7. The resistance of the mortar is reduced by damage from corrosion or freeze/thaw cycles. The device measures the resistance in kΩcm. The Wenner probe measurements were taken from the average of the four sides of the specimen. The Wenner probe testing was to be used until the sample was considered failed under ASTM C666. One study has indicated that electrical resistance is unacceptable as an indicator of permeability, but could be used to compare the quality of concrete with similar chemistries [44]. The electrical resistance was to be analyzed to see the relationship between resistance and freeze/thaw failure as defined by ASTM C666.

Due to the time constraints on the research, the full 300 cycles of freeze-thaw were not carried out at the writing of this thesis. The data collected does not show any significance at this time. It is recommended that this research is continued by another researcher.

4 Results

4.1 Compressive Strength

Figure 9 shows the maximum average compressive strength of each design mix at 3, 7, and 28 days of age. The highest strength is the 7 day AAS with waterglass solution with a strength of 8105 ± 461 psi (55.9 ± 3.18 MPa). The average 7 day strength, 8105 ± 461 psi (55.9 ± 3.18 MPa, for Mix 3 is more than the average of the measured 28 day strength, 7471 ± 631 psi (51.5 ± 4.35 MPa), but is within the standard deviation calculated for 28 day testing (Figure 9).

Figure 9 shows that Mix 1 had similar strength gain to the control case, and only 3.6% more than the 28 day strength. Mix 1 and Mix 2 both increased their strengths by about 40% (39% and 42% respectively), but Mix 2 was 20% weaker than Mix 1. Mix 3 had the smallest strength gain between day 3 and day 28 with only an 8% increase, but when day 3 strength is compared to day 7 strength, that increase jumps to an 18% increase, which makes the Mix 3 strength gain only slightly less than the control (24%). The size of the compressive strength increase from day 3 to day 7 may suggest that the reaction between the AAS and the waterglass occurred at a faster rate than the control and other mixes. The Mix 3 strength gain trend is similar to the strength gain shown in Sakulich *et al.*, where strength was fairly level after day 3.

The three test mixes showed similar results to testing by Fernández-Jiménez et al [15], who used a binder:activator ratio of 0.51. The NaOH activated mortar reached almost 40 MPa by day 28, Na_2CO_3 activated slag reached almost 50 MPa, and the waterglass and NaOH activated samples reached around 60 MPa.

When conducting the mixing of the mortar, the batches using the AAS set significantly faster than the OPC batches, sometimes becoming unworkable and requiring smaller batch sizing. This was especially the case with the AAS and waterglass (Mix 3), which was completely unworkable within 20 minutes of adding the waterglass solution. This seems to support the assertion that the AAS and waterglass reaction occurs at a faster rate than the control reaction as discussed in 2.3.

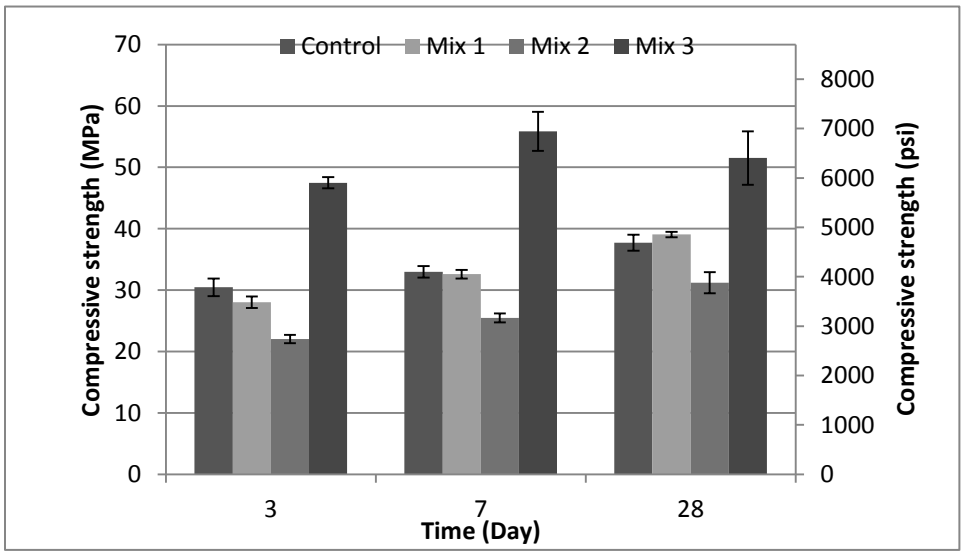

Figure 9 Average Compressive Strength Results

4.2 Guarded Longitudinal Comparative Calorimetry

Figures 10 through 13 show the change in heat flow (W/m^2) by the average sample temperature for the control, Mix 1, Mix 2, and Mix 3, respectively. The average sample temperature was determined by Equation 5 mentioned in section 3.4. All the figures show an almost complete oval shape; incomplete shapes are due to the samples not being completely heated back to original conditions by the end of the thermal cycle. The lower edges of the graphs indicate the cooling period and the upper edges indicate the heating period. Changes in slope and spikes in the graph indicate changes in thermal conditions. Changing slopes indicate changing heat flows due to the programed heat cycle or a change in thermal properties. Spikes indicate energy released or consumed by a phase change in water.

The graphs for all four mixes have similar shapes but varied magnitudes. The control graph shows changes in slope at around 9°C on the upper edge, and a change in slope on the lower edge occurs at around -2°C, a gradual change between 2°C and -2°C. The difference in minimum average temperatures in the control was 3°C. The control had a spike in two samples around 4.5°C on the lower edge, and a small spike in sample 3 at around 0°C.

When the average temperature of the concrete reaches 4.5°C the water starts to freeze but there is no identifiable spike indicating the thawing of water. The lack of identifiable increase probably indicates a gradual thawing over a temperature range. Because the freezing point of water was identified as above 0°C, the data analysis was preformed again using the temperature found at the base of the concrete instead of the average temperature. This analysis was used to show to that while the average temperature of the samples were 4.5°C, parts of the samples were below the expected freezing point of water. The freezing of the internal water was then determined to occur when the base of the samples were at -3°C and -6°C (Figure 14).

Mix 1 shows a flat shape like two of the control samples with a spike at around 4°C on the lower edge and -2°C on the upper edge. The change in slope occurs at around 9°C on the upper edge and -5°C on the lower edge. The spikes indicate that the freezing of water happens at 4°C and the thawing on the water occurs at -2°C. The difference in minimum average temperature in the Mix 1 samples was 2.1°C. Since the freezing point of water was again found to be above 0°C, the analysis was run again using the temperature at the sample bottoms. This time a consistent set of spikes is seen at -5°C for freezing and 0°C for thawing (Figure 15).

Mix 2 shows a much harsher slope change on the upper edge at 10°C and a clearer set of spikes at 2°C and -2°C. The lower edge has change in slope at slope at around -6°C. Also, the lower edge has a clear and consistent spike at 6°C. The difference in minimum average temperature in the Mix 2 samples was 4.0°C. The spikes indicate the internal water freezing at an average specimen temperature of 6°C and thawing at either -2°C or 2°C. Since the freezing point of water was again found to be above 0°C, the analysis was run again using the temperature at the sample bottoms. Like the graph for Mix 1, there are consistent spikes at -5°C for freezing and 0°C for thawing (Figure 16).

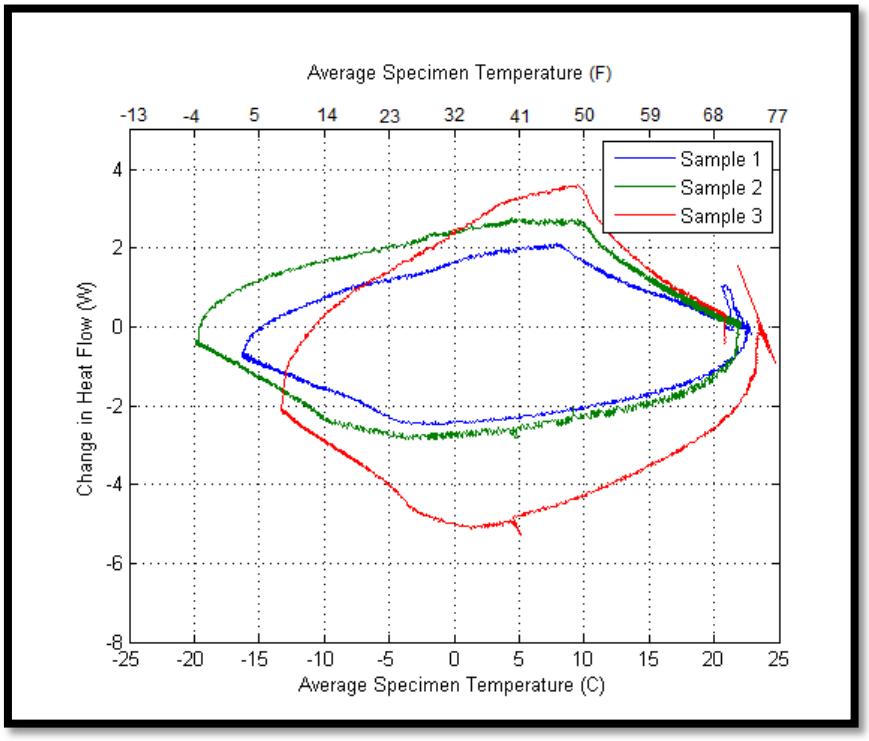

Figure 10 Control average sample temperature vs change in heat flow

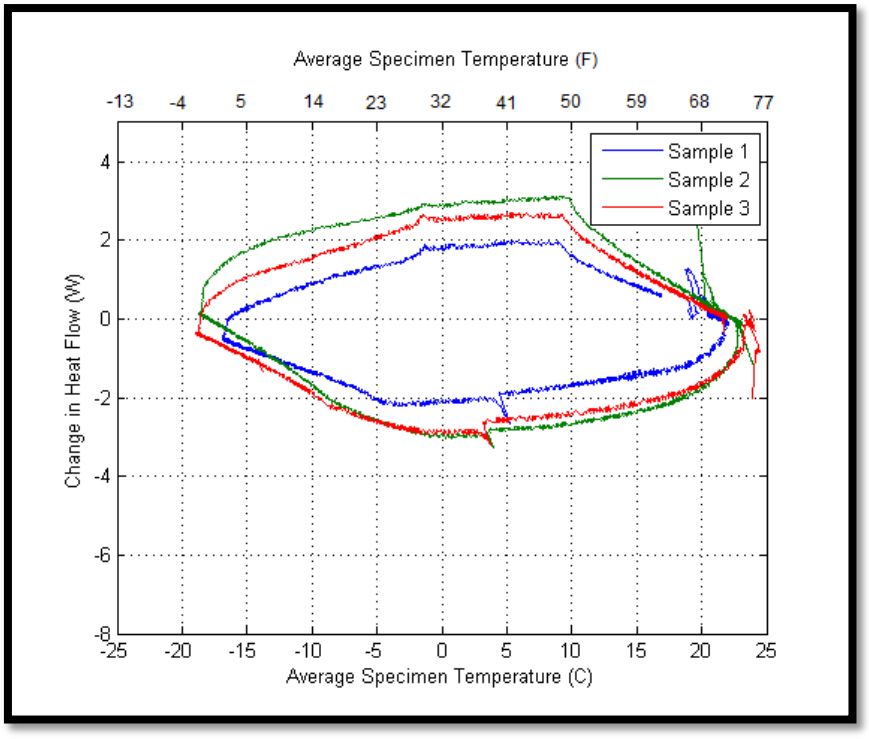

Figure 11 Mix 1 average sample temperature vs change in heat flow

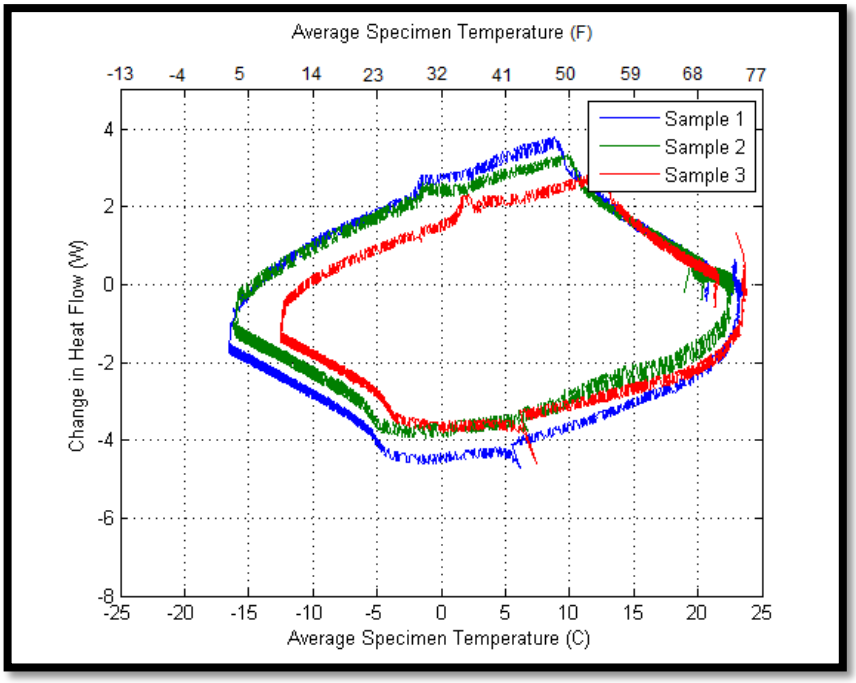

Figure 12 Mix 2 average sample temperature vs change in heat flow

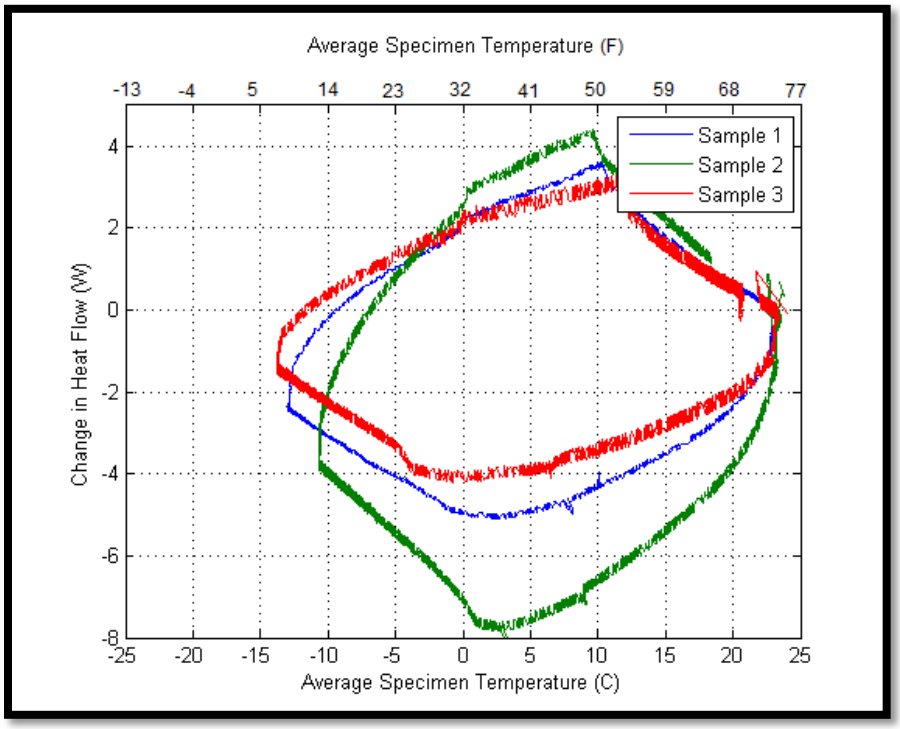

Figure 13 Mix 3 average sample temperature vs change in heat flow

Mix 3 shows the greatest variance of all the mixes. The difference between the minimum average temperatures is 2.3°C, but the shape given by sample 2 is not similar to samples 1 or 3. The samples have a small spike at around 0°C on the upper edge, and on the lower edge, the samples had a small spike at around 8.5°C. Sample 2 has another spike at around 3°C. The change in slopes happens at 10°C on the upper edge and at 2°C, 0°C, and -4°C on the lower edge. The spikes indicate that the water is freezing at an average specimen temperature of around 8°C and thawing at 0°C. When the second analysis using the bottom temperatures was performed, spikes were found at 0°C, -2°C, -5°C, and -9°C (Figure 17). The freezing seen at 0°C may be loose water at the base of the sample, not internal water. Mix 3 also exhibits the highest change in heat flows of all the mixes.

All the mixes except Mix 3 show a change in slope on the lower edge at around -5°C, meaning that the average temperature of the control and mixes 1 and 2 reach -5°C at the 6-hour mark, while mix 3 only reaches the 6 hour mark at three degrees lower at -2°C. This means that mix 3 cools at a slower rate than the control and other mixes.

The minimum temperatures of each mix are shown in Table 5. The control reaches the lowest temperature, but Mix 1 has the lowest average temperature. Mix 3 has the highest minimum temperature with 10.7 °C (Figure 18). While the Control and mixes 1 and 2 have similar average minimum temperatures, only Mix 3 shows significant deviation from the other mixes.

The higher minimum temperature in Mix 3, and the earlier changes in slope is evidence of a higher heat capacity in Mix 3 compared to Mix 1 and Mix 2. Like the addition of PCM in concrete could prevent some freeze/thaw cycling in bridge decks, the increased thermal capacity of can offset some of the freeze/thaw cycles caused by the environmental conditions[8, 9]. This is along with the improved freeze/thaw resistance that AAS has been shown to have in comparison to OPC concretes [18, 26, 39, 40]. Mix 1 and Mix 2 do not show improved thermal properties over the control mix, having similar minimum temperatures and base temperatures at freezing, though AAS are still shown to have increased resistance to freeze/thaw [18, 26, 39, 40].

Table 5 Minimum Temperature (°C)

Minimum Temperature (°C)			
Control	**Mix 1**	**Mix 2**	**Mix 3**
-16.3	-16.9	-16.5	-13
-19.9	-18.7	-16.2	-10.7
-13.3	-18.9	-12.5	-13.8

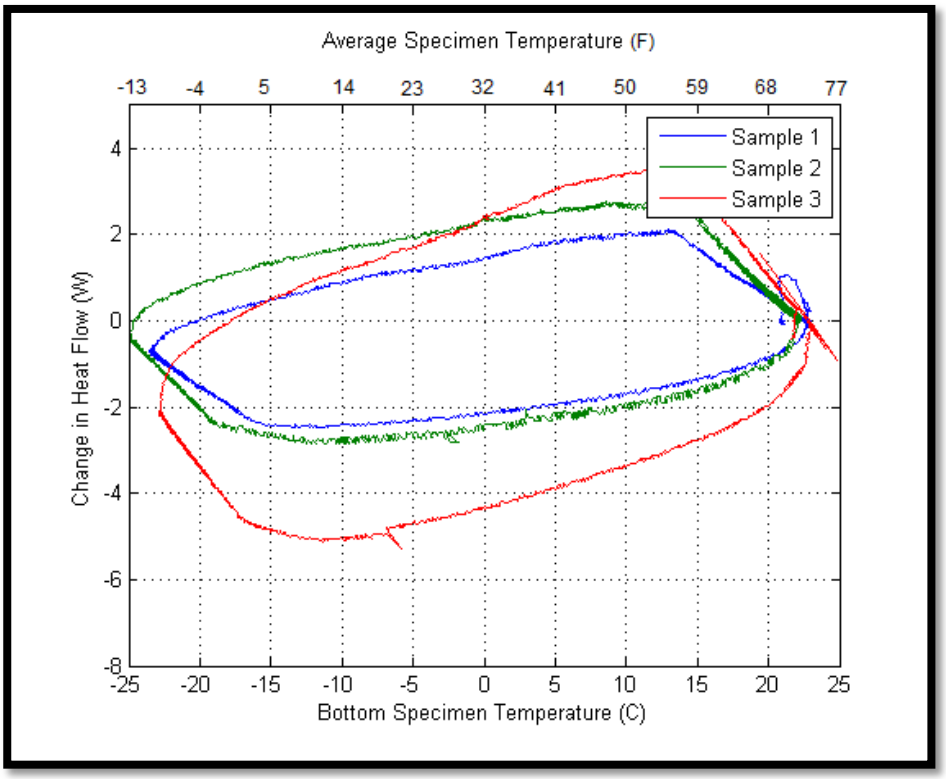

Figure 14 Control bottom of sample temperature vs change in heat flow

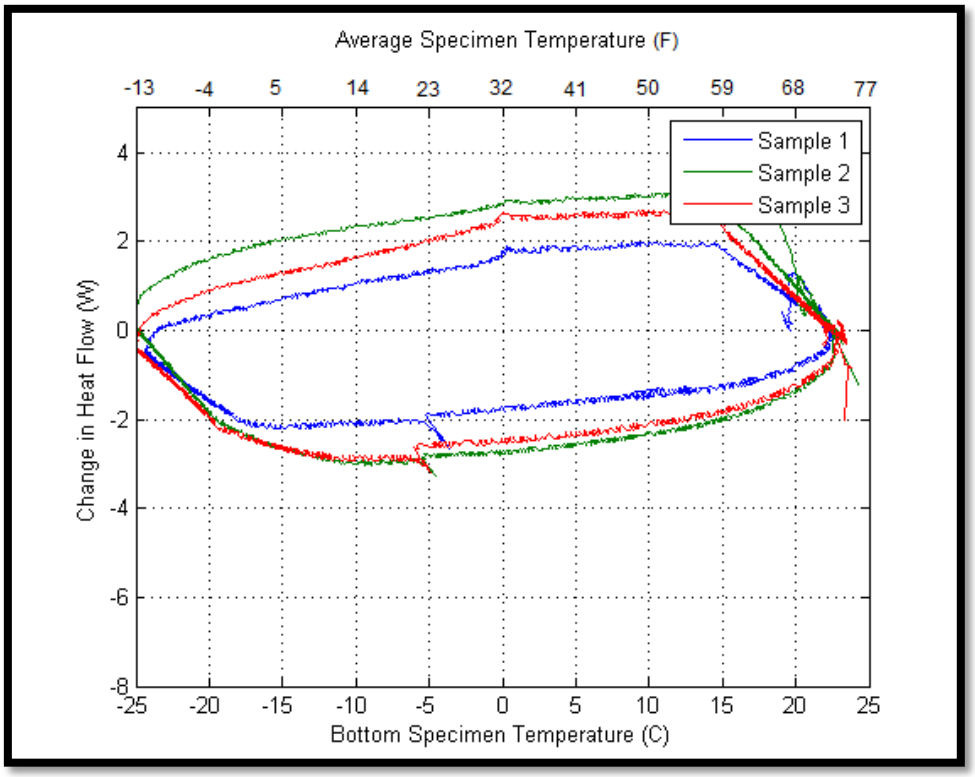

Figure 15 Mix 1 bottom of sample temperature vs change in heat flow

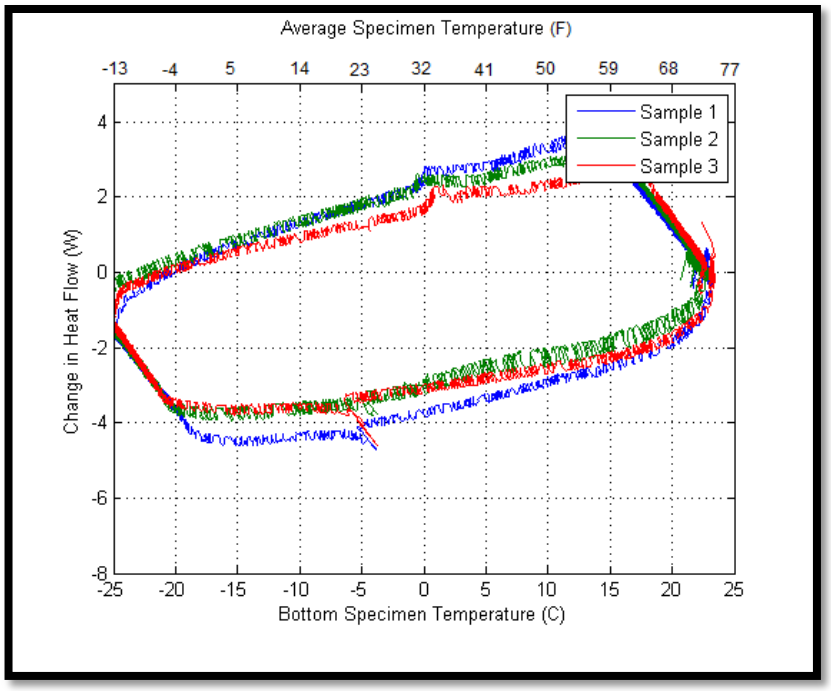

Figure 17 Mix 2 bottom of sample temperature vs change in heat flow

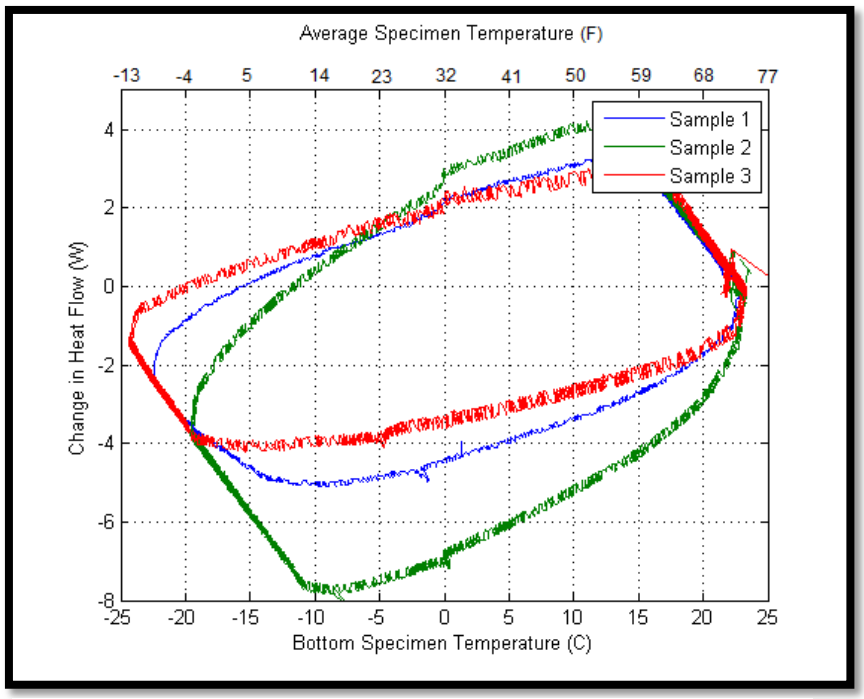

Figure 18 Mix 3 bottom of sample temperature vs change in heat flow

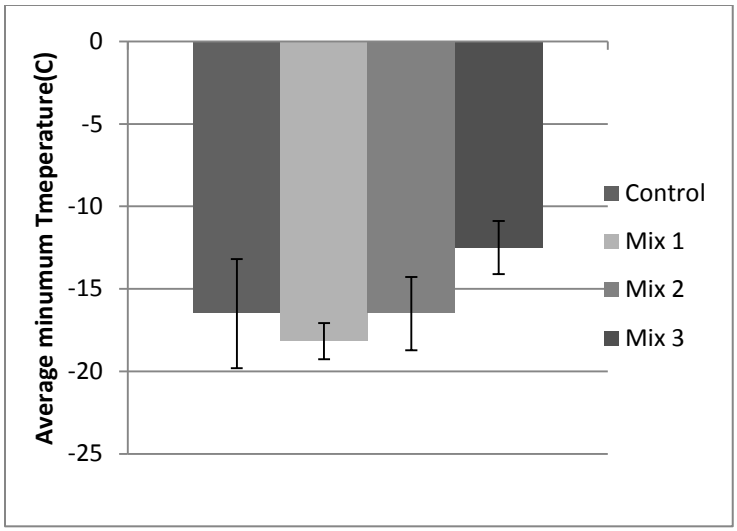

Figure 19 Minimum Temperatures with standard deviations

4.3 Computer Modeling

Originally both a 2D and 3D model of the GLCC were created. Since there was no difference between the 3D model and the 2D model results, the focus of the modeling research is on 2D model. The 2D model was chosen over the 3D model because of its much shorter computation time.

The temperature over time graphs of 2D COMSOL models of the GLCC shows similar shape to the experimental data (Figure 19), but the modeled results show more complete cooling on all thermocouples than the experimental. For example, the experimental thermocouple in contact with the cold plate never reaches the -30°C that the models achieve despite the cold plate being programed to reach that temperature and the cold plate indicating that -30°C was achieved. This experimental failure to reach the specified -30°C temperature while the model achieved that temperature is an indication of the inefficiencies of the cold plate. The percent error of the model temperatures compared to one of the control samples is 15%.

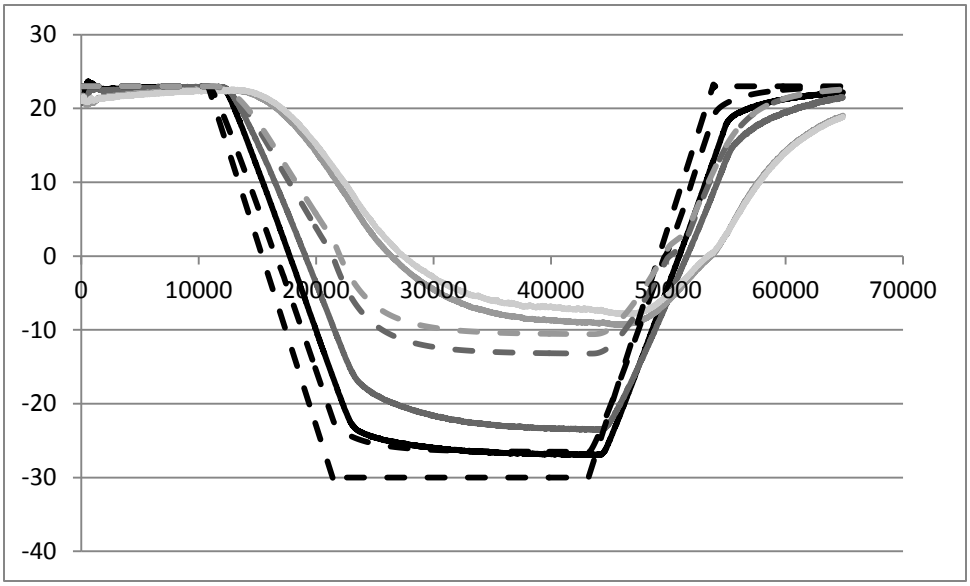

Figure 20 Temperature(C) over time(s). Dashed lines are Modeled temperature, solid lines are experimental temperature

While the temperature graphs show some variation between model and experiment, the change in heat flow over average temperature graphs show similarities (Figure 20). The experimental data shows that a change in heat flow hits a high at 2.0 W/m^2 and a low of -2.5 W/m^2. The COMSOL model reaches 2.1 W/m^2 as a high and -2.3 W/m^2 as a low. The percent error of the model compared to the experimental data is only 5% in change in heat flow.

The computer model also shows the spike from freezing at around 6°C, which is in line with the mixes

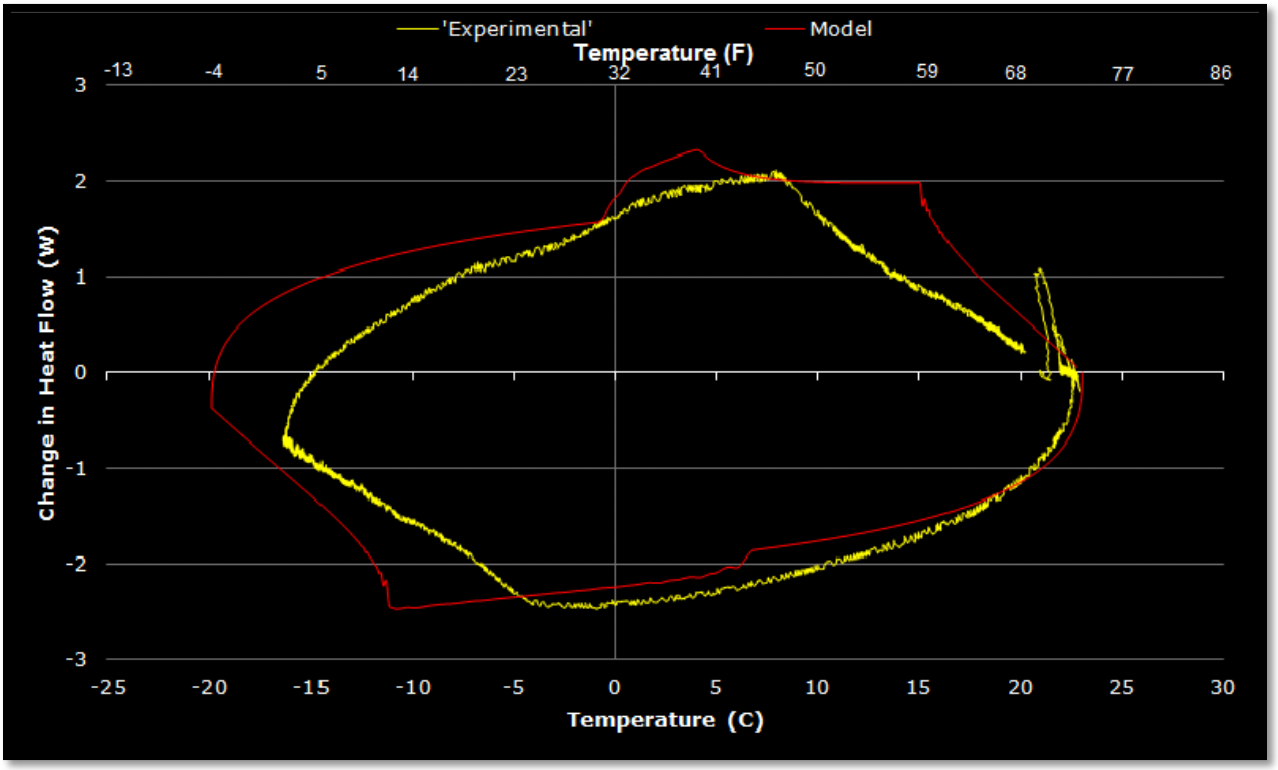

Figure 21 Model and Experimental Average Specimen Temperature vs change in heat flow

studied in the experimental GLCC. But the thawing spike has become a thawing curve which starts at around 0°C and ends at around 6°C, unlike the spikes seen in most of the specimens. The model is able to clearly show the thawing and freezing points of the GLCC experiment with some accuracy.

5 Conclusions

The control and all AAS mixes showed similar freezing and thawing average temperatures, which indicates that there is no significant difference in pore solution freezing temperature compared to both the control and each other. Both AAS with NaOH and AAS with waterglass could be good alternatives to OPC in freeze/thaw environments based on their established resistance to damage, compressive strengths, and comparable pore solution freezing points. AAS with waterglass had poor workability and is not suited to large mix projects without the addition of a setting time retarder, but the use of retarders in AAS with waterglass have been shown to reduce compressive strength [17]. Both AAS with NaOH or AAS with waterglass and a setting time retarder could be a durable alternative to OPC for concrete structures in danger of freeze/thaw degradation. To determine which AAS is a better alternative, it is suggested that further research be performed to compare the workability, compressive strength, and freeze/thaw resistance of AAS with NaOH and AAS with waterglass and a retarding agent.

The COMSOL model created shows good agreement with the experimental data. The model has similar average temperatures to the experimental (15% difference), and shows good agreement in change in heat flows (only a 5% difference). The model also is in good agreement in the freezing and thawing peaks compared to the experimental data. The finished model could now be used to provide approximations of different thermal cycles such as using the thermal cycle of a city to estimate the number of freezing and thawing that would occur in an average year. Also, by changing the concrete material and water solution properties, approximations of the freezing and thawing of new materials can be studied without a GLCC apparatus on site. Since the model accounts for the latent heat of fusion, one possible field that this model could be used in is the studying of the thermal effects of concretes, or asphalts, with PCMs.

6 Appendix: Computer Model MATLAB Code

```
function out = model
%
% gregsmodel.m
%
% Model exported on Apr 24 2014, 19:05 by COMSOL 4.3.2.189.

import com.comsol.model.*
import com.comsol.model.util.*

model = ModelUtil.create('Model');

model.modelPath('C:\Users\gfreeman501\Desktop');

model.modelNode.create('mod1');

model.geom.create('geom1', 2);

model.mesh.create('mesh1', 'geom1');

model.physics.create('ht', 'HeatTransfer', 'geom1');

model.study.create('std1');
model.study('std1').feature.create('stat', 'Stationary');
model.study('std1').feature('stat').activate('ht', true);

model.geom('geom1').feature.create('r1', 'Rectangle');
model.geom('geom1').feature('r1').setIndex('size', '0.6', 0);
model.geom('geom1').runAll;
model.geom('geom1').run;

model.physics('ht').feature.create('temp1', 'TemperatureBoundary', 1);
model.physics('ht').feature('temp1').selection.set([2]);
model.physics('ht').feature('temp1').set('T0', 1, '100[degC]');
model.physics('ht').feature.create('hf1', 'HeatFluxBoundary', 1);
model.physics('ht').feature('hf1').selection.set([3 4]);
model.physics('ht').feature('hf1').set('HeatFluxType', 1,
'GeneralInwardHeatFlux');
model.physics('ht').feature('hf1').set('HeatFluxType', 1,
'InwardHeatFlux');
model.physics('ht').feature('hf1').set('h', 1, '750');
model.physics('ht').feature('hf1').set('Text', 1, '0[degC]');
model.physics('ht').feature('solid1').set('k_mat', 1, 'userdef');
model.physics('ht').feature('solid1').set('k', {'52' '0' '0' '0' '52' '0'
'0' '0' '52'});

model.mesh('mesh1').feature.create('map1', 'Map');
model.mesh('mesh1').run;

model.sol.create('sol1');
model.sol('sol1').study('std1');
model.sol('sol1').feature.create('st1', 'StudyStep');
model.sol('sol1').feature('st1').set('study', 'std1');
```

```
model.sol('sol1').feature('st1').set('studystep', 'stat');
model.sol('sol1').feature.create('v1', 'Variables');
model.sol('sol1').feature('v1').set('control', 'stat');
model.sol('sol1').feature.create('s1', 'Stationary');
model.sol('sol1').feature('s1').feature.create('fc1', 'FullyCoupled');
model.sol('sol1').feature('s1').feature('fc1').set('dtech', 'auto');
model.sol('sol1').feature('s1').feature('fc1').set('initstep', 0.01);
model.sol('sol1').feature('s1').feature('fc1').set('minstep', 1.0E-6);
model.sol('sol1').feature('s1').feature('fc1').set('maxiter', 50);
model.sol('sol1').feature('s1').feature.create('d1', 'Direct');
model.sol('sol1').feature('s1').feature('d1').set('linsolver', 'pardiso');
model.sol('sol1').feature('s1').feature('fc1').set('linsolver', 'd1');
model.sol('sol1').feature('s1').feature('fc1').set('dtech', 'auto');
model.sol('sol1').feature('s1').feature('fc1').set('initstep', 0.01);
model.sol('sol1').feature('s1').feature('fc1').set('minstep', 1.0E-6);
model.sol('sol1').feature('s1').feature('fc1').set('maxiter', 50);
model.sol('sol1').feature('s1').feature.remove('fcDef');
model.sol('sol1').attach('std1');

model.result.create('pg1', 'PlotGroup2D');
model.result('pg1').name('Temperature (ht)');
model.result('pg1').set('oldanalysistype', 'noneavailable');
model.result('pg1').set('data', 'dset1');
model.result('pg1').feature.create('surf1', 'Surface');
model.result('pg1').feature('surf1').name('Surface');
model.result('pg1').feature('surf1').set('oldanalysistype',
'noneavailable');
model.result('pg1').feature('surf1').set('colortable', 'ThermalLight');
model.result('pg1').feature('surf1').set('data', 'parent');
model.result.create('pg2', 'PlotGroup2D');
model.result('pg2').name('Isothermal Contours (ht)');
model.result('pg2').set('oldanalysistype', 'noneavailable');
model.result('pg2').set('data', 'dset1');
model.result('pg2').feature.create('con1', 'Contour');
model.result('pg2').feature('con1').name('Contour');
model.result('pg2').feature('con1').set('oldanalysistype',
'noneavailable');
model.result('pg2').feature('con1').set('colortable', 'ThermalLight');
model.result('pg2').feature('con1').set('data', 'parent');
model.result('pg2').feature.create('arws1', 'ArrowSurface');
model.result('pg2').feature('arws1').name('Arrow surface');
model.result('pg2').feature('arws1').set('oldanalysistype',
'noneavailable');
model.result('pg2').feature('arws1').set('color', 'gray');
model.result('pg2').feature('arws1').set('data', 'parent');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result.dataset.create('cpt1', 'CutPoint2D');
model.result.dataset('cpt1').set('pointx', '0.6');
model.result.dataset('cpt1').set('pointy', '0.2');
model.result.numerical.create('pev1', 'EvalPoint');
model.result.numerical('pev1').set('data', 'cpt1');
```

```
model.result.numerical('pev1').set('unit', 'degC');
model.result.table.create('tbl1', 'Table');
model.result.table('tbl1').comments('Point Evaluation 1 (T)');
model.result.numerical('pev1').set('table', 'tbl1');
model.result.numerical('pev1').setResult;
model.result('pg1').run;

model.comments(['Steady-State 2D Heat Transfer with Conduction\n\nThis is
a benchmark model for a 2D steady-state thermal analysis with convection
to 0 degrees C on two boundaries. The temperature field from the analysis
is compared with a NAFEMS benchmark solution.']);

model.name('heat_convection_2d.mph');

model.result('pg1').run;
model.result('pg1').set('titletype', 'auto');

model.geom('geom1').lengthUnit('mm');
model.geom('geom1').lengthUnit('cm');
model.geom('geom1').lengthUnit('mm');
model.geom('geom1').lengthUnit('mil');
model.geom('geom1').lengthUnit([native2unicode(hex2dec('00b5'), 'Cp1252')
'm']);
% model.geom('geom1').scale({}, [2.2666666507720947 1], [0 1]);
model.geom('geom1').run('r1');
% model.geom('geom1').scale({'r1'}, [3.25 1], [0 1]);
model.geom('geom1').feature('r1').set('size', {'1.95' '1'});
model.geom('geom1').feature('r1').set('pos', {'0' '0'});
model.geom('geom1').run('r1');
% model.geom('geom1').scale({'r1'}, [2.461538553237915 1], [0 1]);
model.geom('geom1').feature('r1').set('size', {'4.8000001788139' '1'});
model.geom('geom1').feature('r1').set('pos', {'0' '0'});
model.geom('geom1').run('r1');
% model.geom('geom1').scale({'r1'}, [1.0208332538604736 1], [0 1]);
model.geom('geom1').feature('r1').set('size', {'4.8999998010694' '1'});
model.geom('geom1').feature('r1').set('pos', {'0' '0'});
model.geom('geom1').run('r1');
% model.geom('geom1').scale({'r1'}, [1.0408164262771606 1], [0 1]);
model.geom('geom1').feature('r1').set('size', {'5.1000002817079' '1'});
model.geom('geom1').feature('r1').set('pos', {'0' '0'});
model.geom('geom1').run('r1');
% model.geom('geom1').scale({'r1'}, [1 2.4000000953674316], [2.55 0]);
model.geom('geom1').feature('r1').set('size', {'5.1000002817079'
'2.4000000953674'});
model.geom('geom1').feature('r1').set('pos', {'0' '0'});
model.geom('geom1').run('r1');
model.geom('geom1').lengthUnit('cm');
model.geom('geom1').feature.create('sq1', 'Square');
model.geom('geom1').feature('sq1').set('type', 'solid');
model.geom('geom1').feature('sq1').set('base', 'corner');
model.geom('geom1').feature('sq1').set('pos', {'0' '2.4000000953674'});
model.geom('geom1').feature('sq1').set('size', '5.1');
model.geom('geom1').run('sq1');
model.geom('geom1').feature.create('r2', 'Rectangle');
```

```
model.geom('geom1').feature('r2').set('type', 'solid');
model.geom('geom1').feature('r2').set('base', 'corner');
model.geom('geom1').feature('r2').set('pos', {'0' '7.5000000953674'});
model.geom('geom1').feature('r2').set('size', {'5' '2.0999999046326'});
model.geom('geom1').run('r2');
% model.geom('geom1').scale({'r2'}, [1.0199999809265137 1], [0 9.6]);
model.geom('geom1').feature('r2').set('size', {'5.0999999046326'
'2.0999999046326'});
model.geom('geom1').feature('r2').set('pos', {'0' '7.5000000953674'});
model.geom('geom1').run('r2');
model.geom('geom1').run;

model.physics('ht').feature('hf1').selection.set([2 4]);

model.material.create('mat1');
model.material('mat1').name('Pyroceram 9606 [solid]');
model.material('mat1').info.create('Composition');
model.material('mat1').info('Composition').body('SiO2, Al2O3, MgO, TiO2');
model.material('mat1').set('family', 'custom');
model.material('mat1').set('lighting', 'cooktorrance');
model.material('mat1').set('specular', 'custom');
model.material('mat1').set('customspecular', [1 1 1]);
model.material('mat1').set('diffuse', 'custom');
model.material('mat1').set('customdiffuse', [1 1 1]);
model.material('mat1').set('ambient', 'custom');
model.material('mat1').set('customambient', [1 1 1]);
model.material('mat1').set('fresnel', 0.99);
model.material('mat1').set('roughness', 0.02);
model.material('mat1').set('shininess', 200);
model.material('mat1').set('alpha', 1);
model.material('mat1').propertyGroup('def').set('thermalconductivity',
'k(T[1/K])[W/(m*K)]');
model.material('mat1').propertyGroup('def').set('heatcapacity',
'C(T[1/K])[J/(kg*K)]');
model.material('mat1').propertyGroup('def').set('mu', 'mu(T[1/K])[Pa]');
model.material('mat1').propertyGroup('def').set('nemiss',
'nemiss(T[1/K])');
model.material('mat1').propertyGroup('def').set('TD',
'TD(T[1/K])[m^2/s]');
model.material('mat1').propertyGroup('def').set('kappa',
'kappa(T[1/K])[Pa]');
model.material('mat1').propertyGroup('def').func.create('k', 'Piecewise');
model.material('mat1').propertyGroup('def').func('k').set('funcname',
'k');
model.material('mat1').propertyGroup('def').func('k').set('arg', 'T');
model.material('mat1').propertyGroup('def').func('k').set('extrap',
'constant');
model.material('mat1').propertyGroup('def').func('k').set('pieces',
{'293.0' '1173.0' '4.419251-0.002558443*T^1+1.223563E-6*T^2-7.998112E-
11*T^3'});
model.material('mat1').propertyGroup('def').func.create('C', 'Piecewise');
model.material('mat1').propertyGroup('def').func('C').set('funcname',
'C');
model.material('mat1').propertyGroup('def').func('C').set('arg', 'T');
```

```
model.material('mat1').propertyGroup('def').func('C').set('extrap',
'constant');
model.material('mat1').propertyGroup('def').func('C').set('pieces',
{'273.0' '1173.0' '-250.1486+5.636718*T^1-0.009491764*T^2+7.485975E-6*T^3-
2.18025E-9*T^4'});
model.material('mat1').propertyGroup('def').func.create('mu',
'Piecewise');
model.material('mat1').propertyGroup('def').func('mu').set('funcname',
'mu');
model.material('mat1').propertyGroup('def').func('mu').set('arg', 'T');
model.material('mat1').propertyGroup('def').func('mu').set('extrap',
'constant');
model.material('mat1').propertyGroup('def').func('mu').set('pieces',
{'293.0' '473.0' '2.659874E11-2.49558E9*T^1+1.073845E7*T^2-
20566.72*T^3+14.70566*T^4'; '473.0' '1173.0' '8.135809E9+1.85214E8*T^1-
307199.9*T^2+225.0098*T^3-0.06203428*T^4'});
model.material('mat1').propertyGroup('def').func.create('nemiss',
'Piecewise');
model.material('mat1').propertyGroup('def').func('nemiss').set('funcname',
'nemiss');
model.material('mat1').propertyGroup('def').func('nemiss').set('arg',
'T');
model.material('mat1').propertyGroup('def').func('nemiss').set('extrap',
'constant');
model.material('mat1').propertyGroup('def').func('nemiss').set('pieces',
{'88.0' '1588.0' '0.8739956-9.16277E-5*T^1+3.607643E-7*T^2-1.268683E-
9*T^3+1.091325E-12*T^4-2.891077E-16*T^5'});
model.material('mat1').propertyGroup('def').func.create('TD',
'Piecewise');
model.material('mat1').propertyGroup('def').func('TD').set('funcname',
'TD');
model.material('mat1').propertyGroup('def').func('TD').set('arg', 'T');
model.material('mat1').propertyGroup('def').func('TD').set('extrap',
'constant');
model.material('mat1').propertyGroup('def').func('TD').set('pieces',
{'278.0' '1000.0' '7.163348E-6-2.990097E-8*T^1+5.510692E-11*T^2-4.70817E-
14*T^3+1.522625E-17*T^4'});
model.material('mat1').propertyGroup('def').func.create('kappa',
'Piecewise');
model.material('mat1').propertyGroup('def').func('kappa').set('funcname',
'kappa');
model.material('mat1').propertyGroup('def').func('kappa').set('arg', 'T');
model.material('mat1').propertyGroup('def').func('kappa').set('extrap',
'constant');
model.material('mat1').propertyGroup('def').func('kappa').set('pieces',
{'293.0' '473.0' '-1.49149E12+2.270688E10*T^1-1.311062E8*T^2+377708.6*T^3-
543.2037*T^4+0.311815*T^5'; '473.0' '1173.0' '3.271268E10+2.288433E8*T^1-
392464.6*T^2+290.2539*T^3-0.08177703*T^4'});
model.material('mat1').propertyGroup('def').addInput('temperature');
model.material('mat1').propertyGroup.create('Enu', 'Young''s modulus and
Poisson''s ratio');
model.material('mat1').propertyGroup('Enu').set('youngsmodulus',
'E(T[1/K])[Pa]');
```

```
model.material('mat1').propertyGroup('Enu').set('poissonsratio',
'nu(T[1/K])');
model.material('mat1').propertyGroup('Enu').func.create('E', 'Piecewise');
model.material('mat1').propertyGroup('Enu').func('E').set('funcname',
'E');
model.material('mat1').propertyGroup('Enu').func('E').set('arg', 'T');
model.material('mat1').propertyGroup('Enu').func('E').set('extrap',
'constant');
model.material('mat1').propertyGroup('Enu').func('E').set('pieces',
{'293.0' '473.0' '9.046606E11-8.993293E9*T^1+3.851862E7*T^2-
73108.91*T^3+51.69883*T^4'; '473.0' '1173.0' '7.031484E10+2.193794E8*T^1-
340955.7*T^2+236.8627*T^3-0.06405389*T^4'});
model.material('mat1').propertyGroup('Enu').func.create('nu',
'Piecewise');
model.material('mat1').propertyGroup('Enu').func('nu').set('funcname',
'nu');
model.material('mat1').propertyGroup('Enu').func('nu').set('arg', 'T');
model.material('mat1').propertyGroup('Enu').func('nu').set('extrap',
'constant');
model.material('mat1').propertyGroup('Enu').func('nu').set('pieces',
{'293.0' '438.0' '0.2435135'; '438.0' '473.0' '-1.865782+0.0121177*T^1-
2.30436E-5*T^2+1.4549E-8*T^3'; '473.0' '1173.0' '0.2516289+1.035528E-
5*T^1-3.164928E-8*T^2+8.490241E-12*T^3'});
model.material('mat1').propertyGroup('Enu').addInput('temperature');
model.material('mat1').set('family', 'custom');
model.material('mat1').set('lighting', 'cooktorrance');
model.material('mat1').set('specular', 'custom');
model.material('mat1').set('customspecular', [1 1 1]);
model.material('mat1').set('diffuse', 'custom');
model.material('mat1').set('customdiffuse', [1 1 1]);
model.material('mat1').set('ambient', 'custom');
model.material('mat1').set('customambient', [1 1 1]);
model.material('mat1').set('fresnel', 0.99);
model.material('mat1').set('roughness', 0.02);
model.material('mat1').set('shininess', 200);
model.material('mat1').set('alpha', 1);

model.selection.create('sel1');
model.selection('sel1').geom(2);
model.selection('sel1').name('Standard Blocks');
model.selection('sel1').set([1 2 3]);

model.material('mat1').selection.named('sel1');
model.material.create('mat2');
model.material('mat2').name('Concrete [solid,dry]');
model.material('mat2').set('family', 'concrete');
model.material('mat2').propertyGroup('def').set('thermalconductivity',
'k_solid_dry_1(T[1/K])[W/(m*K)]');
model.material('mat2').propertyGroup('def').set('TD',
'TD_solid_dry_1(T[1/K])[m^2/s]');
model.material('mat2').propertyGroup('def').func.create('k_solid_dry_1',
'Piecewise');
model.material('mat2').propertyGroup('def').func('k_solid_dry_1').set('fun
cname', 'k_solid_dry_1');
```

```
model.material('mat2').propertyGroup('def').func('k_solid_dry_1').set('arg
', 'T');
model.material('mat2').propertyGroup('def').func('k_solid_dry_1').set('ext
rap', 'constant');
model.material('mat2').propertyGroup('def').func('k_solid_dry_1').set('pie
ces', {'253.0' '363.0' '26.91105-0.2477056*T^1+8.606168E-4*T^2-1.00482E-
6*T^3'});
model.material('mat2').propertyGroup('def').func.create('TD_solid_dry_1',
'Piecewise');
model.material('mat2').propertyGroup('def').func('TD_solid_dry_1').set('fu
ncname', 'TD_solid_dry_1');
model.material('mat2').propertyGroup('def').func('TD_solid_dry_1').set('ar
g', 'T');
model.material('mat2').propertyGroup('def').func('TD_solid_dry_1').set('ex
trap', 'constant');
model.material('mat2').propertyGroup('def').func('TD_solid_dry_1').set('pi
eces', {'253.0' '363.0' '-1.361995E-4+1.854099E-6*T^1-9.285239E-
9*T^2+2.050095E-11*T^3-1.68777E-14*T^4'});
model.material('mat2').propertyGroup('def').addInput('temperature');
model.material('mat2').set('family', 'concrete');
model.material('mat2').selection.set([2]);

model.result('pg1').run;

model.modelNode('mod1').baseSystem('SI');

model.physics('ht').prop('PhysicalModel').set('HeatTransferInPorousMedia',
1, '1');
model.physics('ht').prop('PhysicalModel').set('HeatTransferInPorousMedia',
1, '0');
model.physics('ht').prop('PhysicalModel').set('HeatTransferInPorousMedia',
1, '1');

model.material('mat2').propertyGroup('def').set('density', '');
model.material('mat2').propertyGroup('def').set('heatcapacity', {'3.5'});

model.modelNode('mod1').baseSystem([]);

model.geom('geom1').lengthUnit('in');
model.geom('geom1').lengthUnit('mm');
model.geom('geom1').lengthUnit('cm');
model.geom('geom1').scaleUnitValue(true);
model.geom('geom1').lengthUnit('in');
model.geom('geom1').lengthUnit('cm');
model.geom('geom1').run;

model.material('mat2').propertyGroup('def').set('heatcapacity', {'0.75'});
model.material('mat2').propertyGroup('def').set('density', {'2400'});
model.material('mat1').propertyGroup('def').set('density', {'2600'});

model.physics('ht').feature('temp1').selection.set([2]);
model.physics('ht').feature.duplicate('temp2', 'temp1');
model.physics('ht').feature('temp2').selection.set([7]);
model.physics('ht').feature('temp2').set('T0', 1, '24[degC]');
```

```
model.physics('ht').feature.duplicate('init2', 'init1');
model.physics('ht').feature.move('init2', 5);
model.physics('ht').feature.remove('init2');
model.physics('ht').feature.remove('temp2');

model.sol('sol1').study('std1');
model.sol('sol1').feature.remove('s1');
model.sol('sol1').feature.remove('v1');
model.sol('sol1').feature.remove('st1');
model.sol('sol1').feature.create('st1', 'StudyStep');
model.sol('sol1').feature('st1').set('study', 'std1');
model.sol('sol1').feature('st1').set('studystep', 'stat');
model.sol('sol1').feature.create('v1', 'Variables');
model.sol('sol1').feature('v1').set('control', 'stat');
model.sol('sol1').feature.create('s1', 'Stationary');
model.sol('sol1').feature('s1').feature.create('fc1', 'FullyCoupled');
model.sol('sol1').feature('s1').feature('fc1').set('dtech', 'auto');
model.sol('sol1').feature('s1').feature('fc1').set('initstep', 0.01);
model.sol('sol1').feature('s1').feature('fc1').set('minstep', 1.0E-6);
model.sol('sol1').feature('s1').feature('fc1').set('maxiter', 50);
model.sol('sol1').feature('s1').feature.create('d1', 'Direct');
model.sol('sol1').feature('s1').feature('d1').set('linsolver', 'pardiso');
model.sol('sol1').feature('s1').feature('fc1').set('linsolver', 'd1');
model.sol('sol1').feature('s1').feature('fc1').set('dtech', 'auto');
model.sol('sol1').feature('s1').feature('fc1').set('initstep', 0.01);
model.sol('sol1').feature('s1').feature('fc1').set('minstep', 1.0E-6);
model.sol('sol1').feature('s1').feature('fc1').set('maxiter', 50);
model.sol('sol1').feature('s1').feature.remove('fcDef');
model.sol('sol1').attach('std1');
model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg2').run;
model.result('pg1').run;
model.result('pg2').run;
model.result('pg2').run;
model.result('pg1').run;
model.result('pg1').set('view', 'auto');

model.physics('ht').feature('temp1').set('T0', 1, '-30[degC]');

model.sol('sol1').study('std1');
model.sol('sol1').feature.remove('s1');
model.sol('sol1').feature.remove('v1');
model.sol('sol1').feature.remove('st1');
model.sol('sol1').feature.create('st1', 'StudyStep');
model.sol('sol1').feature('st1').set('study', 'std1');
model.sol('sol1').feature('st1').set('studystep', 'stat');
model.sol('sol1').feature.create('v1', 'Variables');
model.sol('sol1').feature('v1').set('control', 'stat');
model.sol('sol1').feature.create('s1', 'Stationary');
model.sol('sol1').feature('s1').feature.create('fc1', 'FullyCoupled');
model.sol('sol1').feature('s1').feature('fc1').set('dtech', 'auto');
model.sol('sol1').feature('s1').feature('fc1').set('initstep', 0.01);
```

```
model.sol('sol1').feature('s1').feature('fc1').set('minstep', 1.0E-6);
model.sol('sol1').feature('s1').feature('fc1').set('maxiter', 50);
model.sol('sol1').feature('s1').feature.create('d1', 'Direct');
model.sol('sol1').feature('s1').feature('d1').set('linsolver', 'pardiso');
model.sol('sol1').feature('s1').feature('fc1').set('linsolver', 'd1');
model.sol('sol1').feature('s1').feature('fc1').set('dtech', 'auto');
model.sol('sol1').feature('s1').feature('fc1').set('initstep', 0.01);
model.sol('sol1').feature('s1').feature('fc1').set('minstep', 1.0E-6);
model.sol('sol1').feature('s1').feature('fc1').set('maxiter', 50);
model.sol('sol1').feature('s1').feature.remove('fcDef');
model.sol('sol1').attach('std1');
model.sol('sol1').runAll;

model.result('pg1').run;

model.physics('ht').feature.create('porous1', 'PorousHeatTransferModel',
2);

model.material('mat2').materialType('nonSolid');

model.physics('ht').feature.duplicate('hf2', 'hf1');
model.physics('ht').feature('hf2').selection.set([4 7]);
model.physics('ht').feature('hf2').set('HeatFluxType', 1,
'InwardHeatFlux');
model.physics('ht').feature('hf2').set('HeatFluxType', 1,
'GeneralInwardHeatFlux');
model.physics('ht').feature('hf2').set('HeatFluxType', 1,
'GeneralInwardHeatFlux');
model.physics('ht').feature('hf2').set('HeatFluxType', 1,
'TotalHeatFlux');

model.material('mat2').propertyGroup.create('PoroelasticModel',
'Poroelastic material');
model.material('mat2').propertyGroup('PoroelasticModel').set('alphaB',
{'0.54'});
model.material('mat2').propertyGroup('PoroelasticModel').set('porosity',
{'0.0549'});
model.material('mat2').propertyGroup('PoroelasticModel').set('hydraulicper
meability', {'6.2799*10^-17'});
model.material.create('mat3');
model.material('mat3').name('Water, liquid');
model.material('mat3').set('family', 'water');
model.material('mat3').propertyGroup('def').set('dynamicviscosity',
'eta(T[1/K])[Pa*s]');
model.material('mat3').propertyGroup('def').set('ratioofspecificheat',
'1.0');
model.material('mat3').propertyGroup('def').set('electricconductivity',
'5.5e-6[S/m]');
model.material('mat3').propertyGroup('def').set('heatcapacity',
'Cp(T[1/K])[J/(kg*K)]');
model.material('mat3').propertyGroup('def').set('density',
'rho(T[1/K])[kg/m^3]');
model.material('mat3').propertyGroup('def').set('thermalconductivity',
'k(T[1/K])[W/(m*K)]');
```

```
model.material('mat3').propertyGroup('def').set('soundspeed',
'cs(T[1/K])[m/s]');
model.material('mat3').propertyGroup('def').func.create('eta',
'Piecewise');
model.material('mat3').propertyGroup('def').func('eta').set('funcname',
'eta');
model.material('mat3').propertyGroup('def').func('eta').set('arg', 'T');
model.material('mat3').propertyGroup('def').func('eta').set('extrap',
'constant');
model.material('mat3').propertyGroup('def').func('eta').set('pieces',
{'273.15' '413.15' '1.3799566804-0.021224019151*T^1+1.3604562827E-4*T^2-
4.6454090319E-7*T^3+8.9042735735E-10*T^4-9.0790692686E-
13*T^5+3.8457331488E-16*T^6'; '413.15' '553.75' '0.00401235783-
2.10746715E-5*T^1+3.85772275E-8*T^2-2.39730284E-11*T^3'});
model.material('mat3').propertyGroup('def').func.create('Cp',
'Piecewise');
model.material('mat3').propertyGroup('def').func('Cp').set('funcname',
'Cp');
model.material('mat3').propertyGroup('def').func('Cp').set('arg', 'T');
model.material('mat3').propertyGroup('def').func('Cp').set('extrap',
'constant');
model.material('mat3').propertyGroup('def').func('Cp').set('pieces',
{'273.15' '553.75' '12010.1471-80.4072879*T^1+0.309866854*T^2-5.38186884E-
4*T^3+3.62536437E-7*T^4'});
model.material('mat3').propertyGroup('def').func.create('rho',
'Piecewise');
model.material('mat3').propertyGroup('def').func('rho').set('funcname',
'rho');
model.material('mat3').propertyGroup('def').func('rho').set('arg', 'T');
model.material('mat3').propertyGroup('def').func('rho').set('extrap',
'constant');
model.material('mat3').propertyGroup('def').func('rho').set('pieces',
{'273.15' '553.75' '838.466135+1.40050603*T^1-
0.0030112376*T^2+3.71822313E-7*T^3'});
model.material('mat3').propertyGroup('def').func.create('k', 'Piecewise');
model.material('mat3').propertyGroup('def').func('k').set('funcname',
'k');
model.material('mat3').propertyGroup('def').func('k').set('arg', 'T');
model.material('mat3').propertyGroup('def').func('k').set('extrap',
'constant');
model.material('mat3').propertyGroup('def').func('k').set('pieces',
{'273.15' '553.75' '-0.869083936+0.00894880345*T^1-1.58366345E-
5*T^2+7.97543259E-9*T^3'});
model.material('mat3').propertyGroup('def').func.create('cs',
'Interpolation');
model.material('mat3').propertyGroup('def').func('cs').set('sourcetype',
'user');
model.material('mat3').propertyGroup('def').func('cs').set('source',
'table');
model.material('mat3').propertyGroup('def').func('cs').set('funcname',
'cs');
model.material('mat3').propertyGroup('def').func('cs').set('table', {'273'
'1403'; '278' '1427'; '283' '1447'; '293' '1481'; '303' '1507'; '313'
'1526'; '323' '1541'; '333' '1552'; '343' '1555'; '353' '1555';  ...
```

```
'363' '1550'; '373' '1543'});
model.material('mat3').propertyGroup('def').func('cs').set('interp',
'piecewisecubic');
model.material('mat3').propertyGroup('def').func('cs').set('extrap',
'const');
model.material('mat3').propertyGroup('def').addInput('temperature');
model.material('mat3').set('family', 'water');
model.material('mat3').selection.set([2]);
model.material('mat2').materialType('solid');
model.material.move('mat3', 1);

model.study('std1').feature('stat').set('plot', 'on');
model.study('std1').feature('stat').set('probesel', 'manual');
model.study('std1').feature('stat').set('probes', {});
model.study('std1').feature('stat').set('probesel', 'all');
model.study('std1').feature('stat').set('useadvanceddisable', 'off');
model.study('std1').feature('stat').set('useinitsol', 'on');
model.study('std1').feature('stat').set('useparam', 'on');
model.study('std1').feature('stat').set('useloadcase', 'on');
model.study('std1').feature('stat').setIndex('loadcase', 'Load case 1',
0);
model.study('std1').feature('stat').setIndex('loadcase', 'Load case 1',
0);
model.study('std1').feature('stat').setIndex('loadcase', 'Temperature
cycle', 0);
model.study('std1').feature('stat').set('useparam', 'off');

model.physics('ht').feature('hf2').set('HeatFluxType', 1,
'TotalHeatFlux');
model.physics('ht').feature('hf2').set('HeatFluxType', 1,
'InwardHeatFlux');
model.physics('ht').feature('hf2').set('Text', 1, '24[degC]');
model.physics('ht').feature('hf2').set('Text', 1, '293.15[K]');
model.physics('ht').feature('hf1').set('Text', 1, 'T0[k]');
model.physics('ht').feature('hf1').set('Text', 1, 'To[k]');
model.physics('ht').feature('hf1').set('Text', 1, 'Temperature 1');
model.physics('ht').feature('hf1').set('Text', 1, '0[degC]');
model.physics('ht').feature('hf1').set('Text', 1, '273.15[K]');
model.physics.create('ht2', 'PorousMediaHeat', 'geom1');
model.physics('ht2').field('temperature').field('T3');

model.study('std1').feature('stat').activate('ht2', false);

model.sol.remove('sol1');

model.study('std1').feature.clear;
model.study('std1').feature.create('time', 'Transient');
model.study('std1').feature('time').activate('ht', true);
model.study('std1').feature('time').activate('ht2', true);

model.physics('ht').feature.remove('porous1');
model.physics('ht2').feature.create('solid1', 'SolidHeatTransferModel',
2);
model.physics('ht2').feature('solid1').selection.set([1 3]);
```

```
model.physics('ht2').feature.create('temp1', 'TemperatureBoundary', 1);
model.physics('ht2').feature('temp1').selection.set([2]);
model.physics('ht2').feature.create('temp2', 'TemperatureBoundary', 1);
model.physics('ht2').feature('temp2').selection.set([7]);
model.physics('ht2').feature.create('hs1', 'HeatSource', 2);
model.physics('ht2').feature('hs1').set('heatSourceType', 1,
'generalSource');
model.physics('ht2').feature('hs1').set('heatSourceType', 1,
'linearSource');
model.physics('ht2').feature('hs1').set('heatSourceType', 1,
'linearSource');
model.physics('ht2').feature('hs1').set('heatSourceType', 1,
'generalSource');

model.geom('geom1').feature.create('b1', 'BezierPolygon');
model.geom('geom1').feature('b1').set('type', 'solid');
model.geom('geom1').feature('b1').set('p', {'0' '5.1000002817079'; '0'
'0'});
model.geom('geom1').feature('b1').set('w', {'1' '1'});
model.geom('geom1').feature('b1').set('degree', [1]);
model.geom('geom1').run('b1');
model.geom('geom1').run;

model.physics('ht2').feature.remove('hs1');
model.physics('ht2').feature.create('sar1', 'SurfaceToAmbientRadiation',
1);
model.physics('ht2').feature('sar1').selection.set([7]);
model.physics('ht2').feature('sar1').selection.all;
model.physics('ht2').feature('sar1').selection.set([7]);
model.physics('ht2').feature.create('bhs1', 'BoundaryHeatSource', 1);
model.physics('ht2').feature('bhs1').selection.set([2]);
model.physics('ht2').feature('bhs1').set('heatSourceType', 1,
'generalSource');
model.physics('ht2').feature('bhs1').set('heatSourceType', 1,
'TotalBoundaryPower');
model.physics('ht2').feature('bhs1').set('heatSourceType', 1,
'TotalBoundaryPower');
model.physics('ht2').feature('bhs1').set('heatSourceType', 1,
'generalSource');
model.physics('ht2').feature.remove('hcl1');
model.physics('ht2').feature.remove('hcl1');
model.physics('ht2').feature.create('ins2', 'ThermalInsulation', 1);
model.physics('ht2').feature.remove('ins2');

model.geom('geom1').feature.remove('b1');
model.geom('geom1').run;

model.func.create('pw1', 'Piecewise');
model.func('pw1').model('mod1');
model.func('pw1').set('arg', 'T');
model.func('pw1').setIndex('pieces', '24[degC]', 0, 0);
model.func('pw1').setIndex('pieces', '24[degC]', 0, 1);
model.func('pw1').setIndex('pieces', 'T=T', 0, 2);
model.func('pw1').setIndex('pieces', '24[degC]', 1, 0);
```

```
model.func('pw1').setIndex('pieces', '-30[degC]', 1, 1);
model.func('pw1').set('smooth', 'cont');
model.func('pw1').set('extrap', 'interior');
model.func('pw1').setIndex('pieces', 'T=-0.3[degC/min]*T', 1, 2);
model.func('pw1').setIndex('pieces', '-30', 2, 0);
model.func('pw1').setIndex('pieces', '-30[degC]', 2, 0);
model.func('pw1').setIndex('pieces', '-30[degC]', 2, 1);
model.func('pw1').setIndex('pieces', 'T=T', 2, 2);
model.func('pw1').setIndex('pieces', '24', 0, 0);
model.func('pw1').setIndex('pieces', '24', 0, 1);
model.func('pw1').setIndex('pieces', '', 0, 2);
model.func('pw1').setIndex('pieces', '', 1, 2);
model.func('pw1').setIndex('pieces', '', 2, 2);
model.func('pw1').setIndex('pieces', '-30', 2, 1);
model.func('pw1').setIndex('pieces', '-30', 1, 1);
model.func('pw1').setIndex('pieces', '24', 1, 0);
model.func('pw1').setIndex('pieces', '-30', 2, 0);
model.func.remove('pw1');

model.probe.create('bnd1', 'Boundary');
model.probe('bnd1').model('mod1');

model.view.create('view2', 'geom1');
model.view.remove('view2');

model.variable.create('var1');
model.variable('var1').model('mod1');
model.variable.remove('var1');

model.func.create('pw1', 'Piecewise');
model.func('pw1').model('mod1');
model.func('pw1').setIndex('pieces', '24', 0, 0);
model.func('pw1').setIndex('pieces', '24', 0, 1);
model.func('pw1').setIndex('pieces', 'x=y', 0, 2);
model.func('pw1').setIndex('pieces', 'y=x', 0, 2);
model.func('pw1').setIndex('pieces', '-30', 0, 1);
model.func('pw1').setIndex('pieces', 'y=x+24', 0, 2);
model.func('pw1').setIndex('pieces', '293.15', 0, 0);
model.func('pw1').setIndex('pieces', '243.15', 0, 1);
model.func('pw1').setIndex('pieces', '', 0, 1);
model.func('pw1').setIndex('pieces', '243.15', 0, 0);
model.func('pw1').setIndex('pieces', '293.15', 0, 1);
model.func.remove('pw1');
model.func.create('rm1', 'Ramp');
model.func('rm1').model('mod1');
model.func('rm1').set('funcname', 'ramp1');
model.func('rm1').set('slope', '0.3');
model.func('rm1').set('cutoffactive', 'on');
model.func('rm1').set('location', '24');
model.func('rm1').set('slope', '-0.3');
model.func('rm1').set('cutoff', '-30');
model.func.duplicate('rm2', 'rm1');
model.func('rm2').set('funcname', 'ramp2');
model.func('rm2').set('location', '-30');
```

```
model.func('rm2').set('slope', '0.3');
model.func('rm2').set('cutoff', '24');
model.func.create('im1', 'Image');
model.func('im1').model('mod1');
model.func.remove('im1');

model.variable.create('var1');
model.variable('var1').model('mod1');
model.variable('var1').set('Time', '=Tiime+1');
model.variable.remove('var1');

model.material('mat2').propertyGroup('def').set('ratioofspecificheat',
{'0.75/4.210'});

model.func.create('tri1', 'Triangle');
model.func('tri1').model('mod1');
model.func.remove('tri1');
model.func.create('tri1', 'Triangle');
model.func('tri1').model('mod1');
model.func('tri1').set('lower', '-30');
model.func('tri1').set('upper', '24');
model.func('tri1').set('lower', '24');
model.func('tri1').set('upper', '-30');
model.func.remove('tri1');
model.func.create('pw1', 'Piecewise');
model.func('pw1').model('mod1');
model.func('pw1').setIndex('pieces', '0', 0, 0);
model.func('pw1').setIndex('pieces', '120', 0, 1);
model.func('pw1').setIndex('pieces', '24', 0, 2);
model.func('pw1').setIndex('pieces', '120', 1, 0);
model.func('pw1').setIndex('pieces', 'ramp1', 1, 2);
model.func('pw1').setIndex('pieces', '180', 0, 1);
model.func('pw1').setIndex('pieces', '180', 1, 0);
model.func('pw1').setIndex('pieces', '360', 1, 1);
model.func('pw1').setIndex('pieces', '360', 2, 0);
model.func('pw1').setIndex('pieces', '720', 2, 1);
model.func('pw1').setIndex('pieces', '-30', 2, 2);
model.func('pw1').setIndex('pieces', '720', 3, 0);
model.func('pw1').setIndex('pieces', '900', 3, 1);
model.func('pw1').setIndex('pieces', 'ramp2', 3, 2);
model.func('rm1').set('funcname', 'rm1');
model.func('rm2').set('funcname', 'rm2');
model.func('pw1').setIndex('pieces', 'rm1', 1, 2);
model.func('pw1').setIndex('pieces', 'rm2', 3, 2);
model.func('pw1').setIndex('pieces', 'rm1(x)', 1, 2);
model.func('pw1').setIndex('pieces', 'rm2(x)', 3, 2);
model.func('pw1').setIndex('pieces', 'rm11)', 1, 2);
model.func('pw1').setIndex('pieces', 'rm2(1)', 3, 2);
model.func('pw1').setIndex('pieces', 'rm(1)', 1, 2);
model.func('pw1').setIndex('pieces', 'rm(x)', 1, 2);
model.func('pw1').setIndex('pieces', 'rm2(x)', 3, 2);

model.result.create('pg1', 1);
model.result('pg1').set('data', 'none');
```

```
model.result('pg1').active(false);
model.result('pg1').set('titletype', 'manual');
model.result('pg1').set('title', 'pw1(x)');
model.result.dataset.create('pw1_ds1', 'Function1D');
model.result.dataset('pw1_ds1').set('functionlist', '');
model.result.dataset('pw1_ds1').set('function', 'all');
model.result.dataset('pw1_ds1').set('par1', 'x');
model.result.dataset('pw1_ds1').set('parmin1', 0);
model.result.dataset('pw1_ds1').set('parmax1', 900);
model.result('pg1').set('xlabelactive', 'on');
model.result('pg1').set('ylabelactive', 'on');
model.result('pg1').feature.create('plot1', 'LineGraph');
model.result('pg1').feature('plot1').set('xdata', 'expr');
model.result('pg1').feature('plot1').set('xdataexpr', 'root.x');
model.result('pg1').feature('plot1').set('xdataunit', '');
model.result('pg1').feature('plot1').set('legend', false);
model.result.dataset.create('pw1_ds2', 'Function1D');
model.result.dataset('pw1_ds2').set('functionlist', '');
model.result.dataset('pw1_ds2').set('function', 'all');
model.result.dataset('pw1_ds2').set('par1', 'x');
model.result.dataset('pw1_ds2').set('parmin1', -90);
model.result.dataset('pw1_ds2').set('parmax1', 0);
model.result('pg1').feature.create('plot2', 'LineGraph');
model.result('pg1').feature('plot2').name('Left Extrapolation');
model.result('pg1').feature('plot2').set('data', 'pw1_ds2');
model.result('pg1').feature('plot2').set('expr', 'mod1.pw1(root.x)');
model.result('pg1').feature('plot2').set('xdata', 'expr');
model.result('pg1').feature('plot2').set('xdataexpr', 'root.x');
model.result('pg1').feature('plot2').set('xdataunit', '');
model.result('pg1').feature('plot2').set('legend', false);
model.result('pg1').feature('plot2').set('linecolor', 'red');
model.result('pg1').feature('plot2').set('linestyle', 'dashed');
model.result.dataset.create('pw1_ds3', 'Function1D');
model.result.dataset('pw1_ds3').set('functionlist', '');
model.result.dataset('pw1_ds3').set('function', 'all');
model.result.dataset('pw1_ds3').set('par1', 'x');
model.result.dataset('pw1_ds3').set('parmin1', 900);
model.result.dataset('pw1_ds3').set('parmax1', 990);
model.result('pg1').feature.create('plot3', 'LineGraph');
model.result('pg1').feature('plot3').name('Right Extrapolation');
model.result('pg1').feature('plot3').set('data', 'pw1_ds3');
model.result('pg1').feature('plot3').set('expr', 'mod1.pw1(root.x)');
model.result('pg1').feature('plot3').set('xdata', 'expr');
model.result('pg1').feature('plot3').set('xdataexpr', 'root.x');
model.result('pg1').feature('plot3').set('xdataunit', '');
model.result('pg1').feature('plot3').set('legend', false);
model.result('pg1').feature('plot3').set('linecolor', 'red');
model.result('pg1').feature('plot3').set('linestyle', 'dashed');
model.result('pg1').feature('plot1').set('expr', 'mod1.pw1(root.x)');
model.result('pg1').feature('plot1').set('descr', 'pw1(x)');
model.result('pg1').feature('plot1').set('data', 'pw1_ds1');
model.result('pg1').active(true);
model.result('pg1').run;
```

```
model.func('pw1').setIndex('pieces', 'rm1(x)', 1, 2);
model.func('pw1').setIndex('pieces', '24+rm1(x)', 1, 2);
model.func('pw1').setIndex('pieces', '-30+rm2(x)', 3, 2);
model.func('pw1').setIndex('pieces', '+rm2(x)', 3, 2);
model.func('pw1').setIndex('pieces', 'rm2(x)', 3, 2);
model.func('pw1').setIndex('pieces', 'rm1(x)', 1, 2);
model.func('pw1').setIndex('pieces', 'rm1(0.3)', 1, 2);
model.func('pw1').setIndex('pieces', 'rm1(t)', 1, 2);
model.func('pw1').setIndex('pieces', 'rm2(t)', 3, 2);
model.func('pw1').set('extrap', 'interior');
model.func('pw1').setIndex('pieces', 'rm1(x)', 1, 2);
model.func('pw1').setIndex('pieces', 'rm2(x)', 3, 2);
model.func('pw1').set('extrap', 'constant');

model.physics('ht2').feature('bhs1').set('Qb', 1, '750');

model.probe('bnd1').selection.set([2 4 6 7]);
model.probe('bnd1').set('unit', 'degC');
model.probe('bnd1').set('descractive', 'on');

model.func('rm1').set('location', '0');
model.func('rm2').set('location', '0');
model.func('pw1').setIndex('pieces', 'rm1(180)', 1, 2);
model.func('pw1').setIndex('pieces', 'rm2(720)', 3, 2);
model.func('pw1').setIndex('pieces', 'rm2(x)', 3, 2);
model.func('pw1').setIndex('pieces', 'rm1(x)', 1, 2);

model.geom('geom1').feature('r1').setIndex('size', '5.0800002817079', 0);
model.geom('geom1').feature('r1').setIndex('size', '5.08', 0);
model.geom('geom1').feature('r1').setIndex('size', '2.5', 1);
model.geom('geom1').feature('r1').setIndex('size', '2.54', 1);
model.geom('geom1').feature('sq1').set('size', '5.08');
model.geom('geom1').feature('sq1').setIndex('pos', '2.54', 1);
model.geom('geom1').feature('r2').setIndex('size', '5.08', 0);
model.geom('geom1').feature('r2').setIndex('size', '2.54', 1);
model.geom('geom1').feature('r2').setIndex('pos', '7.6', 1);
model.geom('geom1').feature('r2').setIndex('pos', '7.62', 1);
model.geom('geom1').run('r1');
model.geom('geom1').run('sq1');
model.geom('geom1').run('r2');
model.geom('geom1').run;

model.physics('ht2').feature('temp2').active(false);

model.study('std1').feature('time').set('plot', 'on');

model.result('pg1').run;

model.study('std1').feature('time').set('tlist', 'range(0,1,900)');
model.study('std1').feature('time').set('plot', 'off');
model.study('std1').feature('time').set('useinitsol', 'off');

model.sol.create('sol1');
model.sol('sol1').study('std1');
```

```
model.sol('sol1').feature.create('st1', 'StudyStep');
model.sol('sol1').feature('st1').set('study', 'std1');
model.sol('sol1').feature('st1').set('studystep', 'time');
model.sol('sol1').feature.create('v1', 'Variables');
model.sol('sol1').feature('v1').set('control', 'time');
model.sol('sol1').feature.create('t1', 'Time');
model.sol('sol1').feature('t1').set('tlist', 'range(0,1,900)');
model.sol('sol1').feature('t1').set('plot', 'off');
model.sol('sol1').feature('t1').set('plotgroup', 'pg1');
model.sol('sol1').feature('t1').set('plotfreq', 'tout');
model.sol('sol1').feature('t1').set('probesel', 'all');
model.sol('sol1').feature('t1').set('probes', {'bnd1'});
model.sol('sol1').feature('t1').set('probefreq', 'tsteps');
model.sol('sol1').feature('t1').set('atolglobalmethod', 'scaled');
model.sol('sol1').feature('t1').set('atolglobal', 0.0010);
model.sol('sol1').feature('t1').set('maxorder', 2);
model.sol('sol1').feature('t1').set('control', 'time');
model.sol('sol1').feature('t1').feature.create('seDef', 'Segregated');
model.sol('sol1').feature('t1').feature.create('fc1', 'FullyCoupled');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.create('d1', 'Direct');
model.sol('sol1').feature('t1').feature('d1').set('linsolver', 'pardiso');
model.sol('sol1').feature('t1').feature('fc1').set('linsolver', 'd1');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.remove('fcDef');
model.sol('sol1').feature('t1').feature.remove('seDef');
model.sol('sol1').attach('std1');

model.result.create('pg2', 'PlotGroup2D');
model.result('pg2').name('Temperature (ht)');
model.result('pg2').set('oldanalysistype', 'noneavailable');
model.result('pg2').set('data', 'dset1');
model.result('pg2').feature.create('surf1', 'Surface');
model.result('pg2').feature('surf1').name('Surface');
model.result('pg2').feature('surf1').set('oldanalysistype',
'noneavailable');
model.result('pg2').feature('surf1').set('colortable', 'ThermalLight');
model.result('pg2').feature('surf1').set('data', 'parent');
model.result.create('pg3', 'PlotGroup2D');
model.result('pg3').name('Isothermal Contours (ht)');
model.result('pg3').set('oldanalysistype', 'noneavailable');
model.result('pg3').set('data', 'dset1');
model.result('pg3').feature.create('con1', 'Contour');
model.result('pg3').feature('con1').name('Contour');
model.result('pg3').feature('con1').set('oldanalysistype',
'noneavailable');
model.result('pg3').feature('con1').set('colortable', 'ThermalLight');
model.result('pg3').feature('con1').set('data', 'parent');
model.result('pg3').feature.create('arws1', 'ArrowSurface');
model.result('pg3').feature('arws1').name('Arrow surface');
```

```
model.result('pg3').feature('arws1').set('oldanalysistype',
'noneavailable');
model.result('pg3').feature('arws1').set('color', 'gray');
model.result('pg3').feature('arws1').set('data', 'parent');
model.result.create('pg4', 'PlotGroup2D');
model.result('pg4').name('Temperature (ht2)');
model.result('pg4').set('oldanalysistype', 'noneavailable');
model.result('pg4').set('data', 'dset1');
model.result('pg4').feature.create('surf1', 'Surface');
model.result('pg4').feature('surf1').name('Surface');
model.result('pg4').feature('surf1').set('oldanalysistype',
'noneavailable');
model.result('pg4').feature('surf1').set('expr', 'T3');
model.result('pg4').feature('surf1').set('colortable', 'ThermalLight');
model.result('pg4').feature('surf1').set('data', 'parent');
model.result.create('pg5', 'PlotGroup2D');
model.result('pg5').name('Isothermal Contours (ht2)');
model.result('pg5').set('oldanalysistype', 'noneavailable');
model.result('pg5').set('data', 'dset1');
model.result('pg5').feature.create('con1', 'Contour');
model.result('pg5').feature('con1').name('Contour');
model.result('pg5').feature('con1').set('oldanalysistype',
'noneavailable');
model.result('pg5').feature('con1').set('expr', 'T3');
model.result('pg5').feature('con1').set('colortable', 'ThermalLight');
model.result('pg5').feature('con1').set('data', 'parent');
model.result('pg5').feature.create('arws1', 'ArrowSurface');
model.result('pg5').feature('arws1').name('Arrow surface');
model.result('pg5').feature('arws1').set('oldanalysistype',
'noneavailable');
model.result('pg5').feature('arws1').set('expr', {'ht2.tfluxx'
'ht2.tfluxy'});
model.result('pg5').feature('arws1').set('color', 'gray');
model.result('pg5').feature('arws1').set('data', 'parent');

model.probe('bnd1').genResult('none');

model.physics('ht2').feature('temp2').active(true);

model.sol('sol1').study('std1');
model.sol('sol1').feature.remove('t1');
model.sol('sol1').feature.remove('v1');
model.sol('sol1').feature.remove('st1');
model.sol('sol1').feature.create('st1', 'StudyStep');
model.sol('sol1').feature('st1').set('study', 'std1');
model.sol('sol1').feature('st1').set('studystep', 'time');
model.sol('sol1').feature.create('v1', 'Variables');
model.sol('sol1').feature('v1').set('control', 'time');
model.sol('sol1').feature.create('t1', 'Time');
model.sol('sol1').feature('t1').set('tlist', 'range(0,1,900)');
model.sol('sol1').feature('t1').set('plot', 'off');
model.sol('sol1').feature('t1').set('plotgroup', 'pg1');
model.sol('sol1').feature('t1').set('plotfreq', 'tout');
model.sol('sol1').feature('t1').set('probesel', 'all');
```

```
model.sol('sol1').feature('t1').set('probes', {'bnd1'});
model.sol('sol1').feature('t1').set('probefreq', 'tsteps');
model.sol('sol1').feature('t1').set('atolglobalmethod', 'scaled');
model.sol('sol1').feature('t1').set('atolglobal', 0.0010);
model.sol('sol1').feature('t1').set('maxorder', 2);
model.sol('sol1').feature('t1').set('control', 'time');
model.sol('sol1').feature('t1').feature.create('seDef', 'Segregated');
model.sol('sol1').feature('t1').feature.create('fc1', 'FullyCoupled');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.create('d1', 'Direct');
model.sol('sol1').feature('t1').feature('d1').set('linsolver', 'pardiso');
model.sol('sol1').feature('t1').feature('fc1').set('linsolver', 'd1');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.remove('fcDef');
model.sol('sol1').feature('t1').feature.remove('seDef');
model.sol('sol1').attach('std1');

model.probe('bnd1').genResult('none');

model.physics('ht').active(false);

model.sol('sol1').study('std1');
model.sol('sol1').feature.remove('t1');
model.sol('sol1').feature.remove('v1');
model.sol('sol1').feature.remove('st1');
model.sol('sol1').feature.create('st1', 'StudyStep');
model.sol('sol1').feature('st1').set('study', 'std1');
model.sol('sol1').feature('st1').set('studystep', 'time');
model.sol('sol1').feature.create('v1', 'Variables');
model.sol('sol1').feature('v1').set('control', 'time');
model.sol('sol1').feature.create('t1', 'Time');
model.sol('sol1').feature('t1').set('tlist', 'range(0,1,900)');
model.sol('sol1').feature('t1').set('plot', 'off');
model.sol('sol1').feature('t1').set('plotgroup', 'pg1');
model.sol('sol1').feature('t1').set('plotfreq', 'tout');
model.sol('sol1').feature('t1').set('probesel', 'all');
model.sol('sol1').feature('t1').set('probes', {'bnd1'});
model.sol('sol1').feature('t1').set('probefreq', 'tsteps');
model.sol('sol1').feature('t1').set('atolglobalmethod', 'scaled');
model.sol('sol1').feature('t1').set('atolglobal', 0.0010);
model.sol('sol1').feature('t1').set('maxorder', 2);
model.sol('sol1').feature('t1').set('control', 'time');
model.sol('sol1').feature('t1').feature.create('fc1', 'FullyCoupled');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.create('d1', 'Direct');
model.sol('sol1').feature('t1').feature('d1').set('linsolver', 'pardiso');
model.sol('sol1').feature('t1').feature('fc1').set('linsolver', 'd1');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
```

```
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.remove('fcDef');
model.sol('sol1').attach('std1');

model.probe('bnd1').genResult('none');

model.func('rm1').set('location', '');
model.func('pw1').setIndex('pieces', 'rm1(x)+180', 1, 2);
model.func('pw1').setIndex('pieces', 'rm2(x)+720', 3, 2);
model.func('rm1').set('location', '0');
model.func('pw1').setIndex('pieces', 'rm1(x+180)', 1, 2);
model.func('pw1').setIndex('pieces', 'rm2(x+720)', 3, 2);
model.func('pw1').setIndex('pieces', 'rm1(x)', 1, 2);
model.func('pw1').setIndex('pieces', 'rm2(x)', 3, 2);
model.func('rm1').set('location', '180');
model.func('rm2').set('location', '720');
model.func('pw1').setIndex('pieces', '24+rm1(x)', 1, 2);
model.func('pw1').setIndex('pieces', '-30+rm2(x)', 3, 2);
model.func('pw1').remove('pieces', 3);
model.func('rm1').set('cutoff', '-54');
model.func('rm2').set('cutoff', '');
model.func('rm2').set('cutoffactive', 'off');
model.func('rm1').set('cutoffactive', 'off');
model.func('pw1').setIndex('pieces', '720', 3, 0);
model.func('pw1').setIndex('pieces', '900', 3, 1);
model.func('pw1').setIndex('pieces', '-30+rm2(x)', 3, 2);

model.sol('sol1').study('std1');
model.sol('sol1').feature.remove('t1');
model.sol('sol1').feature.remove('v1');
model.sol('sol1').feature.remove('st1');
model.sol('sol1').feature.create('st1', 'StudyStep');
model.sol('sol1').feature('st1').set('study', 'std1');
model.sol('sol1').feature('st1').set('studystep', 'time');
model.sol('sol1').feature.create('v1', 'Variables');
model.sol('sol1').feature('v1').set('control', 'time');
model.sol('sol1').feature.create('t1', 'Time');
model.sol('sol1').feature('t1').set('tlist', 'range(0,1,900)');
model.sol('sol1').feature('t1').set('plot', 'off');
model.sol('sol1').feature('t1').set('plotgroup', 'pg1');
model.sol('sol1').feature('t1').set('plotfreq', 'tout');
model.sol('sol1').feature('t1').set('probesel', 'all');
model.sol('sol1').feature('t1').set('probes', {'bnd1'});
model.sol('sol1').feature('t1').set('probefreq', 'tsteps');
model.sol('sol1').feature('t1').set('atolglobalmethod', 'scaled');
model.sol('sol1').feature('t1').set('atolglobal', 0.0010);
model.sol('sol1').feature('t1').set('maxorder', 2);
model.sol('sol1').feature('t1').set('control', 'time');
model.sol('sol1').feature('t1').feature.create('fc1', 'FullyCoupled');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.create('d1', 'Direct');
```

```
model.sol('sol1').feature('t1').feature('d1').set('linsolver', 'pardiso');
model.sol('sol1').feature('t1').feature('fc1').set('linsolver', 'd1');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.remove('fcDef');
model.sol('sol1').attach('std1');

model.probe('bnd1').genResult('none');

model.geom('geom1').run('r2');
model.geom('geom1').feature.create('uni1', 'Union');
model.geom('geom1').feature('uni1').selection('input').set({'r1' 'r2'
'sq1'});
model.geom('geom1').feature('uni1').set('keep', 'on');
model.geom('geom1').runAll;
model.geom('geom1').run;
model.geom('geom1').runAll;
model.geom('geom1').runAll;

model.sol('sol1').study('std1');
model.sol('sol1').feature.remove('t1');
model.sol('sol1').feature.remove('v1');
model.sol('sol1').feature.remove('st1');
model.sol('sol1').feature.create('st1', 'StudyStep');
model.sol('sol1').feature('st1').set('study', 'std1');
model.sol('sol1').feature('st1').set('studystep', 'time');
model.sol('sol1').feature.create('v1', 'Variables');
model.sol('sol1').feature('v1').set('control', 'time');
model.sol('sol1').feature.create('t1', 'Time');
model.sol('sol1').feature('t1').set('tlist', 'range(0,1,900)');
model.sol('sol1').feature('t1').set('plot', 'off');
model.sol('sol1').feature('t1').set('plotgroup', 'pg1');
model.sol('sol1').feature('t1').set('plotfreq', 'tout');
model.sol('sol1').feature('t1').set('probesel', 'all');
model.sol('sol1').feature('t1').set('probes', {'bnd1'});
model.sol('sol1').feature('t1').set('probefreq', 'tsteps');
model.sol('sol1').feature('t1').set('atolglobalmethod', 'scaled');
model.sol('sol1').feature('t1').set('atolglobal', 0.0010);
model.sol('sol1').feature('t1').set('maxorder', 2);
model.sol('sol1').feature('t1').set('control', 'time');
model.sol('sol1').feature('t1').feature.create('fc1', 'FullyCoupled');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.create('d1', 'Direct');
model.sol('sol1').feature('t1').feature('d1').set('linsolver', 'pardiso');
model.sol('sol1').feature('t1').feature('fc1').set('linsolver', 'd1');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.remove('fcDef');
model.sol('sol1').attach('std1');
```

```
model.probe('bnd1').genResult('none');

model.physics('ht2').feature('sar1').set('epsilon_rad_mat', 1, 'userdef');
model.physics('ht2').feature('sar1').set('epsilon_rad', 1, '1');

model.sol('sol1').study('std1');
model.sol('sol1').feature.remove('t1');
model.sol('sol1').feature.remove('v1');
model.sol('sol1').feature.remove('st1');
model.sol('sol1').feature.create('st1', 'StudyStep');
model.sol('sol1').feature('st1').set('study', 'std1');
model.sol('sol1').feature('st1').set('studystep', 'time');
model.sol('sol1').feature.create('v1', 'Variables');
model.sol('sol1').feature('v1').set('control', 'time');
model.sol('sol1').feature.create('t1', 'Time');
model.sol('sol1').feature('t1').set('tlist', 'range(0,1,900)');
model.sol('sol1').feature('t1').set('plot', 'off');
model.sol('sol1').feature('t1').set('plotgroup', 'pg1');
model.sol('sol1').feature('t1').set('plotfreq', 'tout');
model.sol('sol1').feature('t1').set('probesel', 'all');
model.sol('sol1').feature('t1').set('probes', {'bnd1'});
model.sol('sol1').feature('t1').set('probefreq', 'tsteps');
model.sol('sol1').feature('t1').set('atolglobalmethod', 'scaled');
model.sol('sol1').feature('t1').set('atolglobal', 0.0010);
model.sol('sol1').feature('t1').set('maxorder', 2);
model.sol('sol1').feature('t1').set('control', 'time');
model.sol('sol1').feature('t1').feature.create('fc1', 'FullyCoupled');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.create('d1', 'Direct');
model.sol('sol1').feature('t1').feature('d1').set('linsolver', 'pardiso');
model.sol('sol1').feature('t1').feature('fc1').set('linsolver', 'd1');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.remove('fcDef');
model.sol('sol1').attach('std1');

model.probe('bnd1').genResult('none');

model.physics('ht2').feature('temp1').set('T0', 1, 'pw1(t)+273.15[k]');
model.physics('ht2').feature('temp1').set('T0', 1, 'pw1(t)[]+273.15');
model.physics('ht2').feature('temp1').set('T0', 1, 'pw1(t)+273.15');

model.func('pw1').set('fununit', '1');

model.physics('ht2').feature('temp1').set('T0', 1, 'pw1(t)+273.15[1\K]');
model.physics('ht2').feature('temp1').set('T0', 1,
'(pw1(t)+273.15)[1\K]');
model.physics('ht2').feature('temp1').set('T0', 1, '(pw1(t)+273.15)[K]');
model.physics('ht2').feature('temp1').set('T0', 1, 'pw1(t)');

model.func('pw1').set('argunit', '1');
```

```
model.variable.create('var1');
model.variable('var1').model('mod1');
model.variable('var1').set('Time', 't');
model.variable('var1').remove('Time');
model.variable('var1').set('t', 'range(0,1,900)[s]');

model.func('pw1').set('argunit', 's');

model.physics('ht2').feature('temp1').set('T0', 1, 'pw1(x)');

model.variable('var1').remove('t');
model.variable('var1').set('x', 'range(0,1,900)[s]');

model.physics('ht2').feature('temp1').set('T0', 1, '1[K]');
model.physics('ht2').feature('temp1').set('T0', 1, '[K]');

model.func('pw1').set('fununit', 'K');

model.physics('ht2').feature('temp1').set('T0', 1, 'pw1(x)');
model.physics('ht2').feature('temp1').set('T0', 1, 'pw1');

model.func('pw1').set('argunit', '1');
model.func('pw1').set('fununit', '1');

model.physics('ht2').feature('temp1').set('T0', 1, 'pw1(x)');

model.sol('sol1').study('std1');
model.sol('sol1').feature.remove('t1');
model.sol('sol1').feature.remove('v1');
model.sol('sol1').feature.remove('st1');
model.sol('sol1').feature.create('st1', 'StudyStep');
model.sol('sol1').feature('st1').set('study', 'std1');
model.sol('sol1').feature('st1').set('studystep', 'time');
model.sol('sol1').feature.create('v1', 'Variables');
model.sol('sol1').feature('v1').set('control', 'time');
model.sol('sol1').feature.create('t1', 'Time');
model.sol('sol1').feature('t1').set('tlist', 'range(0,1,900)');
model.sol('sol1').feature('t1').set('plot', 'off');
model.sol('sol1').feature('t1').set('plotgroup', 'pg1');
model.sol('sol1').feature('t1').set('plotfreq', 'tout');
model.sol('sol1').feature('t1').set('probesel', 'all');
model.sol('sol1').feature('t1').set('probes', {'bnd1'});
model.sol('sol1').feature('t1').set('probefreq', 'tsteps');
model.sol('sol1').feature('t1').set('atolglobalmethod', 'scaled');
model.sol('sol1').feature('t1').set('atolglobal', 0.0010);
model.sol('sol1').feature('t1').set('maxorder', 2);
model.sol('sol1').feature('t1').set('control', 'time');
model.sol('sol1').feature('t1').feature.create('fc1', 'FullyCoupled');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.create('d1', 'Direct');
model.sol('sol1').feature('t1').feature('d1').set('linsolver', 'pardiso');
```

```
model.sol('sol1').feature('t1').feature('fc1').set('linsolver', 'd1');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.remove('fcDef');
model.sol('sol1').attach('std1');

model.probe('bnd1').genResult('none');

model.variable('var1').remove('x');
model.variable('var1').set('tx', 'range(0,1,900)[s]');

model.physics('ht2').feature('temp1').set('T0', 1, 'pw1(tx)');

model.func('pw1').set('fununit', 'K');

model.sol('sol1').study('std1');
model.sol('sol1').feature.remove('t1');
model.sol('sol1').feature.remove('v1');
model.sol('sol1').feature.remove('st1');
model.sol('sol1').feature.create('st1', 'StudyStep');
model.sol('sol1').feature('st1').set('study', 'std1');
model.sol('sol1').feature('st1').set('studystep', 'time');
model.sol('sol1').feature.create('v1', 'Variables');
model.sol('sol1').feature('v1').set('control', 'time');
model.sol('sol1').feature.create('t1', 'Time');
model.sol('sol1').feature('t1').set('tlist', 'range(0,1,900)');
model.sol('sol1').feature('t1').set('plot', 'off');
model.sol('sol1').feature('t1').set('plotgroup', 'pg1');
model.sol('sol1').feature('t1').set('plotfreq', 'tout');
model.sol('sol1').feature('t1').set('probesel', 'all');
model.sol('sol1').feature('t1').set('probes', {'bnd1'});
model.sol('sol1').feature('t1').set('probefreq', 'tsteps');
model.sol('sol1').feature('t1').set('atolglobalmethod', 'scaled');
model.sol('sol1').feature('t1').set('atolglobal', 0.0010);
model.sol('sol1').feature('t1').set('maxorder', 2);
model.sol('sol1').feature('t1').set('control', 'time');
model.sol('sol1').feature('t1').feature.create('fc1', 'FullyCoupled');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.create('d1', 'Direct');
model.sol('sol1').feature('t1').feature('d1').set('linsolver', 'pardiso');
model.sol('sol1').feature('t1').feature('fc1').set('linsolver', 'd1');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.remove('fcDef');
model.sol('sol1').attach('std1');

model.probe('bnd1').genResult('none');

model.physics('ht2').feature('temp1').set('T0', 1, 'pw1(range(0,1,900))');
```

```
model.sol('sol1').study('std1');
model.sol('sol1').feature.remove('t1');
model.sol('sol1').feature.remove('v1');
model.sol('sol1').feature.remove('st1');
model.sol('sol1').feature.create('st1', 'StudyStep');
model.sol('sol1').feature('st1').set('study', 'std1');
model.sol('sol1').feature('st1').set('studystep', 'time');
model.sol('sol1').feature.create('v1', 'Variables');
model.sol('sol1').feature('v1').set('control', 'time');
model.sol('sol1').feature.create('t1', 'Time');
model.sol('sol1').feature('t1').set('tlist', 'range(0,1,900)');
model.sol('sol1').feature('t1').set('plot', 'off');
model.sol('sol1').feature('t1').set('plotgroup', 'pg1');
model.sol('sol1').feature('t1').set('plotfreq', 'tout');
model.sol('sol1').feature('t1').set('probesel', 'all');
model.sol('sol1').feature('t1').set('probes', {'bnd1'});
model.sol('sol1').feature('t1').set('probefreq', 'tsteps');
model.sol('sol1').feature('t1').set('atolglobalmethod', 'scaled');
model.sol('sol1').feature('t1').set('atolglobal', 0.0010);
model.sol('sol1').feature('t1').set('maxorder', 2);
model.sol('sol1').feature('t1').set('control', 'time');
model.sol('sol1').feature('t1').feature.create('fc1', 'FullyCoupled');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.create('d1', 'Direct');
model.sol('sol1').feature('t1').feature('d1').set('linsolver', 'pardiso');
model.sol('sol1').feature('t1').feature('fc1').set('linsolver', 'd1');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.remove('fcDef');
model.sol('sol1').attach('std1');

model.probe('bnd1').genResult('none');

model.physics('ht2').feature('temp1').set('T0', 1, 'pw1(range(t)');
model.physics('ht2').feature('temp1').set('T0', 1, 'pw1(t)');

model.func('pw1').set('argunit', 's');

model.sol('sol1').study('std1');
model.sol('sol1').feature.remove('t1');
model.sol('sol1').feature.remove('v1');
model.sol('sol1').feature.remove('st1');
model.sol('sol1').feature.create('st1', 'StudyStep');
model.sol('sol1').feature('st1').set('study', 'std1');
model.sol('sol1').feature('st1').set('studystep', 'time');
model.sol('sol1').feature.create('v1', 'Variables');
model.sol('sol1').feature('v1').set('control', 'time');
model.sol('sol1').feature.create('t1', 'Time');
model.sol('sol1').feature('t1').set('tlist', 'range(0,1,900)');
model.sol('sol1').feature('t1').set('plot', 'off');
model.sol('sol1').feature('t1').set('plotgroup', 'pg1');
```

```
model.sol('sol1').feature('t1').set('plotfreq', 'tout');
model.sol('sol1').feature('t1').set('probesel', 'all');
model.sol('sol1').feature('t1').set('probes', {'bnd1'});
model.sol('sol1').feature('t1').set('probefreq', 'tsteps');
model.sol('sol1').feature('t1').set('atolglobalmethod', 'scaled');
model.sol('sol1').feature('t1').set('atolglobal', 0.0010);
model.sol('sol1').feature('t1').set('maxorder', 2);
model.sol('sol1').feature('t1').set('control', 'time');
model.sol('sol1').feature('t1').feature.create('fc1', 'FullyCoupled');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.create('d1', 'Direct');
model.sol('sol1').feature('t1').feature('d1').set('linsolver', 'pardiso');
model.sol('sol1').feature('t1').feature('fc1').set('linsolver', 'd1');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.remove('fcDef');
model.sol('sol1').attach('std1');

model.probe('bnd1').genResult('none');

model.sol('sol1').runAll;

model.physics('ht2').feature.create('chf1', 'ConvectiveHeatFlux', 1);
model.physics('ht2').feature('chf1').set('h', 1, '5');
model.physics('ht2').feature('sar1').active(false);
model.physics('ht2').feature('temp2').active(false);
model.physics('ht2').feature('chf1').selection.set([7]);

model.sol.remove('sol1');

model.result('pg6').set('window', 'window1');
model.result('pg6').run;
model.result.remove('pg6');
model.result('pg1').run;
model.result.remove('pg1');
model.result.table.remove('tbl1');
model.result.table.remove('tbl2');

model.sol.create('sol1');
model.sol('sol1').study('std1');
model.sol('sol1').feature.create('st1', 'StudyStep');
model.sol('sol1').feature('st1').set('study', 'std1');
model.sol('sol1').feature('st1').set('studystep', 'time');
model.sol('sol1').feature.create('v1', 'Variables');
model.sol('sol1').feature('v1').set('control', 'time');
model.sol('sol1').feature.create('t1', 'Time');
model.sol('sol1').feature('t1').set('tlist', 'range(0,1,900)');
model.sol('sol1').feature('t1').set('plot', 'off');
model.sol('sol1').feature('t1').set('plotfreq', 'tout');
model.sol('sol1').feature('t1').set('probesel', 'all');
model.sol('sol1').feature('t1').set('probes', {'bnd1'});
```

```
model.sol('sol1').feature('t1').set('probefreq', 'tsteps');
model.sol('sol1').feature('t1').set('atolglobalmethod', 'scaled');
model.sol('sol1').feature('t1').set('atolglobal', 0.0010);
model.sol('sol1').feature('t1').set('maxorder', 2);
model.sol('sol1').feature('t1').set('control', 'time');
model.sol('sol1').feature('t1').feature.create('fc1', 'FullyCoupled');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.create('d1', 'Direct');
model.sol('sol1').feature('t1').feature('d1').set('linsolver', 'pardiso');
model.sol('sol1').feature('t1').feature('fc1').set('linsolver', 'd1');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.remove('fcDef');
model.sol('sol1').attach('std1');

model.result.create('pg1', 'PlotGroup2D');
model.result('pg1').name('Temperature (ht2)');
model.result('pg1').set('oldanalysistype', 'noneavailable');
model.result('pg1').set('data', 'dset1');
model.result('pg1').feature.create('surf1', 'Surface');
model.result('pg1').feature('surf1').name('Surface');
model.result('pg1').feature('surf1').set('oldanalysistype',
'noneavailable');
model.result('pg1').feature('surf1').set('colortable', 'ThermalLight');
model.result('pg1').feature('surf1').set('data', 'parent');
model.result.create('pg2', 'PlotGroup2D');
model.result('pg2').name('Isothermal Contours (ht2)');
model.result('pg2').set('oldanalysistype', 'noneavailable');
model.result('pg2').set('data', 'dset1');
model.result('pg2').feature.create('con1', 'Contour');
model.result('pg2').feature('con1').name('Contour');
model.result('pg2').feature('con1').set('oldanalysistype',
'noneavailable');
model.result('pg2').feature('con1').set('colortable', 'ThermalLight');
model.result('pg2').feature('con1').set('data', 'parent');
model.result('pg2').feature.create('arws1', 'ArrowSurface');
model.result('pg2').feature('arws1').name('Arrow surface');
model.result('pg2').feature('arws1').set('oldanalysistype',
'noneavailable');
model.result('pg2').feature('arws1').set('color', 'gray');
model.result('pg2').feature('arws1').set('data', 'parent');

model.probe('bnd1').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;

model.func('pw1').setIndex('pieces', '24+273.15', 0, 2);
model.func('pw1').setIndex('pieces', '24+273.15+rm1(x)', 1, 2);
model.func('pw1').setIndex('pieces', '-30+273.15', 2, 2);
```

```
model.func('pw1').setIndex('pieces', '-30+273.15+rm2(x)', 3, 2);

model.sol('sol1').study('std1');
model.sol('sol1').feature.remove('t1');
model.sol('sol1').feature.remove('v1');
model.sol('sol1').feature.remove('st1');
model.sol('sol1').feature.create('st1', 'StudyStep');
model.sol('sol1').feature('st1').set('study', 'std1');
model.sol('sol1').feature('st1').set('studystep', 'time');
model.sol('sol1').feature.create('v1', 'Variables');
model.sol('sol1').feature('v1').set('control', 'time');
model.sol('sol1').feature.create('t1', 'Time');
model.sol('sol1').feature('t1').set('tlist', 'range(0,1,900)');
model.sol('sol1').feature('t1').set('plot', 'off');
model.sol('sol1').feature('t1').set('plotgroup', 'pg1');
model.sol('sol1').feature('t1').set('plotfreq', 'tout');
model.sol('sol1').feature('t1').set('probesel', 'all');
model.sol('sol1').feature('t1').set('probes', {'bnd1'});
model.sol('sol1').feature('t1').set('probefreq', 'tsteps');
model.sol('sol1').feature('t1').set('atolglobalmethod', 'scaled');
model.sol('sol1').feature('t1').set('atolglobal', 0.0010);
model.sol('sol1').feature('t1').set('maxorder', 2);
model.sol('sol1').feature('t1').set('control', 'time');
model.sol('sol1').feature('t1').feature.create('fc1', 'FullyCoupled');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.create('d1', 'Direct');
model.sol('sol1').feature('t1').feature('d1').set('linsolver', 'pardiso');
model.sol('sol1').feature('t1').feature('fc1').set('linsolver', 'd1');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.remove('fcDef');
model.sol('sol1').attach('std1');

model.probe('bnd1').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg1').run;

model.func('rm2').set('slope', '0.3/60');
model.func('rm1').set('slope', '-0.3/60');
model.func('pw1').setIndex('pieces', '180*60', 0, 1);
model.func('pw1').setIndex('pieces', '180*60', 1, 0);
model.func('pw1').setIndex('pieces', '360*60', 1, 1);
model.func('pw1').setIndex('pieces', '360*60', 2, 0);
model.func('pw1').setIndex('pieces', '720*60', 2, 1);
model.func('pw1').setIndex('pieces', '720*60', 3, 0);
model.func('pw1').setIndex('pieces', '900*60', 3, 1);

model.study('std1').feature('time').set('tlist', 'range(0,60,900*60)');
```

```
model.sol('sol1').study('std1');
model.sol('sol1').feature.remove('t1');
model.sol('sol1').feature.remove('v1');
model.sol('sol1').feature.remove('st1');
model.sol('sol1').feature.create('st1', 'StudyStep');
model.sol('sol1').feature('st1').set('study', 'std1');
model.sol('sol1').feature('st1').set('studystep', 'time');
model.sol('sol1').feature.create('v1', 'Variables');
model.sol('sol1').feature('v1').set('control', 'time');
model.sol('sol1').feature.create('t1', 'Time');
model.sol('sol1').feature('t1').set('tlist', 'range(0,60,900*60)');
model.sol('sol1').feature('t1').set('plot', 'off');
model.sol('sol1').feature('t1').set('plotgroup', 'pg1');
model.sol('sol1').feature('t1').set('plotfreq', 'tout');
model.sol('sol1').feature('t1').set('probesel', 'all');
model.sol('sol1').feature('t1').set('probes', {'bnd1'});
model.sol('sol1').feature('t1').set('probefreq', 'tsteps');
model.sol('sol1').feature('t1').set('atolglobalmethod', 'scaled');
model.sol('sol1').feature('t1').set('atolglobal', 0.0010);
model.sol('sol1').feature('t1').set('maxorder', 2);
model.sol('sol1').feature('t1').set('control', 'time');
model.sol('sol1').feature('t1').feature.create('fc1', 'FullyCoupled');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.create('d1', 'Direct');
model.sol('sol1').feature('t1').feature('d1').set('linsolver', 'pardiso');
model.sol('sol1').feature('t1').feature('fc1').set('linsolver', 'd1');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.remove('fcDef');
model.sol('sol1').attach('std1');

model.probe('bnd1').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;

model.func('pw1').setIndex('pieces', '900', 3, 1);
model.func('pw1').setIndex('pieces', '720', 3, 0);
model.func('pw1').setIndex('pieces', '360', 2, 0);
model.func('pw1').setIndex('pieces', '180', 1, 0);
model.func('pw1').setIndex('pieces', '360', 1, 1);
model.func('pw1').setIndex('pieces', '720', 2, 1);
model.func('pw1').setIndex('pieces', '180', 0, 1);
model.func('rm1').set('slope', '-0.3');
model.func('rm2').set('slope', '0.3');
model.func('rm2').set('cutoffactive', 'off');
model.func('pw1').setIndex('pieces', '900', 4, 0);
model.func('pw1').setIndex('pieces', '1080', 4, 1);
model.func('pw1').setIndex('pieces', '-24', 4, 2);
```

```
model.func('pw1').setIndex('pieces', '24+273.15', 4, 2);
model.func('pw1').set('argunit', 'min');

model.sol('sol1').study('std1');
model.sol('sol1').feature.remove('t1');
model.sol('sol1').feature.remove('v1');
model.sol('sol1').feature.remove('st1');
model.sol('sol1').feature.create('st1', 'StudyStep');
model.sol('sol1').feature('st1').set('study', 'std1');
model.sol('sol1').feature('st1').set('studystep', 'time');
model.sol('sol1').feature.create('v1', 'Variables');
model.sol('sol1').feature('v1').set('control', 'time');
model.sol('sol1').feature.create('t1', 'Time');
model.sol('sol1').feature('t1').set('tlist', 'range(0,60,900*60)');
model.sol('sol1').feature('t1').set('plot', 'off');
model.sol('sol1').feature('t1').set('plotgroup', 'pg1');
model.sol('sol1').feature('t1').set('plotfreq', 'tout');
model.sol('sol1').feature('t1').set('probesel', 'all');
model.sol('sol1').feature('t1').set('probes', {'bnd1'});
model.sol('sol1').feature('t1').set('probefreq', 'tsteps');
model.sol('sol1').feature('t1').set('atolglobalmethod', 'scaled');
model.sol('sol1').feature('t1').set('atolglobal', 0.0010);
model.sol('sol1').feature('t1').set('maxorder', 2);
model.sol('sol1').feature('t1').set('control', 'time');
model.sol('sol1').feature('t1').feature.create('fc1', 'FullyCoupled');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.create('d1', 'Direct');
model.sol('sol1').feature('t1').feature('d1').set('linsolver', 'pardiso');
model.sol('sol1').feature('t1').feature('fc1').set('linsolver', 'd1');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.remove('fcDef');
model.sol('sol1').attach('std1');

model.probe('bnd1').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg1').setIndex('looplevel', 'interp', 0);
model.result('pg1').setIndex('looplevel', '1', 0);

model.func('pw1').setIndex('pieces', '23+273.15', 0, 2);
model.func('pw1').setIndex('pieces', '23+273.15+rm1(x)', 1, 2);
model.func('pw1').setIndex('pieces', '23+273.15', 4, 2);
model.func('pw1').setIndex('pieces', '357.67', 1, 1);
model.func('pw1').setIndex('pieces', '357.67', 2, 0);
model.func('pw1').setIndex('pieces', '897.67', 3, 1);
model.func('pw1').setIndex('pieces', '897.67', 4, 0);
model.func.duplicate('pw2', 'pw1');
model.func('pw2').setIndex('pieces', '23', 0, 2);
```

```
model.func('pw2').setIndex('pieces', '23+rm1(x)', 1, 2);
model.func('pw2').setIndex('pieces', '-30', 2, 2);
model.func('pw2').setIndex('pieces', '-30+rm2(x)', 3, 2);
model.func('pw2').setIndex('pieces', '23', 4, 2);

model.sol('sol1').study('std1');
model.sol('sol1').feature.remove('t1');
model.sol('sol1').feature.remove('v1');
model.sol('sol1').feature.remove('st1');
model.sol('sol1').feature.create('st1', 'StudyStep');
model.sol('sol1').feature('st1').set('study', 'std1');
model.sol('sol1').feature('st1').set('studystep', 'time');
model.sol('sol1').feature.create('v1', 'Variables');
model.sol('sol1').feature('v1').set('control', 'time');
model.sol('sol1').feature.create('t1', 'Time');
model.sol('sol1').feature('t1').set('tlist', 'range(0,60,900*60)');
model.sol('sol1').feature('t1').set('plot', 'off');
model.sol('sol1').feature('t1').set('plotgroup', 'pg1');
model.sol('sol1').feature('t1').set('plotfreq', 'tout');
model.sol('sol1').feature('t1').set('probesel', 'all');
model.sol('sol1').feature('t1').set('probes', {'bnd1'});
model.sol('sol1').feature('t1').set('probefreq', 'tsteps');
model.sol('sol1').feature('t1').set('atolglobalmethod', 'scaled');
model.sol('sol1').feature('t1').set('atolglobal', 0.0010);
model.sol('sol1').feature('t1').set('maxorder', 2);
model.sol('sol1').feature('t1').set('control', 'time');
model.sol('sol1').feature('t1').feature.create('fc1', 'FullyCoupled');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.create('d1', 'Direct');
model.sol('sol1').feature('t1').feature('d1').set('linsolver', 'pardiso');
model.sol('sol1').feature('t1').feature('fc1').set('linsolver', 'd1');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.remove('fcDef');
model.sol('sol1').attach('std1');

model.probe('bnd1').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg1').setIndex('looplevel', '7', 0);
model.result('pg1').run;
model.result('pg1').setIndex('looplevel', '21', 0);
model.result('pg1').run;
model.result('pg1').setIndex('looplevel', '252', 0);
model.result('pg1').run;
model.result('pg1').setIndex('looplevel', '411', 0);
model.result('pg1').run;
model.result.dataset('dset2').run;
```

```
model.view.remove('view2');

model.sol('sol1').study('std1');
model.sol('sol1').feature.remove('t1');
model.sol('sol1').feature.remove('v1');
model.sol('sol1').feature.remove('st1');
model.sol('sol1').feature.create('st1', 'StudyStep');
model.sol('sol1').feature('st1').set('study', 'std1');
model.sol('sol1').feature('st1').set('studystep', 'time');
model.sol('sol1').feature.create('v1', 'Variables');
model.sol('sol1').feature('v1').set('control', 'time');
model.sol('sol1').feature.create('t1', 'Time');
model.sol('sol1').feature('t1').set('tlist', 'range(0,60,900*60)');
model.sol('sol1').feature('t1').set('plot', 'off');
model.sol('sol1').feature('t1').set('plotgroup', 'pg1');
model.sol('sol1').feature('t1').set('plotfreq', 'tout');
model.sol('sol1').feature('t1').set('probesel', 'all');
model.sol('sol1').feature('t1').set('probes', {'bnd1'});
model.sol('sol1').feature('t1').set('probefreq', 'tsteps');
model.sol('sol1').feature('t1').set('atolglobalmethod', 'scaled');
model.sol('sol1').feature('t1').set('atolglobal', 0.0010);
model.sol('sol1').feature('t1').set('maxorder', 2);
model.sol('sol1').feature('t1').set('control', 'time');
model.sol('sol1').feature('t1').feature.create('fc1', 'FullyCoupled');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.create('d1', 'Direct');
model.sol('sol1').feature('t1').feature('d1').set('linsolver', 'pardiso');
model.sol('sol1').feature('t1').feature('fc1').set('linsolver', 'd1');
model.sol('sol1').feature('t1').feature('fc1').set('jtech', 'once');
model.sol('sol1').feature('t1').feature('fc1').set('damp', 0.9);
model.sol('sol1').feature('t1').feature('fc1').set('maxiter', 5);
model.sol('sol1').feature('t1').feature.remove('fcDef');
model.sol('sol1').attach('std1');

model.probe('bnd1').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg1').setIndex('looplevel', '418', 0);
model.result('pg1').setIndex('looplevel', '431', 0);

model.probe.create('pdom1', 'DomainPoint');
model.probe('pdom1').model('mod1');
model.probe('pdom1').setIndex('coords2', '2.54', 0, 0);
model.probe('pdom1').set('bndsnap2', 'off');
model.probe('pdom1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
```

```
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;

model.probe.duplicate('pdom2', 'pdom1');
model.probe('pdom1').feature('ppb1').set('unit', 'degC');
model.probe('pdom2').feature.remove('ppb2');
model.probe('pdom2').setIndex('coords2', '2.54', 0, 1);
model.probe('pdom2').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;

model.probe.duplicate('pdom3', 'pdom2');
model.probe('pdom3').feature.remove('ppb2');
model.probe('pdom3').setIndex('coords2', '2.54+5.08', 0, 1);
model.probe('pdom3').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;

model.probe('pdom3').feature('ppb1').set('unit', 'degC');
model.probe('pdom2').feature('ppb1').set('unit', 'degC');
model.probe.duplicate('pdom4', 'pdom3');
model.probe('pdom4').feature.remove('ppb2');
model.probe('pdom4').setIndex('coords2', '2.54+5.08+2.54', 0, 1);
model.probe('pdom4').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg4').set('windowtitle', 'Probe Plot 2');
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg4').set('windowtitle', 'Probe Plot 2');

model.sol('sol1').feature('t1').set('timemethod', 'genalpha');
model.sol('sol1').feature('t1').set('maxstepgenalphaactive', 'on');
model.sol('sol1').feature('t1').set('maxstepgenalpha', '10');
```

```
model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');
model.probe('pdom1').setIndex('coords2', '0.001', 0, 1);
model.probe('pdom2').setIndex('coords2', '2.541', 0, 1);
model.probe('pdom3').setIndex('coords2', '2.54+5.081', 0, 1);
model.probe('pdom4').setIndex('coords2', '2.54+5.08+2.541', 0, 1);
model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.mesh('mesh1').feature('size').set('hauto', '4');

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');
model.probe('pdom1').active(false);
model.probe('pdom2').active(false);
model.probe('pdom3').active(false);
model.probe('pdom4').active(false);
model.probe('bnd1').genResult('none');
model.probe('pdom2').feature('ppb1').set('probename', 'ppb2');
model.probe('pdom3').feature('ppb1').set('probename', 'ppb3');
model.probe('pdom4').feature('ppb1').set('probename', 'ppb4');
model.probe('bnd1').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result.dataset('cpt1').run;
model.result.dataset('cpt2').run;

model.probe('pdom1').active(true);
model.probe('pdom1').feature('ppb1').active(true);
model.probe('pdom2').active(true);
model.probe('pdom2').feature('ppb1').active(true);
model.probe('pdom3').active(true);
model.probe('pdom3').feature('ppb1').active(true);
model.probe('pdom4').active(true);
model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
```

```
model.result.dataset('cpt1').run;
model.result.dataset('cpt1').set('data', 'dset2');
model.result.dataset('cpt1').run;

model.probe('pdom1').setIndex('coords2', '0.1', 0, 1);
model.probe('pdom1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg4').set('windowtitle', 'Probe Plot 2');
model.result('pg3').set('window', 'window1');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg3').run;
model.result('pg3').set('data', 'cpt1');
model.result('pg3').set('window', 'window1');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg3').run;
model.result.create('pg5', 'PlotGroup1D');
model.result('pg5').run;
model.result('pg5').run;
model.result('pg5').set('data', 'cpt1');
model.result('pg5').run;
model.result('pg5').run;
model.result('pg5').run;
model.result('pg5').run;
model.result('pg3').set('window', 'window1');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg3').run;
model.result('pg3').set('data', 'dset1');
model.result('pg3').set('window', 'window1');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg3').run;
model.result('pg3').set('data', 'dset2');
model.result('pg3').set('window', 'window1');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg3').run;
model.result('pg3').set('data', 'cpt4');
model.result('pg3').set('window', 'window1');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg3').run;
model.result('pg3').set('window', 'window1');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg3').run;
model.result('pg3').set('window', 'window1');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg3').run;
model.result('pg3').feature('tblp1').set('plotcolumns', {'2'});
```

```
model.result('pg3').set('window', 'window1');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg3').run;

model.probe('pdom2').setIndex('coords2', '2.54+0.01', 0, 1);
model.probe('pdom2').feature('ppb1').set('window', 'window1');
model.probe('pdom1').feature('ppb1').set('window', 'window1');
model.probe('pdom3').feature('ppb1').set('window', 'window1');
model.probe('pdom4').feature('ppb1').set('window', 'window1');
model.probe('pdom2').setIndex('coords2', '2.54+0.1', 0, 1);
model.probe('pdom3').setIndex('coords2', '2.54+5.08+0.1', 0, 1);
model.probe('pdom4').setIndex('coords2', '2.54+5.08+2.54+0.1', 0, 1);
model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');
model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg3').set('window', 'window1');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg3').run;
model.result('pg4').set('window', 'window2');
model.result('pg4').run;
model.result('pg5').run;
model.result('pg3').set('window', 'window1');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg3').run;
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg4').set('windowtitle', 'Probe Plot 2');
model.result('pg5').set('windowtitle', 'Graphics');
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg4').set('windowtitle', 'Probe Plot 2');
model.result('pg5').set('windowtitle', 'Graphics');

model.probe('pdom4').setIndex('coords2', '2.54+5.08+2.54', 0, 1);
model.probe('pdom4').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
```

```
model.result('pg3').run;

model.probe('pdom1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;

model.probe('pdom2').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;

model.probe('pdom3').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;

model.probe('pdom2').feature('ppb1').set('table', 'new');
model.probe('pdom3').feature('ppb1').set('table', 'new');
model.probe('pdom4').feature('ppb1').set('table', 'new');
model.probe('pdom4').feature('ppb1').set('window', 'new');
model.probe('pdom3').feature('ppb1').set('window', 'new');
model.probe('pdom2').feature('ppb1').set('window', 'new');
model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg4').set('window', 'window2');
model.result('pg4').set('windowtitle', 'Probe Plot 2');
model.result('pg4').run;
model.result('pg3').set('window', 'window1');
model.result('pg3').run;

model.mesh('mesh1').feature('size').set('hauto', '2');
model.mesh('mesh1').run;

model.probe('bnd1').genResult('none');
```

```
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg4').set('windowtitle', 'Probe Plot 2');
model.result('pg5').set('windowtitle', 'Graphics');
model.result('pg6').set('windowtitle', 'Probe Plot 3');
model.result('pg7').set('windowtitle', 'Probe Plot 4');

model.probe('pdom1').setIndex('coords2', '0.01', 0, 1);
model.probe('pdom2').setIndex('coords2', '2.54+0.01', 0, 1);
model.probe('pdom3').setIndex('coords2', '2.54+5.08+0.01', 0, 1);
model.probe('pdom4').setIndex('coords2', '2.54+5.08+2.54-0.01', 0, 1);
model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;

model.probe('pdom4').set('coords', [1.9633637 10.5580406]);
model.probe('pdom4').setIndex('coords2', '2.54', 0, 0);
model.probe('pdom4').setIndex('coords2', '2.54+5.08+2.54-0.01', 0, 1);
model.probe('pdom4').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl4');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg7').feature('tblp1').set('plotcolumns', [2]);
model.result('pg7').run;

model.probe('pdom3').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl3');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg6').feature('tblp1').set('plotcolumns', [2]);
model.result('pg6').run;

model.probe('pdom2').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl2');
```

```
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;

model.probe('pdom1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;
model.result.export.create('tbl1', 'tbl1', 'Table');
model.result.export.create('tbl2', 'tbl2', 'Table');
model.result.export.create('tbl3', 'tbl3', 'Table');
model.result.export.create('tbl4', 'tbl4', 'Table');
model.result.export.create('anim1', 'Animation');
model.result.export('anim1').set('height', '480');
model.result.export('anim1').set('width', '640');
model.result.export('anim1').set('lockratio', 'off');
model.result.export('anim1').set('resolution', '96');
model.result.export('anim1').set('size', 'manual');
model.result.export('anim1').set('antialias', 'off');
model.result.export('anim1').set('title', 'on');
model.result.export('anim1').set('legend', 'on');
model.result.export('anim1').set('logo', 'on');
model.result.export('anim1').set('options', 'on');
model.result.export('anim1').set('fontsize', '12');
model.result.export('anim1').set('customcolor', [1 1 1]);
model.result.export('anim1').set('background', 'color');
model.result.export('anim1').set('axisorientation', 'on');
model.result.export('anim1').set('grid', 'on');
model.result.export('anim1').set('axes', 'on');
model.result('pg1').set('window', 'graphics');
model.result('pg1').run;
model.result('pg1').set('window', 'graphics');
model.result('pg1').set('windowtitle', 'Graphics');
model.result.export('anim1').set('type', 'imageseq');
model.result.export('anim1').set('imagefilename',
'C:\Users\gfreeman501\Desktop\GLCC Heat flow.png');
model.result.export('anim1').set('maxframes', '100');
model.result.export('anim1').set('lockratio', 'on');
model.result('pg1').set('window', 'graphics');
model.result('pg1').run;
model.result('pg1').set('window', 'graphics');
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg1').run;
model.result.export('tbl1').set('filename',
'C:\Users\gfreeman501\Desktop\Temp data 1.csv');
model.result.export('tbl2').set('filename',
'C:\Users\gfreeman501\Desktop\Temp data 2.csv');
```

```
model.result.export('tbl3').set('filename',
'C:\Users\gfreeman501\Desktop\Temp data 3.csv');
model.result.export('tbl4').set('filename',
'C:\Users\gfreeman501\Desktop\Temp data 4.csv');
model.result.export('tbl1').run;
model.result.export('tbl2').run;
model.result.export('tbl3').run;
model.result.export('tbl4').run;
model.result.export('anim1').run;
model.result('pg1').set('window', 'graphics');
model.result('pg1').run;
model.result('pg1').set('window', 'graphics');
model.result('pg1').set('windowtitle', 'Graphics');
model.result.export('anim1').active(false);

model.physics('ht2').feature('bhs1').set('heatSourceType', 1,
'generalSource');
model.physics('ht2').feature('bhs1').set('heatSourceType', 1,
'TotalBoundaryPower');
model.physics('ht2').feature('bhs1').set('heatSourceType', 1,
'TotalBoundaryPower');
model.physics('ht2').feature('bhs1').set('heatSourceType', 1,
'generalSource');
model.physics('ht2').feature('bhs1').set('Qb', 1, '250');

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;

model.probe('pdom1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;

model.probe('pdom2').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl2');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;

model.probe('pdom3').genResult('sol1');
```

```
model.result.numerical('pev2').set('table', 'tbl3');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg6').feature('tblp1').set('plotcolumns', [2]);
model.result('pg6').run;

model.probe('pdom4').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl4');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg7').feature('tblp1').set('plotcolumns', [2]);
model.result('pg7').run;
model.result('pg7').set('window', 'window4');
model.result('pg7').set('windowtitle', 'Probe Plot 4');
model.result('pg7').run;

model.material('mat2').propertyGroup('def').set('thermalconductivity',
{'1.65'});

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;

model.probe('pdom1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;

model.probe('pdom2').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl2');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;

model.probe('pdom3').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl3');
```

```
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg6').feature('tblp1').set('plotcolumns', [2]);
model.result('pg6').run;

model.probe('pdom4').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl4');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg7').feature('tblp1').set('plotcolumns', [2]);
model.result('pg7').run;
model.result('pg3').set('window', 'window1');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg3').run;
model.result('pg4').set('window', 'window2');
model.result('pg4').run;
model.result('pg6').set('window', 'window3');
model.result('pg6').set('windowtitle', 'Probe Plot 3');
model.result('pg6').run;
model.result('pg7').set('window', 'window4');
model.result('pg7').set('windowtitle', 'Probe Plot 4');
model.result('pg7').run;
model.result('pg1').set('window', 'graphics');
model.result('pg1').run;
model.result('pg1').set('window', 'graphics');
model.result('pg1').set('windowtitle', 'Graphics');
model.result.export('anim1').set('type', 'movie');
model.result.export('anim1').set('giffilename',
'C:\Users\gfreeman501\Desktop\Gif.gif');
model.result.export('anim1').active(true);
model.result.export('tbl1').run;
model.result.export('tbl2').run;
model.result.export('tbl3').run;
model.result.export('tbl4').run;
model.result.export('anim1').run;

model.physics('ht2').feature('chf1').selection.set([1 3 5 7 8 9 10]);

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;

model.probe('pdom1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
```

```
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;

model.probe('pdom2').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl2');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;

model.probe('pdom2').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl2');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;

model.probe('pdom3').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl3');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg6').feature('tblp1').set('plotcolumns', [2]);
model.result('pg6').run;

model.probe('pdom4').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl4');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg7').feature('tblp1').set('plotcolumns', [2]);
model.result('pg7').run;

model.study('std1').feature('time').set('tlist', 'range(0,60,1080*60)');

model.result('pg7').set('window', 'window4');
model.result('pg7').set('windowtitle', 'Probe Plot 4');
model.result('pg7').run;
model.result('pg6').set('window', 'window3');
model.result('pg6').set('windowtitle', 'Probe Plot 3');
model.result('pg6').run;
model.result.export('tbl1').run;
model.result.export('tbl2').run;
model.result.export('tbl3').run;
model.result.export('tbl4').run;
```

```
model.result.export('anim1').run;

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;

model.probe('pdom1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;

model.probe('pdom2').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl2');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;

model.probe('pdom3').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl3');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg6').feature('tblp1').set('plotcolumns', [2]);
model.result('pg6').run;

model.probe('pdom4').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl4');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg7').feature('tblp1').set('plotcolumns', [2]);
model.result('pg7').run;
model.result('pg7').set('window', 'window4');
model.result('pg7').set('windowtitle', 'Probe Plot 4');
model.result('pg7').run;
model.result.export('tbl1').run;
model.result.export('tbl2').run;
model.result.export('tbl3').run;
model.result.export('tbl4').run;
```

```
model.result.export('anim1').run;

model.material.create('mat4');
model.material('mat2').propertyGroup('def').set('thermalconductivity',
{});
model.material.create('mat5');
model.material('mat5').name('Concrete [solid,dry] (2)');
model.material('mat5').set('family', 'concrete');
model.material('mat5').propertyGroup('def').set('thermalconductivity',
'k_solid_dry_1(T[1/K])[W/(m*K)]');
model.material('mat5').propertyGroup('def').set('TD',
'TD_solid_dry_1(T[1/K])[m^2/s]');
model.material('mat5').propertyGroup('def').func.create('k_solid_dry_1',
'Piecewise');
model.material('mat5').propertyGroup('def').func('k_solid_dry_1').set('fun
cname', 'k_solid_dry_1');
model.material('mat5').propertyGroup('def').func('k_solid_dry_1').set('arg
', 'T');
model.material('mat5').propertyGroup('def').func('k_solid_dry_1').set('ext
rap', 'constant');
model.material('mat5').propertyGroup('def').func('k_solid_dry_1').set('pie
ces', {'253.0' '363.0' '26.91105-0.2477056*T^1+8.606168E-4*T^2-1.00482E-
6*T^3'});
model.material('mat5').propertyGroup('def').func.create('TD_solid_dry_1',
'Piecewise');
model.material('mat5').propertyGroup('def').func('TD_solid_dry_1').set('fu
ncname', 'TD_solid_dry_1');
model.material('mat5').propertyGroup('def').func('TD_solid_dry_1').set('ar
g', 'T');
model.material('mat5').propertyGroup('def').func('TD_solid_dry_1').set('ex
trap', 'constant');
model.material('mat5').propertyGroup('def').func('TD_solid_dry_1').set('pi
eces', {'253.0' '363.0' '-1.361995E-4+1.854099E-6*T^1-9.285239E-
9*T^2+2.050095E-11*T^3-1.68777E-14*T^4'});
model.material('mat5').propertyGroup('def').addInput('temperature');
model.material('mat5').set('family', 'concrete');
model.material('mat2').propertyGroup('def').set('thermalconductivity',
{'k_solid_dry_1(T[1/K])[W/(m*K)]'});
model.material.remove('mat4');
model.material.remove('mat5');

model.name('Heat_Convention 2D_ GLCC_air.mph');

model.physics('ht2').feature.duplicate('chf2', 'chf1');
model.physics('ht2').feature('chf2').set('h', 1, '0.4');
model.physics('ht2').feature('chf2').selection.set([1 3 5 8 9 10]);
model.physics('ht2').feature('chf1').selection.set([7]);
model.physics('ht2').feature('chf1').set('h', 1, '10');
model.physics('ht2').feature('chf1').set('h', 1, '5');

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
```

```
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;

model.probe('pdom4').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl4');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg7').feature('tblp1').set('plotcolumns', [2]);
model.result('pg7').run;

model.probe('pdom3').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl3');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg6').feature('tblp1').set('plotcolumns', [2]);
model.result('pg6').run;

model.probe('pdom2').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl2');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;

model.probe('pdom1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;
model.result('pg3').set('window', 'window1');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg3').run;

model.probe('pdom2').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl2');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;
model.result('pg4').set('window', 'window2');
```

```
model.result('pg4').run;

model.probe('pdom3').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl3');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg6').feature('tblp1').set('plotcolumns', [2]);
model.result('pg6').run;
model.result('pg6').set('window', 'window3');
model.result('pg6').set('windowtitle', 'Probe Plot 3');
model.result('pg6').run;

model.probe('pdom4').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl4');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg7').feature('tblp1').set('plotcolumns', [2]);
model.result('pg7').run;
model.result('pg7').set('window', 'window4');
model.result('pg7').set('windowtitle', 'Probe Plot 4');
model.result('pg7').run;
model.result.export('tbl1').run;
model.result.export('tbl2').run;
model.result.export('tbl3').run;
model.result.export('tbl4').run;
model.result.export('anim1').run;

model.material('mat2').propertyGroup('def').set('heatcapacity', {'880'});

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;

model.probe('pdom1').feature('ppb1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;

model.probe('pdom2').genResult('sol1');
```

```
model.result.numerical('pev2').set('table', 'tbl2');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;

model.probe('pdom3').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl3');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg6').feature('tblp1').set('plotcolumns', [2]);
model.result('pg6').run;

model.probe('pdom4').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl4');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg7').feature('tblp1').set('plotcolumns', [2]);
model.result('pg7').run;
model.result('pg3').set('window', 'window1');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg3').run;
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg4').set('windowtitle', 'Probe Plot 2');
model.result('pg5').set('windowtitle', 'Graphics');
model.result('pg6').set('windowtitle', 'Probe Plot 3');
model.result('pg7').set('windowtitle', 'Probe Plot 4');
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg4').set('windowtitle', 'Probe Plot 2');
model.result('pg5').set('windowtitle', 'Graphics');
model.result('pg6').set('windowtitle', 'Probe Plot 3');
model.result('pg7').set('windowtitle', 'Probe Plot 4');
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg4').set('windowtitle', 'Probe Plot 2');
model.result('pg5').set('windowtitle', 'Graphics');
model.result('pg6').set('windowtitle', 'Probe Plot 3');
model.result('pg7').set('windowtitle', 'Probe Plot 4');
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg4').set('windowtitle', 'Probe Plot 2');
model.result('pg5').set('windowtitle', 'Graphics');
model.result('pg6').set('windowtitle', 'Probe Plot 3');
```

```
model.result('pg7').set('windowtitle', 'Probe Plot 4');
model.result('pg4').set('window', 'window2');
model.result('pg4').set('windowtitle', 'Probe Plot 2');
model.result('pg4').run;
model.result('pg3').set('window', 'window1');
model.result('pg3').run;
model.result('pg4').set('window', 'window2');
model.result('pg4').set('windowtitle', 'Probe Plot 2');
model.result('pg4').run;
model.result('pg3').set('window', 'window1');
model.result('pg3').run;

model.probe('pdom3').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl3');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg6').feature('tblp1').set('plotcolumns', [2]);
model.result('pg6').run;
model.result('pg6').set('window', 'window3');
model.result('pg6').set('windowtitle', 'Probe Plot 3');
model.result('pg6').run;

model.material.create('mat4');
model.material('mat4').name('Concrete [solid,moist]');
model.material('mat4').set('family', 'concrete');
model.material('mat4').propertyGroup('def').set('thermalconductivity',
'k_solid_moist_2(T[1/K])[W/(m*K)]');
model.material('mat4').propertyGroup('def').set('TD',
'TD_solid_moist_2(T[1/K])[m^2/s]');
model.material('mat4').propertyGroup('def').func.create('k_solid_moist_2',
'Piecewise');
model.material('mat4').propertyGroup('def').func('k_solid_moist_2').set('f
uncname', 'k_solid_moist_2');
model.material('mat4').propertyGroup('def').func('k_solid_moist_2').set('a
rg', 'T');
model.material('mat4').propertyGroup('def').func('k_solid_moist_2').set('e
xtrap', 'constant');
model.material('mat4').propertyGroup('def').func('k_solid_moist_2').set('p
ieces', {'253.0' '363.0' '-246.3297+3.404357*T^1-0.01724425*T^2+3.852432E-
5*T^3-3.207617E-8*T^4'});
model.material('mat4').propertyGroup('def').func.create('TD_solid_moist_2'
, 'Piecewise');
model.material('mat4').propertyGroup('def').func('TD_solid_moist_2').set('
funcname', 'TD_solid_moist_2');
model.material('mat4').propertyGroup('def').func('TD_solid_moist_2').set('
arg', 'T');
model.material('mat4').propertyGroup('def').func('TD_solid_moist_2').set('
extrap', 'constant');
model.material('mat4').propertyGroup('def').func('TD_solid_moist_2').set('
pieces', {'253.0' '363.0' '-8.97668E-5+1.24853E-6*T^1-6.327544E-
9*T^2+1.408131E-11*T^3-1.16532E-14*T^4'});
model.material('mat4').propertyGroup('def').addInput('temperature');
```

```
model.material('mat4').set('family', 'concrete');
model.material('mat4').propertyGroup('def').set('heatcapacity', {'1.37'});
model.material.move('mat4', 2);
model.material('mat4').selection.set([2]);
model.material('mat2').active(false);

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.material('mat4').propertyGroup('def').set('density', {'2400'});
model.material('mat4').propertyGroup('def').set('ratioofspecificheat',
{'880/4179'});

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.physics('ht').active(true);
model.physics('ht2').active(false);
model.physics('ht2').feature.duplicate('chf3', 'chf2');
model.physics('ht2').feature.remove('chf3');
model.physics('ht').feature('temp1').set('T0', 1, 'pw1(t)');
model.physics('ht').feature.remove('hf1');
model.physics('ht').feature.remove('hf2');
model.physics('ht2').active(true);
model.physics('ht').feature.create('bhs1', 'BoundaryHeatSource', 1);
model.physics('ht').feature('bhs1').selection.set([2]);
model.physics('ht').feature('bhs1').set('Qb', 1, '250');
model.physics('ht').feature.create('chf1', 'ConvectiveHeatFlux', 1);
model.physics('ht').feature('chf1').selection.set([7]);
model.physics('ht').feature('chf1').set('h', 1, '5');
model.physics('ht').feature.create('chf2', 'ConvectiveHeatFlux', 1);
model.physics('ht').feature('chf2').set('h', 1, '0.3');
model.physics('ht').feature('chf2').selection.set([1 3 5 8 9 10]);
model.physics('ht2').active(false);

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.mesh('mesh1').feature('size').set('hauto', '3');
model.mesh('mesh1').run;

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
```

```
model.probe('pdom4').genResult('none');

model.sol('sol1').feature('t1').set('maxstepgenalpha', '60');
model.sol('sol1').feature('t1').set('maxstepgenalphaactive', 'off');

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.probe('pdom1').feature('ppb1').set('expr', 'T');
model.probe('pdom1').feature('ppb1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;

model.probe('pdom2').feature('ppb1').set('expr', 'T');
model.probe('pdom2').feature('ppb1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl2');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;

model.probe('pdom3').feature('ppb1').set('expr', 'T');
model.probe('pdom3').feature('ppb1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl3');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg6').feature('tblp1').set('plotcolumns', [2]);
model.result('pg6').run;

model.probe('pdom4').feature('ppb1').set('expr', 'T');
model.probe('pdom4').feature('ppb1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl4');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg7').feature('tblp1').set('plotcolumns', [2]);
model.result('pg7').run;
model.result('pg7').set('window', 'window4');
model.result('pg7').set('windowtitle', 'Probe Plot 4');
```

```
model.result('pg7').run;

model.sol('sol1').feature('t1').set('maxstepgenalphaactive', 'on');

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').set('allowtableupdate', true);
model.result('pg1').set('renderdatacached', true);

model.physics.move('ht', 1);

model.probe('pdom1').feature('ppb1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;
model.result('pg3').set('window', 'window1');
model.result('pg3').run;

model.probe('pdom2').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl2');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;
model.result('pg4').set('window', 'window2');
model.result('pg4').set('windowtitle', 'Probe Plot 2');
model.result('pg4').run;
model.result('pg5').run;
model.result('pg6').set('window', 'window3');
model.result('pg6').set('windowtitle', 'Probe Plot 3');
model.result('pg6').run;
model.result('pg6').set('window', 'window3');
model.result('pg6').set('windowtitle', 'Probe Plot 3');
model.result('pg6').run;
model.result('pg6').set('window', 'window3');
model.result('pg6').set('windowtitle', 'Probe Plot 3');
model.result('pg6').run;

model.probe('pdom3').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl3');
model.result.numerical('pev2').set('innerinput', 'all');
```

```
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg6').feature('tblp1').set('plotcolumns', [2]);
model.result('pg6').run;
model.result('pg6').set('window', 'window3');
model.result('pg6').set('windowtitle', 'Probe Plot 3');
model.result('pg6').run;
model.result('pg1').set('window', 'graphics');
model.result('pg1').run;
model.result('pg1').set('window', 'graphics');
model.result('pg1').set('windowtitle', 'Graphics');

model.probe('pdom1').feature('ppb1').set('expr', 'T3');
model.probe('pdom2').feature('ppb1').set('expr', 'T3');
model.probe('pdom3').feature('ppb1').set('expr', 'T3');
model.probe('pdom4').feature('ppb1').set('expr', 'T3');

model.name('Heat_Convention 2D_ GLCC_air.mph');

model.probe('pdom4').feature('ppb1').set('descractive', 'off');

model.physics.move('ht', 0);
model.physics('ht2').active(true);
model.physics('ht').active(false);
model.physics('ht2').feature('solid1').selection.set([1 2 3]);
model.physics('ht2').feature('porous1').feature.create('disp1',
'ThermalDispersion', 2);
model.physics('ht2').feature('porous1').feature.remove('disp1');

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;

model.probe('pdom1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;
model.result('pg3').set('window', 'window1');
model.result('pg3').run;

model.probe('pdom2').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl2');
model.result.numerical('pev2').set('innerinput', 'all');
```

```
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;
model.result('pg4').set('window', 'window2');
model.result('pg4').set('windowtitle', 'Probe Plot 2');
model.result('pg4').run;

model.probe('pdom1').feature('ppb1').set('unit', 'degC');
model.probe('pdom2').feature('ppb1').set('unit', 'degC');
model.probe('pdom3').feature('ppb1').set('unit', 'degC');
model.probe('pdom4').feature('ppb1').set('unit', 'kK');
model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;

model.probe('pdom1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;
model.result('pg3').set('window', 'window1');
model.result('pg3').run;

model.probe('pdom2').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl2');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;
model.result('pg4').set('window', 'window2');
model.result('pg4').set('windowtitle', 'Probe Plot 2');
model.result('pg4').run;

model.probe('pdom3').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl3');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg6').feature('tblp1').set('plotcolumns', [2]);
model.result('pg6').run;
model.result('pg6').set('window', 'window3');
```

```
model.result('pg6').set('windowtitle', 'Probe Plot 3');
model.result('pg6').run;

model.probe('pdom2').feature('ppb1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl2');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;
model.result('pg4').set('window', 'window2');
model.result('pg4').set('windowtitle', 'Probe Plot 2');
model.result('pg4').run;
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 1');
model.result('pg4').set('windowtitle', 'Probe Plot 2');
model.result('pg5').set('windowtitle', 'Graphics');
model.result('pg6').set('windowtitle', 'Probe Plot 3');
model.result('pg7').set('windowtitle', 'Probe Plot 4');

model.probe('pdom4').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl4');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg7').feature('tblp1').set('plotcolumns', [2]);
model.result('pg7').run;
model.result('pg7').set('window', 'window4');
model.result('pg7').set('windowtitle', 'Probe Plot 4');
model.result('pg7').run;

model.probe('pdom4').feature('ppb1').set('unit', 'degC');
model.probe('pdom4').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl4');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg7').feature('tblp1').set('plotcolumns', [2]);
model.result('pg7').run;
model.result('pg1').set('window', 'graphics');
model.result('pg1').run;
model.result('pg1').set('window', 'graphics');
model.result('pg1').set('windowtitle', 'Graphics');
model.result.export('tbl1').run;
model.result.export('tbl2').run;
model.result.export('tbl3').run;
model.result.export('tbl4').run;
model.result.export('anim1').run;
model.result('pg7').set('window', 'window4');
model.result('pg7').set('windowtitle', 'Probe Plot 4');
```

```
model.result('pg7').run;

model.material('mat4').propertyGroup('def').set('ratioofspecificheat',
{'4190/880'});

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;

model.probe('pdom1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;
model.result('pg3').set('window', 'window1');
model.result('pg3').run;

model.probe('pdom2').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl2');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;
model.result('pg4').set('window', 'window2');
model.result('pg4').set('windowtitle', 'Probe Plot 2');
model.result('pg4').run;

model.probe('pdom3').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl3');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg6').feature('tblp1').set('plotcolumns', [2]);
model.result('pg6').run;
model.result('pg6').set('window', 'window3');
model.result('pg6').set('windowtitle', 'Probe Plot 3');
model.result('pg6').run;

model.material('mat4').propertyGroup('def').set('heatcapacity', {'750'});

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
```

```
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;

model.probe('pdom1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;
model.result('pg3').set('window', 'window1');
model.result('pg3').run;

model.probe('pdom2').feature('ppb1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl2');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;
model.result('pg4').set('window', 'window2');
model.result('pg4').set('windowtitle', 'Probe Plot 2');
model.result('pg4').run;

model.probe('pdom3').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl3');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg6').feature('tblp1').set('plotcolumns', [2]);
model.result('pg6').run;
model.result('pg6').set('window', 'window3');
model.result('pg6').set('windowtitle', 'Probe Plot 3');
model.result('pg6').run;

model.probe('pdom4').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl4');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg7').feature('tblp1').set('plotcolumns', [2]);
model.result('pg7').run;
model.result('pg7').set('window', 'window4');
model.result('pg7').set('windowtitle', 'Probe Plot 4');
model.result('pg7').run;
```

```
model.result.export('tbl1').run;
model.result.export('tbl2').run;
model.result.export('tbl3').run;
model.result.export('tbl4').run;
model.result.export('anim1').run;
model.result('pg1').set('window', 'graphics');
model.result('pg1').run;
model.result('pg1').set('window', 'graphics');
model.result('pg1').set('windowtitle', 'Graphics');

model.material.remove('mat3');

model.selection.create('sel2');
model.selection('sel2').geom(2);
model.selection('sel2').name('Concrete');
model.selection('sel2').set([2]);

model.material('mat4').selection.named('sel2');

model.name('Heat_Convention 2D_ GLCC_air.mph');

model.geom('geom1').run('uni1');
model.geom('geom1').feature.create('r3', 'Rectangle');
model.geom('geom1').feature('r3').setIndex('size', '2.54', 0);
model.geom('geom1').feature('r3').setIndex('size', '2.54*4', 1);
model.geom('geom1').feature('r3').setIndex('pos', '-2.54', 0);
model.geom('geom1').run('r3');
model.geom('geom1').feature.duplicate('r4', 'r3');
model.geom('geom1').feature('r4').setIndex('pos', '2.54*2', 0);
model.geom('geom1').run('r4');
model.geom('geom1').run;

model.material.remove('mat2');

model.geom('geom1').feature.move('uni1', 4);
model.geom('geom1').feature.move('uni1', 5);
model.geom('geom1').runAll;
model.geom('geom1').run;

model.material.create('mat5');
model.material('mat5').name('Polystyrene (PS) [solid]');
model.material('mat5').propertyGroup('def').set('TD',
'TD(T[1/K])[m^2/s]');
model.material('mat5').propertyGroup('def').func.create('TD',
'Piecewise');
model.material('mat5').propertyGroup('def').func('TD').set('funcname',
'TD');
model.material('mat5').propertyGroup('def').func('TD').set('arg', 'T');
model.material('mat5').propertyGroup('def').func('TD').set('extrap',
'constant');
model.material('mat5').propertyGroup('def').func('TD').set('pieces',
{'295.0' '377.0' '6.605162E-7-2.866361E-9*T^1+3.645033E-12*T^2'});
model.material('mat5').propertyGroup('def').addInput('temperature');
model.material('mat5').propertyGroup('def').set('density', '');
```

```
model.material('mat5').propertyGroup('def').set('heatcapacity', '');
model.material('mat5').propertyGroup('def').set('density', {'1050'});
model.material('mat5').propertyGroup('def').set('heatcapacity',
{'0.028456'});
model.material('mat5').selection.set([1 5]);

model.physics('ht2').feature('bhs1').selection.set([2 5 12]);

model.material('mat5').propertyGroup('def').set('ratioofspecificheat',
{'1/1'});
model.material('mat5').propertyGroup('def').set('heatcapacity', {});
model.material('mat5').propertyGroup('def').set('thermalconductivity',
{'0.028456'});

model.func.create('an1', 'Analytic');
model.func('an1').model('mod1');
model.func('an1').set('expr', 'PolyCp');
model.func('an1').set('funcname', 'PolyCp');
model.func('an1').set('args', 'T');
model.func('an1').set('expr', '');
model.func('an1').set('argunit', 'K');
model.func('an1').set('fununit', 'J/(mol*K)');
model.func('an1').set('expr', '(7.7551*10^5*T^2+0.53447*T-41.58)');

model.material('mat5').propertyGroup('def').set('heatcapacity',
{'PolyCp[J/(mol*K)]'});

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');
model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.func('an1').setIndex('plotargs', '240', 0, 1);
model.func('an1').setIndex('plotargs', '200', 0, 1);
model.func('an1').setIndex('plotargs', '350', 0, 2);

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.material('mat5').propertyGroup('def').set('heatcapacity',
{'PolyCp'});

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
```

```
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.func('an1').set('expr', '(7.7551*10^5*T^2+0.53447*T-41.58)*.1051');
model.func('an1').set('fununit', 'J/(kg*K)');

model.sol('sol1').updateSolution;

model.result('pg1').run;

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.physics('ht2').feature('chf1').selection.set([1 3 10 15 16]);
model.physics('ht2').feature('solid1').selection.set([1 2 3 4 5]);
model.physics('ht2').feature('temp1').selection.set([2 5 12]);

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.func('an1').set('expr', '(7.7551*10^5*T^2+0.53447*T-41.58)');
model.func('an1').set('fununit', 'J/(mol*K)');
model.func('an1').set('expr', '(7.7551*10^5*T^2+0.53447*T-41.58)*.1051');
model.func('an1').set('fununit', 'J/(kg*K)');

model.variable('var1').set('PolyCp', 'an1(');
model.variable('var1').remove('PolyCp');

model.material('mat5').propertyGroup('def').set('heatcapacity',
{'PolyCp(T3)'});

model.physics('ht2').feature('chf1').set('h', 1, '2');
model.physics('ht2').feature('init1').set('T3', 1, '296.15[K]');
model.physics('ht2').feature.create('porous2', 'PorousHeatTransferModel',
2);
model.physics('ht2').feature.remove('porous2');
model.physics('ht2').feature('porous1').feature.create('disp1',
'ThermalDispersion', 2);

model.mesh('mesh1').feature('size').set('hauto', '4');
model.mesh('mesh1').feature('map1').set('smoothcontrol', 'off');
model.mesh('mesh1').run;
model.mesh.remove('mesh1');
model.mesh.create('mesh1', 'geom1');
model.mesh('mesh1').run;
model.mesh('mesh1').autoMeshSize(4);
model.mesh('mesh1').run;
```

```
model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg1').run;

model.probe('pdom1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;
model.result('pg3').set('window', 'window1');
model.result('pg3').run;

model.probe('pdom2').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl2');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;
model.result('pg4').set('window', 'window2');
model.result('pg4').set('windowtitle', 'Probe Plot 2');
model.result('pg4').run;
model.result('pg3').set('window', 'window1');
model.result('pg3').run;
model.result.remove('pg3');
model.result.remove('pg4');
model.result.remove('pg5');
model.result.remove('pg6');
model.result.remove('pg7');
model.result.table.clear;
model.result.table.clear;

model.probe('pdom3').feature('ppb1').set('window', 'default');
model.probe('pdom2').feature('ppb1').set('window', 'default');
model.probe('pdom1').feature('ppb1').set('window', 'default');
model.probe('pdom4').feature('ppb1').set('window', 'default');
model.probe('bnd1').genResult('sol1');
model.probe('pdom1').genResult('sol1');
model.probe('pdom2').genResult('sol1');
model.probe('pdom3').genResult('sol1');
model.probe('pdom4').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl1');
```

```
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');

model.sol('sol1').updateSolution;

model.probe('bnd1').genResult('sol1');
model.probe('pdom1').genResult('sol1');
model.probe('pdom2').genResult('sol1');
model.probe('pdom3').genResult('sol1');
model.probe('pdom4').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl1');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');

model.probe('bnd1').active(false);
model.probe('pdom1').genResult('sol1');
model.probe('pdom2').genResult('sol1');
model.probe('pdom3').genResult('sol1');
model.probe('pdom4').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;
model.result.table.create('tbl2', 'Table');
model.result.table.remove('tbl1');

model.probe('pdom1').feature('ppb1').set('table', 'tbl2');
model.probe('pdom2').feature('ppb1').set('table', 'tbl2');
model.probe('pdom3').feature('ppb1').set('table', 'tbl2');
model.probe('pdom4').feature('ppb1').set('table', 'tbl2');
model.probe('pdom1').genResult('sol1');
model.probe('pdom2').genResult('sol1');
model.probe('pdom3').genResult('sol1');
model.probe('pdom4').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl2');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;

model.probe('pdom1').feature('ppb1').set('window', 'window1');
model.probe('pdom2').feature('ppb1').set('table', 'default');
model.probe('pdom3').feature('ppb1').set('table', 'default');
model.probe('pdom1').feature('ppb1').set('window', 'default');
model.probe('pdom1').feature('ppb1').set('table', 'default');
model.probe('pdom2').feature('ppb1').set('window', 'default');
model.probe('pdom3').feature('ppb1').set('window', 'default');
```

```
model.sol('sol1').clearSolution;

model.result('pg2').run;
model.result.dataset.remove('pw1_ds1');
model.result.dataset.remove('pw1_ds2');
model.result.dataset.remove('pw1_ds3');
model.result.dataset.remove('dset1');
model.result.dataset.remove('dset2');
model.result.dataset.remove('dset3');
model.result.table.remove('tbl2');

model.sol('sol1').feature('t1').set('maxstepgenalpha', '60*4');

model.result.dataset.create('dset1', 'Solution');
model.result.dataset('dset1').set('solution', 'sol1');
model.result.create('pg1', 'PlotGroup2D');
model.result('pg1').name('Temperature (ht2)');
model.result('pg1').set('oldanalysistype', 'noneavailable');
model.result('pg1').set('data', 'dset1');
model.result('pg1').feature.create('surf1', 'Surface');
model.result('pg1').feature('surf1').name('Surface');
model.result('pg1').feature('surf1').set('oldanalysistype',
'noneavailable');
model.result('pg1').feature('surf1').set('colortable', 'ThermalLight');
model.result('pg1').feature('surf1').set('data', 'parent');
model.result.create('pg2', 'PlotGroup2D');
model.result('pg2').name('Isothermal Contours (ht2)');
model.result('pg2').set('oldanalysistype', 'noneavailable');
model.result('pg2').set('data', 'dset1');
model.result('pg2').feature.create('con1', 'Contour');
model.result('pg2').feature('con1').name('Contour');
model.result('pg2').feature('con1').set('oldanalysistype',
'noneavailable');
model.result('pg2').feature('con1').set('colortable', 'ThermalLight');
model.result('pg2').feature('con1').set('data', 'parent');
model.result('pg2').feature.create('arws1', 'ArrowSurface');
model.result('pg2').feature('arws1').name('Arrow surface');
model.result('pg2').feature('arws1').set('oldanalysistype',
'noneavailable');
model.result('pg2').feature('arws1').set('color', 'gray');
model.result('pg2').feature('arws1').set('data', 'parent');

model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');
model.probe('pdom1').feature('ppb1').set('table', 'default');
model.probe('pdom1').feature('ppb1').set('window', 'default');
model.probe('pdom2').feature('ppb1').set('table', 'default');
model.probe('pdom2').feature('ppb1').set('window', 'default');
model.probe('pdom3').feature('ppb1').set('table', 'default');
model.probe('pdom3').feature('ppb1').set('window', 'default');
model.probe('pdom4').feature('ppb1').set('table', 'default');
model.probe('pdom4').feature('ppb1').set('window', 'default');
```

```
model.result.table.remove('tbl1');

model.probe('pdom2').feature('ppb1').name('Point Probe Expression 2');
model.probe('pdom3').feature('ppb1').name('Point Probe Expression 3');
model.probe('pdom4').feature('ppb1').name('Point Probe Expression 4\');
model.probe('pdom4').feature('ppb1').name('Point Probe Expression 4');

model.mesh('mesh1').autoMeshSize(5);
model.mesh('mesh1').run;

model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result.table.remove('tbl1');

model.probe('pdom1').genResult('sol1');
model.probe('pdom2').genResult('sol1');
model.probe('pdom3').genResult('sol1');
model.probe('pdom4').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl1');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');
model.result.numerical('pev1').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;
model.result.table.create('tbl2', 'Table');
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 7');
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 7');
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 7');
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 7');
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 7');

model.probe('pdom1').feature('ppb1').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl1');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');
```

```
model.result.numerical('pev1').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;
model.result('pg3').set('window', 'window7');
model.result('pg3').set('windowtitle', 'Probe Plot 7');
model.result('pg3').run;

model.probe('pdom2').feature('ppb1').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl1');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');
model.result.numerical('pev1').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;
model.result('pg3').set('window', 'window7');
model.result('pg3').set('windowtitle', 'Probe Plot 7');
model.result('pg3').run;
model.result('pg3').feature('tblp1').set('table', 'tbl1');

model.probe('pdom1').feature('ppb1').set('window', 'new');
model.probe('pdom2').feature('ppb1').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl1');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');
model.result.numerical('pev1').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;
model.result('pg3').set('window', 'window7');
model.result('pg3').set('windowtitle', 'Probe Plot 7');
model.result('pg3').run;

model.probe('pdom3').feature('ppb1').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl1');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');
model.result.numerical('pev1').setResult;
model.result('pg3').feature('tblp1').set('plotcolumns', [2]);
model.result('pg3').run;
model.result('pg3').set('window', 'window7');
model.result('pg3').set('windowtitle', 'Probe Plot 7');
model.result('pg3').run;

model.physics('ht2').feature('porous1').feature('disp1').active(false);
model.physics('ht2').feature('porous1').feature.remove('disp1');

model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').feature('t1').set('maxstepgenalpha', '60*2');
```

```
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;

model.func('an1').set('expr', '(7.7551*10^5*T^-2+0.53447*T-41.58)*.1051');

model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg1').setIndex('looplevel', '635', 0);
model.result('pg1').run;

model.material('mat5').propertyGroup('def').set('heatcapacity',
{'1.3*1000'});

model.result('pg3').set('window', 'window7');
model.result('pg3').set('windowtitle', 'Probe Plot 7');
model.result('pg3').run;

model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg3').set('window', 'window7');
model.result('pg3').set('windowtitle', 'Probe Plot 7');
model.result('pg3').run;

model.physics('ht2').feature('chf1').set('Text', 1, '296.15[K]');
model.physics('ht2').feature('chf2').active(false);

model.result('pg3').set('window', 'window7');
model.result('pg3').set('windowtitle', 'Probe Plot 7');
model.result('pg3').run;
model.result.export.create('tbl1', 'Table');

model.probe('pdom2').feature('ppb1').set('table', 'new');
model.probe('pdom3').feature('ppb1').set('table', 'new');
model.probe('pdom4').feature('ppb1').set('table', 'new');
model.probe('pdom4').feature('ppb1').genResult('sol1');
```

```
model.result.numerical('pev1').set('table', 'tbl3');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');
model.result.numerical('pev1').setResult;
model.result('pg3').feature('tblp2').set('plotcolumns', [2]);
model.result('pg3').run;

model.probe('pdom3').feature('ppb1').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl4');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');
model.result.numerical('pev1').setResult;
model.result('pg3').feature('tblp3').set('plotcolumns', [2]);
model.result('pg3').run;

model.probe('pdom2').feature('ppb1').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl5');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');
model.result.numerical('pev1').setResult;
model.result('pg3').feature('tblp4').set('plotcolumns', [2]);
model.result('pg3').run;

model.probe('pdom1').feature('ppb1').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl1');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');
model.result.numerical('pev1').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;
model.result.export.duplicate('tbl2', 'tbl1');
model.result.export.duplicate('tbl3', 'tbl1');
model.result.export.duplicate('tbl4', 'tbl2');

model.physics('ht2').feature.create('sar2', 'SurfaceToAmbientRadiation',
1);
model.physics('ht2').feature('sar2').selection.set([1 3 10 15 16]);
model.physics('ht2').feature('sar2').set('Tamb', 1, '296.15[K]');

model.material.create('mat6');
model.material('mat6').name('Tape');
model.material('mat6').propertyGroup('def').set('emissivity', {'0.9'});
model.material('mat6').selection.geom('geom1', 1);
model.material('mat6').selection.set([1 3 10 15 16]);

model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');
```

```
model.physics('ht2').feature('sar2').selection.set([1 2 3 5 10 12 15 16]);

model.material('mat6').selection.set([1 2 3 5 10 12 15 16]);

model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result.create('pg5', 1);
model.result('pg5').set('data', 'none');
model.result('pg5').feature.create('tblp1', 'Table');
model.result('pg5').feature('tblp1').set('table', 'tbl3');
model.result('pg5').run;

model.material.create('mat7');
model.material('mat7').selection.geom('geom1', 1);
model.material('mat7').name('Pyroceram');
model.material('mat7').propertyGroup('def').set('emissivity', {'0.85'});
model.material('mat7').selection.set([5 10]);
model.material('mat6').propertyGroup('def').set('emissivity', {'0.95'});

model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg5').run;
model.result.export('tbl2').set('table', 'tbl3');
model.result.export('tbl3').set('table', 'tbl4');
model.result.export('tbl4').set('table', 'tbl5');
model.result.export('tbl1').set('filename',
'C:\Users\gfreeman501\Desktop\BAse Temp.dat');

model.probe('pdom1').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl1');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');
model.result.numerical('pev1').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;

model.probe('pdom2').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl5');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');
```

```
model.result.numerical('pev1').setResult;
model.result('pg3').feature('tblp13').set('plotcolumns', [2]);
model.result('pg3').run;

model.probe('pdom3').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl4');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');
model.result.numerical('pev1').setResult;
model.result('pg3').feature('tblp14').set('plotcolumns', [2]);
model.result('pg3').run;

model.probe('pdom4').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl3');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');
model.result.numerical('pev1').setResult;
model.result('pg3').feature('tblp15').set('plotcolumns', [2]);
model.result('pg3').run;
model.result.export('tbl2').set('filename',
'C:\Users\gfreeman501\Desktop\Top.csv');
model.result.export('tbl3').set('filename',
'C:\Users\gfreeman501\Desktop\Top of Concrete.csv');
model.result.export('tbl4').set('filename',
'C:\Users\gfreeman501\Desktop\Bottom of Concrete.csv');
model.result.export('tbl1').run;
model.result.export('tbl2').run;
model.result.export('tbl3').run;
model.result.export('tbl4').run;
model.result.export('tbl1').set('filename',
'C:\Users\gfreeman501\Desktop\Base Temp.csv');

model.physics('ht2').feature('bhs1').active(false);

model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg4').set('window', 'window1');
model.result('pg4').set('windowtitle', 'Probe Plot 1');
model.result('pg4').run;

model.physics('ht2').feature('chf1').set('h', 1, '5');

model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');
```

```
model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg5').run;

model.probe('pdom1').feature('ppb1').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl1');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');
model.result.numerical('pev1').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;

model.probe('pdom2').feature('ppb1').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl5');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');
model.result.numerical('pev1').setResult;
model.result('pg3').feature('tblp22').set('plotcolumns', [2]);
model.result('pg3').run;

model.probe('pdom3').feature('ppb1').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl4');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');
model.result.numerical('pev1').setResult;
model.result('pg3').feature('tblp23').set('plotcolumns', [2]);
model.result('pg3').run;

model.probe('pdom4').feature('ppb1').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl3');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');
model.result.numerical('pev1').setResult;
model.result('pg3').feature('tblp24').set('plotcolumns', [2]);
model.result('pg3').run;
model.result.export('tbl1').run;
model.result.export('tbl2').run;
model.result.export('tbl3').run;
model.result.export('tbl4').run;
model.result('pg2').run;
model.result('pg2').setIndex('looplevel', '506', 0);
model.result('pg2').run;
model.result('pg2').setIndex('looplevel', '520', 0);
model.result('pg2').run;
model.result.export.create('anim1', 'Animation');
model.result.export('anim1').set('height', '480');
model.result.export('anim1').set('width', '640');
model.result.export('anim1').set('lockratio', 'off');
```

```
model.result.export('anim1').set('resolution', '96');
model.result.export('anim1').set('size', 'manual');
model.result.export('anim1').set('antialias', 'off');
model.result.export('anim1').set('title', 'on');
model.result.export('anim1').set('legend', 'on');
model.result.export('anim1').set('logo', 'on');
model.result.export('anim1').set('options', 'off');
model.result.export('anim1').set('fontsize', '9');
model.result.export('anim1').set('customcolor', [1 1 1]);
model.result.export('anim1').set('background', 'color');
model.result.export('anim1').set('axisorientation', 'on');
model.result.export('anim1').set('grid', 'on');
model.result.export('anim1').set('axes', 'on');
model.result('pg1').set('window', 'graphics');
model.result('pg1').run;
model.result('pg1').set('window', 'graphics');
model.result('pg1').set('windowtitle', 'Graphics');
model.result.export('anim1').set('giffilename',
'C:\Users\gfreeman501\Desktop\Animation.gif');
model.result.export('anim1').set('fps', '60*5');
model.result.export('anim1').set('movietype', 'avi');
model.result.export('anim1').run;
model.result.export('anim1').set('fps', '15');
model.result('pg1').set('window', 'graphics');
model.result('pg1').run;
model.result('pg1').set('window', 'graphics');
model.result('pg1').set('windowtitle', 'Graphics');
model.result.export('anim1').set('avifilename',
'C:\Users\gfreeman501\Desktop\Animation2.avi');
model.result('pg1').set('window', 'graphics');
model.result('pg1').run;
model.result('pg1').set('window', 'graphics');
model.result('pg1').set('windowtitle', 'Graphics');
model.result.export('anim1').run;

model.physics('ht2').feature.create('hcl1', 'HighlyConductiveLayer', 1);
model.physics('ht2').feature('hcl1').selection.set([5 7 9 10]);
model.physics('ht2').feature('hcl1').set('ks_mat', 1, 'userdef');
model.physics('ht2').feature('hcl1').set('rhos_mat', 1, 'userdef');
model.physics('ht2').feature('hcl1').set('Cs_mat', 1, 'userdef');
model.physics('ht2').feature('hcl1').set('ds', 1, '0.025[in]');
model.physics('ht2').feature('hcl1').set('ds', 1, '0.025*0.0254');
model.physics('ht2').feature('hcl1').set('ks', {'3.0' '0' '0' '0' '3.0'
'0' '0' '0' '3.0'});
model.physics('ht2').feature.remove('hcl1');
model.physics('ht2').feature('chf1').set('h', 1, '2');

model.func.create('an2', 'Analytic');
model.func('an2').set('args', 'k_solid_moist_2(T[1/K])[W/(m*K)]');
model.func('an2').set('expr', 'T');
model.func('an2').set('argunit', 'W/(m*K)');
model.func('an2').set('fununit', 'W/(m*K)');
model.func('an2').set('argunit', 'K');
model.func('an2').set('args', 'k_solid_moist_2(T[1/K])');
```

```
model.func('an2').set('expr', 'T3');
model.func('an2').set('args', 'k_solid_moist_2(T3[1/K])');
model.func.create('pw3', 'Piecewise');

model.geom('geom1').feature('r1').setIndex('size', '2.54+0.', 1);
model.geom('geom1').feature('r1').setIndex('size', '2.54+0.020', 1);
model.geom('geom1').run('r1');
model.geom('geom1').feature('r1').setIndex('size', '2.54+(0.020*2.54)',
1);
model.geom('geom1').runAll;
model.geom('geom1').feature('sq1').setIndex('pos', '2.54+(0.020*2.54)',
1);
model.geom('geom1').feature('sq1').setIndex('pos', '2.54+(0.020*2.54)*2',
1);
model.geom('geom1').feature('r1').setIndex('pos', '(0.020*2.54)', 1);
model.geom('geom1').feature('r1').setIndex('size', '2.54', 1);
model.geom('geom1').feature('r2').setIndex('pos', '7.62+(0.020*2.54)*3',
1);
model.geom('geom1').feature('r3').setIndex('size',
'(2.54+(0.020*2.54))*4', 1);
model.geom('geom1').feature('r4').setIndex('size',
'(2.54+(0.020*2.54))*4', 1);
model.geom('geom1').runAll;
model.geom('geom1').run('uni1');
model.geom('geom1').feature.create('r5', 'Rectangle');
model.geom('geom1').feature('r5').setIndex('size', '5.08', 0);
model.geom('geom1').feature('r5').setIndex('size',
'(2.54+(0.020*2.54))*4', 1);
model.geom('geom1').feature('r5').setIndex('size', '0.020*2.54', 1);
model.geom('geom1').runAll;
model.geom('geom1').feature.duplicate('r6', 'r5');
model.geom('geom1').feature.duplicate('r7', 'r5');
model.geom('geom1').feature.duplicate('r8', 'r5');
model.geom('geom1').feature('r6').setIndex('pos', '2.54+0.020*2.54', 1);
model.geom('geom1').runAll;
model.geom('geom1').feature.move('uni1', 9);
model.geom('geom1').feature('r7').setIndex('pos', '2.54+0.020*2.54', 1);
model.geom('geom1').feature('r7').setIndex('pos', '2.54+(0.020*2.54)*3',
1);
model.geom('geom1').feature('r7').setIndex('pos', '2.54+(0.020*2.54)*2',
1);
model.geom('geom1').feature('r7').setIndex('pos', '2.54*3+(0.020*2.54)*2',
1);
model.geom('geom1').runAll;
model.geom('geom1').runAll;
model.geom('geom1').feature('r8').setIndex('pos', '7.62+(0.020*2.54)*3',
1);
model.geom('geom1').feature('r8').setIndex('pos', '2.54*4+(0.020*2.54)*3',
1);
model.geom('geom1').runAll;
model.geom('geom1').run;

model.material.create('mat8');
model.material('mat8').name('TC3008');
```

```
model.material('mat8').propertyGroup('def').set('thermalconductivity',
{'3.0'});
model.material('mat8').selection.set([2 4 6 8]);
model.material('mat8').propertyGroup('def').set('density', {'1500'});
model.material('mat8').propertyGroup('def').set('heatcapacity',
{'4.1855'});

model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.func.remove('an2');
model.func.remove('pw3');

model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg5').run;

model.probe('pdom4').feature('ppb1').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl3');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');
model.result.numerical('pev1').setResult;
model.result('pg3').feature('tblp27').set('plotcolumns', [2]);
model.result('pg3').run;
model.result('pg5').run;

model.probe('pdom1').feature('ppb1').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl1');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');
model.result.numerical('pev1').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;
model.result('pg4').set('window', 'window1');
model.result('pg4').set('windowtitle', 'Probe Plot 1');
model.result('pg4').run;
model.result('pg5').run;

model.probe('pdom3').feature('ppb1').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl4');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');
model.result.numerical('pev1').setResult;
```

```
model.result('pg3').feature('tblp28').set('plotcolumns', [2]);
model.result('pg3').run;
model.result.create('pg6', 1);
model.result('pg6').set('data', 'none');
model.result('pg6').feature.create('tblp1', 'Table');
model.result('pg6').feature('tblp1').set('table', 'tbl4');
model.result('pg6').run;

model.probe('pdom2').feature('ppb1').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl5');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');
model.result.numerical('pev1').setResult;
model.result('pg3').feature('tblp29').set('plotcolumns', [2]);
model.result('pg3').run;
model.result.create('pg7', 1);
model.result('pg7').set('data', 'none');
model.result('pg7').feature.create('tblp1', 'Table');
model.result('pg7').feature('tblp1').set('table', 'tbl5');
model.result('pg7').run;

model.material('mat4').propertyGroup('def').set('thermalconductivity',
{'2'});

model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.material('mat8').propertyGroup('def').set('heatcapacity',
{'4185.5'});

model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.result('pg5').run;

model.physics('ht2').feature('temp1').selection.set([2 5 20]);

model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.result('pg5').run;
model.result('pg5').run;

model.geom('geom1').feature.remove('r5');
model.geom('geom1').feature.remove('r6');
model.geom('geom1').feature.remove('r7');
model.geom('geom1').feature.remove('r8');
```

```
model.geom('geom1').feature('r1').setIndex('pos', '0', 1);
model.geom('geom1').feature('sq1').setIndex('pos', '2.54', 1);
model.geom('geom1').feature('r2').setIndex('pos', '7.62', 1);
model.geom('geom1').runAll;
model.geom('geom1').feature('r4').setIndex('size', '(2.54)*4', 1);
model.geom('geom1').feature('r3').setIndex('size', '2.54*4', 1);
model.geom('geom1').runAll;
model.geom('geom1').run;

model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg5').run;

model.material('mat4').propertyGroup('def').set('thermalconductivity',
{'1.73'});

model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg5').run;

model.physics('ht2').feature('chf1').set('h', 1, '5');

model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg5').run;
model.result('pg5').run;

model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg5').run;
```

```
model.result('pg2').run;
model.result('pg2').setIndex('looplevel', '692', 0);
model.result('pg2').run;

model.material.remove('mat8');
model.material('mat4').propertyGroup('def').set('thermalconductivity',
{'1.78'});

model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg5').run;

model.probe('bnd1').active(true);
model.probe('bnd1').set('expr', 'T3');

model.result('pg5').run;

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg4').set('window', 'window1');
model.result('pg4').set('windowtitle', 'Probe Plot 1');
model.result('pg4').run;

model.probe('bnd1').set('window', 'new');
model.probe('bnd1').set('table', 'tbl2');
model.probe('bnd1').selection.set([5]);
model.probe.duplicate('bnd2', 'bnd1');
model.probe('bnd2').selection.set([7]);
model.probe.duplicate('bnd3', 'bnd2');
model.probe.duplicate('bnd4', 'bnd3');
model.probe('bnd3').selection.set([9]);
model.probe('bnd4').selection.set([10]);
model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');
```

```
model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg8').set('window', 'window2');
model.result('pg8').set('windowtitle', 'Probe Plot 2');
model.result('pg8').run;
model.result('pg8').feature('tblp1').set('plotcolumns', {'2' '3' '4'
'5'});
model.result('pg8').set('window', 'window2');
model.result('pg8').set('windowtitle', 'Probe Plot 2');
model.result('pg8').run;
model.result('pg8').set('window', 'window2');
model.result('pg8').set('windowtitle', 'Probe Plot 2');
model.result('pg8').run;
model.result.export('tbl2').set('table', 'tbl2');
model.result.export('tbl2').set('filename',
'C:\Users\gfreeman501\Desktop\Boundary 2D.csv');
model.result.export('tbl2').run;
model.result('pg2').run;
model.result('pg2').run;
model.result('pg2').setIndex('looplevel', '628', 0);
model.result('pg2').run;
model.result('pg8').set('window', 'window2');
model.result('pg8').set('windowtitle', 'Probe Plot 2');
model.result('pg8').run;

model.physics('ht2').feature('temp1').selection.set([2 5 12]);
model.physics('ht2').feature('solid1').selection.set([1 2 4 5]);

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');

model.sol('sol1').feature('t1').set('maxstepgenalpha', '60*4');

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg8').set('window', 'window2');
model.result('pg8').set('windowtitle', 'Probe Plot 2');
```

```
model.result('pg8').run;
model.result('pg8').feature('tblp1').set('plotcolumns', {'2' '3' '4'
'5'});
model.result('pg8').set('window', 'window2');
model.result('pg8').set('windowtitle', 'Probe Plot 2');
model.result('pg8').run;
model.result('pg8').feature('tblp1').set('linestyle', 'solid');
model.result('pg8').feature('tblp1').set('linewidth', '1');
model.result('pg8').set('window', 'window2');
model.result('pg8').set('windowtitle', 'Probe Plot 2');
model.result('pg8').run;

model.material.create('mat8');
model.material('mat8').name('H2O (water) [liquid]');
model.material('mat8').info.create('Composition');
model.material('mat8').info('Composition').body('11.2 H, 88.8 O (wt%)');
model.material('mat8').propertyGroup('def').set('dL',
'(dL_liquid_2(T[1/K])-
dL_liquid_2(Tempref[1/K]))/(1+dL_liquid_2(Tempref[1/K]))');
model.material('mat8').propertyGroup('def').set('CTE',
'CTE_liquid_2(T[1/K])[1/K]');
model.material('mat8').propertyGroup('def').set('thermalconductivity',
'k_liquid_2(T[1/K])[W/(m*K)]');
model.material('mat8').propertyGroup('def').set('thermalexpansioncoefficie
nt', '(alpha_liquid_2(T[1/K])[1/K]+(Tempref-293[K])*if(abs(T-Tempref)>1e-
3,(alpha_liquid_2(T[1/K])[1/K]-alpha_liquid_2(Tempref[1/K])[1/K])/(T-
Tempref),d(alpha_liquid_2(T[1/K]),T)[1/K]))/(1+alpha_liquid_2(Tempref[1/K]
)[1/K]*(Tempref-293[K]))');
model.material('mat8').propertyGroup('def').set('heatcapacity',
'C_liquid_2(T[1/K])[J/(kg*K)]');
model.material('mat8').propertyGroup('def').set('HC',
'HC_liquid_2(T[1/K])[J/(mol*K)]');
model.material('mat8').propertyGroup('def').set('density',
'rho_liquid_2(T[1/K])[kg/m^3]');
model.material('mat8').propertyGroup('def').set('TD',
'TD_liquid_2(T[1/K])[m^2/s]');
model.material('mat8').propertyGroup('def').set('VP',
'VP_liquid_2(T[1/K])[Pa]');
model.material('mat8').propertyGroup('def').set('dynamicviscosity',
'eta_liquid_1(T[1/K])[Pa*s]');
model.material('mat8').propertyGroup('def').func.create('dL_liquid_2',
'Piecewise');
model.material('mat8').propertyGroup('def').func('dL_liquid_2').set('funcn
ame', 'dL_liquid_2');
model.material('mat8').propertyGroup('def').func('dL_liquid_2').set('arg',
'T');
model.material('mat8').propertyGroup('def').func('dL_liquid_2').set('extra
p', 'constant');
model.material('mat8').propertyGroup('def').func('dL_liquid_2').set('piece
s', {'273.0' '283.0' '0.008486158-6.947021E-5*T^1+1.333373E-7*T^2';
'283.0' '373.0' '0.2324466-0.002030447*T^1+5.510259E-6*T^2-4.395999E-
9*T^3'});
model.material('mat8').propertyGroup('def').func.create('CTE_liquid_2',
'Piecewise');
```

```
model.material('mat8').propertyGroup('def').func('CTE_liquid_2').set('func
name', 'CTE_liquid_2');
model.material('mat8').propertyGroup('def').func('CTE_liquid_2').set('arg'
, 'T');
model.material('mat8').propertyGroup('def').func('CTE_liquid_2').set('extr
ap', 'constant');
model.material('mat8').propertyGroup('def').func('CTE_liquid_2').set('piec
es', {'273.0' '283.0' '-6.947321E-5+2.666746E-7*T^1'; '283.0' '293.0' '-
0.01363715+8.893977E-5*T^1-1.43925E-7*T^2'; '293.0' '373.0' '-
0.00203045+1.102052E-5*T^1-1.3188E-8*T^2'});
model.material('mat8').propertyGroup('def').func.create('k_liquid_2',
'Piecewise');
model.material('mat8').propertyGroup('def').func('k_liquid_2').set('funcna
me', 'k_liquid_2');
model.material('mat8').propertyGroup('def').func('k_liquid_2').set('arg',
'T');
model.material('mat8').propertyGroup('def').func('k_liquid_2').set('extrap
', 'constant');
model.material('mat8').propertyGroup('def').func('k_liquid_2').set('pieces
', {'275.0' '370.0' '-0.9003748+0.008387698*T^1-1.118205E-5*T^2'});
model.material('mat8').propertyGroup('def').func.create('alpha_liquid_2',
'Piecewise');
model.material('mat8').propertyGroup('def').func('alpha_liquid_2').set('fu
ncname', 'alpha_liquid_2');
model.material('mat8').propertyGroup('def').func('alpha_liquid_2').set('ar
g', 'T');
model.material('mat8').propertyGroup('def').func('alpha_liquid_2').set('ex
trap', 'constant');
model.material('mat8').propertyGroup('def').func('alpha_liquid_2').set('pi
eces', {'273.0' '283.0' '0.01032507-7.62815E-5*T^1+1.412474E-7*T^2';
'283.0' '373.0' '-0.002464185+1.947611E-5*T^1-5.049672E-8*T^2+4.616995E-
11*T^3'});
model.material('mat8').propertyGroup('def').func.create('C_liquid_2',
'Piecewise');
model.material('mat8').propertyGroup('def').func('C_liquid_2').set('funcna
me', 'C_liquid_2');
model.material('mat8').propertyGroup('def').func('C_liquid_2').set('arg',
'T');
model.material('mat8').propertyGroup('def').func('C_liquid_2').set('extrap
', 'constant');
model.material('mat8').propertyGroup('def').func('C_liquid_2').set('pieces
', {'293.0' '373.0' '4035.841+0.492312*T^1'});
model.material('mat8').propertyGroup('def').func.create('HC_liquid_2',
'Piecewise');
model.material('mat8').propertyGroup('def').func('HC_liquid_2').set('funcn
ame', 'HC_liquid_2');
model.material('mat8').propertyGroup('def').func('HC_liquid_2').set('arg',
'T');
model.material('mat8').propertyGroup('def').func('HC_liquid_2').set('extra
p', 'constant');
model.material('mat8').propertyGroup('def').func('HC_liquid_2').set('piece
s', {'293.0' '373.0' '72.64512+0.008861616*T^1'});
model.material('mat8').propertyGroup('def').func.create('rho_liquid_2',
'Piecewise');
```

```
model.material('mat8').propertyGroup('def').func('rho_liquid_2').set('func
name', 'rho_liquid_2');
model.material('mat8').propertyGroup('def').func('rho_liquid_2').set('arg'
, 'T');
model.material('mat8').propertyGroup('def').func('rho_liquid_2').set('extr
ap', 'constant');
model.material('mat8').propertyGroup('def').func('rho_liquid_2').set('piec
es', {'273.0' '283.0' '972.7584+0.2084*T^1-4.0E-4*T^2'; '283.0' '373.0'
'345.28+5.749816*T^1-0.0157244*T^2+1.264375E-5*T^3'});
model.material('mat8').propertyGroup('def').func.create('TD_liquid_2',
'Piecewise');
model.material('mat8').propertyGroup('def').func('TD_liquid_2').set('funcn
ame', 'TD_liquid_2');
model.material('mat8').propertyGroup('def').func('TD_liquid_2').set('arg',
'T');
model.material('mat8').propertyGroup('def').func('TD_liquid_2').set('extra
p', 'constant');
model.material('mat8').propertyGroup('def').func('TD_liquid_2').set('piece
s', {'273.0' '333.0' '8.04E-8+2.0E-10*T^1'});
model.material('mat8').propertyGroup('def').func.create('VP_liquid_2',
'Piecewise');
model.material('mat8').propertyGroup('def').func('VP_liquid_2').set('funcn
ame', 'VP_liquid_2');
model.material('mat8').propertyGroup('def').func('VP_liquid_2').set('arg',
'T');
model.material('mat8').propertyGroup('def').func('VP_liquid_2').set('extra
p', 'constant');
model.material('mat8').propertyGroup('def').func('VP_liquid_2').set('piece
s', {'280.0' '600.0' '(exp((-2.005122e+003/T-5.565700e-
001*log10(T)+9.898790e+000-
1.111690e+007/T^3)*log(10.0)))*1.333200e+002'});
model.material('mat8').propertyGroup('def').func.create('eta_liquid_1',
'Piecewise');
model.material('mat8').propertyGroup('def').func('eta_liquid_1').set('func
name', 'eta_liquid_1');
model.material('mat8').propertyGroup('def').func('eta_liquid_1').set('arg'
, 'T');
model.material('mat8').propertyGroup('def').func('eta_liquid_1').set('extr
ap', 'constant');
model.material('mat8').propertyGroup('def').func('eta_liquid_1').set('piec
es', {'265.0' '293.0' '5.948859-0.08236196*T^1+4.287142E-4*T^2-9.938045E-
7*T^3+8.65316E-10*T^4'; '293.0' '353.0' '0.410191-
0.004753985*T^1+2.079795E-5*T^2-4.061698E-8*T^3+2.983925E-11*T^4'; '353.0'
'423.0' '0.03625638-3.265463E-4*T^1+1.127139E-6*T^2-1.75363E-
9*T^3+1.033976E-12*T^4'});
model.material('mat8').propertyGroup('def').addInput('temperature');
model.material('mat8').propertyGroup('def').addInput('strainreferencetempe
rature');
model.material('mat8').materialType('nonSolid');

model.physics('ht2').feature('porous1').set('SolidMaterial', 1, 'mat8');
model.physics('ht2').feature('porous1').set('SolidMaterial', 1, 'mat1');
model.physics('ht2').feature('porous1').set('SolidMaterial', 1, 'dommat');
model.physics('ht2').feature('porous1').set('theta_p', 1, '.09');
```

```
model.physics('ht2').feature('porous1').set('k_p_mat', 1, 'userdef');
model.physics('ht2').feature('porous1').set('k_p_mat', 1, 'from_mat');
model.physics('ht2').feature('porous1').set('rho_p_mat', 1, 'userdef');
model.physics('ht2').feature('porous1').set('rho_p', 1, '1000');
model.physics('ht2').feature('porous1').set('C_pp_mat', 1, 'userdef');
model.physics('ht2').feature('porous1').set('C_pp', 1, '41');
model.physics('ht2').feature('porous1').set('C_pp', 1, '4190');

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg8').set('window', 'window2');
model.result('pg8').set('windowtitle', 'Probe Plot 2');
model.result('pg8').run;
model.result('pg8').feature('tblp1').set('plotcolumns', {'2' '3' '4'
'5'});
model.result.table.remove('tbl2');

model.probe('bnd2').genResult('sol1');

model.result.numerical('pev3').set('table', 'tbl1');
model.result.numerical('pev3').set('innerinput', 'all');
model.result.numerical('pev3').set('outerinput', 'all');
model.result.numerical('pev3').setResult;
model.result('pg8').feature('tblp1').set('plotcolumns', [2]);
model.result('pg8').run;

model.probe('pdom1').genResult('sol1');

model.result.numerical('pev1').set('table', 'tbl1');
model.result.numerical('pev1').set('innerinput', 'all');
model.result.numerical('pev1').set('outerinput', 'all');
model.result.numerical('pev1').setResult;
model.result('pg4').feature('tblp1').set('plotcolumns', [2]);
model.result('pg4').run;

model.probe('bnd3').genResult('sol1');

model.result.numerical('pev4').set('table', 'tbl1');
model.result.numerical('pev4').set('innerinput', 'all');
model.result.numerical('pev4').set('outerinput', 'all');
model.result.numerical('pev4').setResult;
model.result('pg9').feature('tblp1').set('plotcolumns', [2]);
model.result('pg9').run;
```

```
model.probe('bnd1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl1');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg10').feature('tblp1').set('plotcolumns', [2]);
model.result('pg10').run;

model.probe('bnd1').genResult('none');
model.probe('pdom1').genResult('none');
model.probe('pdom2').genResult('none');
model.probe('pdom3').genResult('none');
model.probe('pdom4').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;

model.probe.remove('pdom1');
model.probe.remove('pdom2');
model.probe.remove('pdom3');
model.probe.remove('pdom4');
model.probe('bnd1').set('table', 'default');

model.result.table.create('tbl6', 'Table');

model.probe('bnd1').set('table', 'tbl6');
model.probe('bnd2').set('table', 'tbl6');
model.probe('bnd3').set('table', 'tbl6');
model.probe('bnd4').set('table', 'tbl6');
model.probe('bnd1').genResult('sol1');

model.result.numerical('pev2').set('table', 'tbl6');
model.result.numerical('pev2').set('innerinput', 'all');
model.result.numerical('pev2').set('outerinput', 'all');
model.result.numerical('pev2').setResult;
model.result('pg10').feature('tblp2').set('plotcolumns', [2]);
model.result('pg10').run;

model.probe('bnd1').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result.create('pg12', 1);
model.result('pg12').set('data', 'none');
model.result('pg12').feature.create('tblp1', 'Table');
```

```
model.result('pg12').feature('tblp1').set('table', 'tbl6');
model.result('pg12').run;
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 7');
model.result('pg4').set('windowtitle', 'Probe Plot 1');
model.result('pg5').set('windowtitle', 'Graphics');
model.result('pg6').set('windowtitle', 'Graphics');
model.result('pg7').set('windowtitle', 'Graphics');
model.result('pg8').set('windowtitle', 'Probe Plot 5');
model.result('pg9').set('windowtitle', 'Probe Plot 6');
model.result('pg10').set('windowtitle', 'Probe Plot 2');
model.result('pg11').set('windowtitle', 'Probe Plot 8');
model.result('pg12').set('windowtitle', 'Graphics');
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 7');
model.result('pg4').set('windowtitle', 'Probe Plot 1');
model.result('pg5').set('windowtitle', 'Graphics');
model.result('pg6').set('windowtitle', 'Graphics');
model.result('pg7').set('windowtitle', 'Graphics');
model.result('pg8').set('windowtitle', 'Probe Plot 5');
model.result('pg9').set('windowtitle', 'Probe Plot 6');
model.result('pg10').set('windowtitle', 'Probe Plot 2');
model.result('pg11').set('windowtitle', 'Probe Plot 8');
model.result('pg12').set('windowtitle', 'Graphics');
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 7');
model.result('pg4').set('windowtitle', 'Probe Plot 1');
model.result('pg5').set('windowtitle', 'Graphics');
model.result('pg6').set('windowtitle', 'Graphics');
model.result('pg7').set('windowtitle', 'Graphics');
model.result('pg8').set('windowtitle', 'Probe Plot 5');
model.result('pg9').set('windowtitle', 'Probe Plot 6');
model.result('pg10').set('windowtitle', 'Probe Plot 2');
model.result('pg11').set('windowtitle', 'Probe Plot 8');
model.result('pg12').set('windowtitle', 'Graphics');
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 7');
model.result('pg4').set('windowtitle', 'Probe Plot 1');
model.result('pg5').set('windowtitle', 'Graphics');
model.result('pg6').set('windowtitle', 'Graphics');
model.result('pg7').set('windowtitle', 'Graphics');
model.result('pg8').set('windowtitle', 'Probe Plot 5');
model.result('pg9').set('windowtitle', 'Probe Plot 6');
model.result('pg10').set('windowtitle', 'Probe Plot 2');
model.result('pg11').set('windowtitle', 'Probe Plot 8');
model.result('pg12').set('windowtitle', 'Graphics');
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 7');
model.result('pg4').set('windowtitle', 'Probe Plot 1');
```

```
model.result('pg5').set('windowtitle', 'Graphics');
model.result('pg6').set('windowtitle', 'Graphics');
model.result('pg7').set('windowtitle', 'Graphics');
model.result('pg8').set('windowtitle', 'Probe Plot 5');
model.result('pg9').set('windowtitle', 'Probe Plot 6');
model.result('pg10').set('windowtitle', 'Probe Plot 2');
model.result('pg11').set('windowtitle', 'Probe Plot 8');
model.result('pg12').set('windowtitle', 'Graphics');
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 7');
model.result('pg4').set('windowtitle', 'Probe Plot 1');
model.result('pg5').set('windowtitle', 'Graphics');
model.result('pg6').set('windowtitle', 'Graphics');
model.result('pg7').set('windowtitle', 'Graphics');
model.result('pg8').set('windowtitle', 'Probe Plot 5');
model.result('pg9').set('windowtitle', 'Probe Plot 6');
model.result('pg10').set('windowtitle', 'Probe Plot 2');
model.result('pg11').set('windowtitle', 'Probe Plot 8');
model.result('pg12').set('windowtitle', 'Graphics');

model.physics('ht2').feature('porous1').set('k_p_mat', 1, 'userdef');
model.physics('ht2').feature('porous1').set('rho_mat', 1, 'userdef');
model.physics('ht2').feature('porous1').set('rho', 1, '1000');
model.physics('ht2').feature('porous1').set('Cp_mat', 1, 'userdef');
model.physics('ht2').feature('porous1').set('Cp', 1, '4190');
model.physics('ht2').feature('porous1').set('gamma_mat', 1, 'userdef');
model.physics('ht2').feature('porous1').set('k_p_mat', 1, 'from_mat');
model.physics('ht2').feature('porous1').set('rho_p_mat', 1, 'from_mat');
model.physics('ht2').feature('porous1').set('C_pp_mat', 1, 'from_mat');
model.physics('ht2').feature('porous1').set('gamma_mat', 1, 'from_mat');
model.physics('ht2').feature('porous1').set('k_mat', 1, 'userdef');

model.func('an1').setIndex('plotargs', '273', 0, 1);

model.physics('ht2').feature('porous1').set('gamma_mat', 1, 'userdef');

model.func('an1').set('expr', '-1.48445+4.12292');
model.func('an1').setIndex('plotargs', '370', 0, 2);
model.func('pw2').set('argunit', 'K');
model.func('pw2').set('fununit', 'W/(K*m)');
model.func('pw2').remove('pieces', 1);
model.func('pw2').remove('pieces', 1);
model.func('pw2').remove('pieces', 1);
model.func('pw2').remove('pieces', 1);
model.func('pw2').set('argunit', 'degC');
model.func('pw2').setIndex('pieces', '120', 0, 1);
model.func('pw2').setIndex('pieces', '0.6505', 0, 2);
model.func('pw2').setIndex('pieces', '-50', 1, 0);
model.func('pw2').move('pieces', 1, 2, 0);
model.func('pw2').setIndex('pieces', '0', 0, 1);
model.func('pw2').setIndex('pieces', '-40', 0, 0);
model.func('pw2').setIndex('pieces', '2.1+0.1375*x', 0, 2);
```

```
model.func('pw2').setIndex('pieces', '-1.48445+4.12292*(x/298.15)-
1.63866*(x/298.15)^2', 1, 2);
model.func('pw2').setIndex('pieces', '2.1+0.1375*(-x)', 0, 2);
model.func('pw2').setIndex('pieces', '0.6505*(-1.48445+4.12292*(x/298.15)-
1.63866*(x/298.15)^2)', 1, 2);
model.func('pw2').set('argunit', 'k');
model.func('pw2').setIndex('pieces', '370', 1, 1);
model.func('pw2').setIndex('pieces', '273.15', 1, 0);
model.func('pw2').setIndex('pieces', '233.15', 0, 0);
model.func('pw2').setIndex('pieces', '273.15', 0, 1);
model.func('pw2').setIndex('pieces', '2.1+0.1375*(-x-273.15)', 0, 2);
model.func('pw2').setIndex('pieces', '2.1+0.1375*(-x+273.15)', 0, 2);
model.func('pw2').setIndex('pieces', '2.1+0.1375*(x-273.15)', 0, 2);
model.func('pw2').setIndex('pieces', '2.1+0.1375*(-(x-273.15)', 0, 2);
model.func('pw2').setIndex('pieces', '2.1+0.1375*(-(x-273.15))', 0, 2);
model.func('pw2').set('argunit', 'K');

model.material.remove('mat8');

model.physics('ht2').feature('porous1').set('k', {'pw2(T3)' '0' '0' '0'
'pw2(T3)' '0' '0' '0' 'pw2(T3)'});

model.probe('bnd1').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg12').run;

model.physics('ht2').feature('porous1').set('theta_p', 1, '.91');

model.probe('bnd1').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg12').run;
model.result('pg12').run;
model.result.export.create('tbl5', 'Table');
model.result.export('tbl5').set('table', 'tbl6');
model.result.export('tbl5').set('filename',
'C:\Users\gfreeman501\Desktop\2d Model Data.csv');
model.result.export('tbl5').run;
model.result.export('tbl5').run;
model.result.export('tbl5').run;
model.result.export('tbl5').run;
model.result.export('tbl5').run;
```

```
model.physics('ht2').feature('porous1').set('theta_p', 1, '.96');

model.probe('bnd1').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg12').run;

model.physics('ht2').feature('porous1').set('theta_p', 1, '.965');

model.probe('bnd1').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg12').run;
model.result('pg11').set('window', 'window8');
model.result('pg11').set('windowtitle', 'Probe Plot 8');
model.result('pg11').run;
model.result('pg1').set('windowtitle', 'Graphics');
model.result('pg2').set('windowtitle', 'Graphics');
model.result('pg3').set('windowtitle', 'Probe Plot 7');
model.result('pg4').set('windowtitle', 'Probe Plot 1');
model.result('pg5').set('windowtitle', 'Graphics');
model.result('pg6').set('windowtitle', 'Graphics');
model.result('pg7').set('windowtitle', 'Graphics');
model.result('pg8').set('windowtitle', 'Probe Plot 5');
model.result('pg9').set('windowtitle', 'Probe Plot 6');
model.result('pg10').set('windowtitle', 'Probe Plot 2');
model.result('pg11').set('windowtitle', 'Probe Plot 8');
model.result('pg12').set('windowtitle', 'Graphics');
model.result('pg3').set('window', 'window7');
model.result('pg3').set('windowtitle', 'Probe Plot 7');
model.result('pg3').run;
model.result.remove('pg3');
model.result.remove('pg4');
model.result.remove('pg5');
model.result.remove('pg6');
model.result.remove('pg7');
model.result.remove('pg8');
model.result.remove('pg9');
model.result.remove('pg10');
model.result.remove('pg11');
model.result('pg12').run;
model.result('pg1').run;
model.result('pg1').feature('surf1').set('descractive', 'on');
model.result('pg1').run;
```

```
model.result('pg1').run;
model.result('pg2').run;
model.result('pg2').setIndex('looplevel', '334', 0);
model.result('pg2').run;
model.result('pg2').set('allowtableupdate', true);
model.result('pg2').set('renderdatacached', true);
model.result('pg1').run;
model.result('pg1').setIndex('looplevel', '306', 0);
model.result('pg1').run;
model.result('pg1').set('window', 'graphics');
model.result('pg1').run;
model.result('pg1').set('window', 'graphics');
model.result('pg1').set('windowtitle', 'Graphics');
model.result.export.create('img1', 'Image2D');
model.result.export('img1').set('unit', 'px');
model.result.export('img1').set('height', '600');
model.result.export('img1').set('width', '800');
model.result.export('img1').set('lockratio', 'off');
model.result.export('img1').set('resolution', '96');
model.result.export('img1').set('size', 'manual');
model.result.export('img1').set('antialias', 'off');
model.result.export('img1').set('title', 'on');
model.result.export('img1').set('legend', 'on');
model.result.export('img1').set('logo', 'on');
model.result.export('img1').set('options', 'off');
model.result.export('img1').set('fontsize', '9');
model.result.export('img1').set('customcolor', [1 1 1]);
model.result.export('img1').set('background', 'color');
model.result.export('img1').set('qualitylevel', '92');
model.result.export('img1').set('qualityactive', 'off');
model.result.export('img1').set('imagetype', 'png');
model.result.export('img1').set('axes', 'on');
model.result('pg1').set('window', 'graphics');
model.result('pg1').run;
model.result('pg1').set('window', 'graphics');
model.result('pg1').set('windowtitle', 'Graphics');
model.result.export('tbl5').run;

model.physics.remove('ht');

model.result('pg2').run;
model.result('pg2').run;
model.result('pg2').feature('con1').set('unit', 'degC');
model.result('pg2').feature('con1').set('coloring', 'uniform');
model.result('pg2').feature('con1').set('color', 'black');
model.result('pg2').feature('con1').set('coloring', 'colortable');
model.result('pg2').feature('con1').set('colortable', 'GrayScale');
model.result('pg2').feature('con1').set('colortablesym', 'off');
model.result('pg2').feature('con1').set('colortable', 'RainbowLight');
model.result('pg2').feature('con1').set('colortablesym', 'off');
model.result('pg2').feature('con1').set('colortablerev', 'off');
model.result('pg2').feature('con1').set('colortable',
'ThermalEquidistant');
model.result('pg2').feature('con1').set('colortablesym', 'off');
```

```
model.result('pg2').feature('con1').set('colortablerev', 'on');
model.result('pg2').feature('con1').set('colortable', 'Rainbow');
model.result('pg2').feature('con1').set('number', '60');
model.result('pg2').feature('con1').set('colortablerev', 'off');
model.result('pg2').feature('con1').set('number', '40');
model.result('pg2').feature('con1').set('colortablesym', 'on');
model.result('pg2').feature('con1').set('contourlabels', 'on');
model.result('pg2').feature('con1').set('colortable', 'GrayScale');
model.result('pg2').feature('con1').set('number', '20');
model.result('pg2').feature('con1').set('labelprec', '2');
model.result('pg2').feature('con1').set('colorlegend', 'off');
model.result('pg2').run;
model.result('pg2').run;
model.result('pg2').feature('arws1').set('scale', '0');
model.result('pg2').run;
model.result('pg2').set('view', 'auto');

model.view.create('view2', 'geom1');
model.view.remove('view2');

% model.geom('geom1').move({'uni1'}, [0.17087125778198 -
0.36300373077393]);
model.geom('geom1').feature.create('mov1', 'Move');
model.geom('geom1').feature('mov1').selection('input').init;
model.geom('geom1').feature('mov1').selection('input').set({'uni1'});
model.geom('geom1').feature('mov1').set('displ', [0.17087125778198 -
0.36300373077393]);
model.geom('geom1').run('mov1');
% model.geom('geom1').move({}, [-3 0.5]);
model.geom('geom1').run('mov1');
% model.geom('geom1').move({'mov1'}, [-3 -6.5]);
model.geom('geom1').feature('mov1').set('displx', {'-2.829128742218'});
model.geom('geom1').feature('mov1').set('disply', {'-6.8630037307739'});
model.geom('geom1').run('mov1');
% model.geom('geom1').move({'mov1'}, [-4 5.5]);
model.geom('geom1').feature('mov1').set('displx', {'-6.829128742218'});
model.geom('geom1').feature('mov1').set('disply', {'-1.3630037307739'});
model.geom('geom1').run('mov1');
% model.geom('geom1').move({'mov1'}, [1 1.5]);
model.geom('geom1').feature('mov1').set('displx', {'-5.829128742218'});
model.geom('geom1').feature('mov1').set('disply', {'0.1369962692261'});
model.geom('geom1').run('mov1');
model.geom('geom1').runAll;
% model.geom('geom1').move({'mov1'}, [7 0]);
model.geom('geom1').feature('mov1').set('displx', {'1.170871257782'});
model.geom('geom1').run('mov1');
% model.geom('geom1').move({'mov1'}, [4 1]);
model.geom('geom1').feature('mov1').set('displx', {'5.170871257782'});
model.geom('geom1').feature('mov1').set('disply', {'1.1369962692261'});
model.geom('geom1').run('mov1');
% model.geom('geom1').move({'mov1'}, [-5 -1]);
model.geom('geom1').feature('mov1').set('displx', {'0.170871257782'});
model.geom('geom1').feature('mov1').set('disply', {'0.1369962692261'});
model.geom('geom1').run('mov1');
```

```
% model.geom('geom1').move({'mov1'}, [-4 0]);
model.geom('geom1').feature('mov1').set('displx', {'-3.829128742218'});
model.geom('geom1').run('mov1');
% model.geom('geom1').scale({'mov1'}, [0.5415101051330566
0.8231302499771118], [1.250871 0.1369963]);
model.geom('geom1').feature.create('sca1', 'Scale');
model.geom('geom1').feature('sca1').selection('input').init;
model.geom('geom1').feature('sca1').selection('input').set({'mov1'});
model.geom('geom1').feature('sca1').set('pos', [1.250871 0.1369963]);
model.geom('geom1').feature('sca1').set('type', 'anisotropic');
model.geom('geom1').feature('sca1').set('anisotropic', [0.5415101051330566
0.8231302499771118]);
model.geom('geom1').run('sca1');
% model.geom('geom1').move({'sca1'}, [-3.5 1]);
model.geom('geom1').feature('sca1').set('pos', {'-6.382885030797'
'5.790874364907'});
model.geom('geom1').run('sca1');
% model.geom('geom1').move({}, [-0.5 0.5]);
model.geom('geom1').run('sca1');
% model.geom('geom1').move({'sca1'}, [12 0]);
model.geom('geom1').feature('sca1').set('pos', {'19.789992789078'
'5.790874364907'});
model.geom('geom1').run('sca1');
% model.geom('geom1').move({'sca1'}, [-12.5 -1]);
model.geom('geom1').feature('sca1').set('pos', {'-7.4734216066255'
'0.13699629999995'});
model.geom('geom1').run('sca1');
model.geom('geom1').feature.remove('mov1');
model.geom('geom1').runAll;
model.geom('geom1').feature.remove('sca1');
model.geom('geom1').runAll;
model.geom('geom1').run;

model.physics('ht2').feature.remove('temp2');
model.physics('ht2').feature.remove('sar1');
model.physics('ht2').feature.remove('bhs1');
model.physics('ht2').feature.remove('chf2');
model.physics('ht2').feature('sar2').selection.set([1 3 10 15 16]);

model.probe('bnd1').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg12').run;
model.result('pg1').set('window', 'graphics');
model.result('pg1').run;
model.result('pg1').set('window', 'graphics');
model.result('pg1').set('windowtitle', 'Graphics');
```

```
model.material('mat4').propertyGroup('def').set('ratioofspecificheat',
{'1'});

model.result.export('tbl5').run;

model.material.move('mat7', 3);

model.result('pg14').set('window', 'window5');
model.result('pg14').set('windowtitle', 'Probe Plot 5');
model.result('pg14').run;

model.material('mat1').propertyGroup('def').set('thermalconductivity',
{'k(T3[1/K])[W/(m*K)]'});
model.material('mat1').propertyGroup('def').set('heatcapacity',
{'C(T3[1/K])[J/(kg*K)]'});

model.probe('bnd1').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;

model.physics('ht2').feature.create('fluid1', 'FluidHeatTransferModel',
2);
model.physics('ht2').feature.remove('fluid1');
model.physics('ht2').feature.create('phc1',
'PhaseChangeHeatTransferModel', 2);

model.material.create('mat8');
model.material('mat8').name('Water');
model.material('mat8').set('family', 'water');
model.material('mat8').propertyGroup('def').set('dynamicviscosity',
'eta(T[1/K])[Pa*s]');
model.material('mat8').propertyGroup('def').set('ratioofspecificheat',
'1.0');
model.material('mat8').propertyGroup('def').set('electricconductivity',
'5.5e-6[S/m]');
model.material('mat8').propertyGroup('def').set('heatcapacity',
'Cp(T[1/K])[J/(kg*K)]');
model.material('mat8').propertyGroup('def').set('density',
'rho(T[1/K])[kg/m^3]');
model.material('mat8').propertyGroup('def').set('thermalconductivity',
'k(T[1/K])[W/(m*K)]');
model.material('mat8').propertyGroup('def').set('soundspeed',
'cs(T[1/K])[m/s]');
model.material('mat8').propertyGroup('def').func.create('eta',
'Piecewise');
model.material('mat8').propertyGroup('def').func('eta').set('funcname',
'eta');
model.material('mat8').propertyGroup('def').func('eta').set('arg', 'T');
```

```
model.material('mat8').propertyGroup('def').func('eta').set('extrap',
'constant');
model.material('mat8').propertyGroup('def').func('eta').set('pieces',
{'273.15' '413.15' '1.3799566804-0.021224019151*T^1+1.3604562827E-4*T^2-
4.6454090319E-7*T^3+8.9042735735E-10*T^4-9.0790692686E-
13*T^5+3.8457331488E-16*T^6'; '413.15' '553.75' '0.00401235783-
2.10746715E-5*T^1+3.85772275E-8*T^2-2.39730284E-11*T^3'});
model.material('mat8').propertyGroup('def').func.create('Cp',
'Piecewise');
model.material('mat8').propertyGroup('def').func('Cp').set('funcname',
'Cp');
model.material('mat8').propertyGroup('def').func('Cp').set('arg', 'T');
model.material('mat8').propertyGroup('def').func('Cp').set('extrap',
'constant');
model.material('mat8').propertyGroup('def').func('Cp').set('pieces',
{'273.15' '553.75' '12010.1471-80.4072879*T^1+0.309866854*T^2-5.38186884E-
4*T^3+3.62536437E-7*T^4'});
model.material('mat8').propertyGroup('def').func.create('rho',
'Piecewise');
model.material('mat8').propertyGroup('def').func('rho').set('funcname',
'rho');
model.material('mat8').propertyGroup('def').func('rho').set('arg', 'T');
model.material('mat8').propertyGroup('def').func('rho').set('extrap',
'constant');
model.material('mat8').propertyGroup('def').func('rho').set('pieces',
{'273.15' '553.75' '838.466135+1.40050603*T^1-
0.0030112376*T^2+3.71822313E-7*T^3'});
model.material('mat8').propertyGroup('def').func.create('k', 'Piecewise');
model.material('mat8').propertyGroup('def').func('k').set('funcname',
'k');
model.material('mat8').propertyGroup('def').func('k').set('arg', 'T');
model.material('mat8').propertyGroup('def').func('k').set('extrap',
'constant');
model.material('mat8').propertyGroup('def').func('k').set('pieces',
{'273.15' '553.75' '-0.869083936+0.00894880345*T^1-1.58366345E-
5*T^2+7.97543259E-9*T^3'});
model.material('mat8').propertyGroup('def').func.create('cs',
'Interpolation');
model.material('mat8').propertyGroup('def').func('cs').set('sourcetype',
'user');
model.material('mat8').propertyGroup('def').func('cs').set('source',
'table');
model.material('mat8').propertyGroup('def').func('cs').set('funcname',
'cs');
model.material('mat8').propertyGroup('def').func('cs').set('table', {'273'
'1403'; '278' '1427'; '283' '1447'; '293' '1481'; '303' '1507'; '313'
'1526'; '323' '1541'; '333' '1552'; '343' '1555'; '353' '1555';  ...
'363' '1550'; '373' '1543'});
model.material('mat8').propertyGroup('def').func('cs').set('interp',
'piecewisecubic');
model.material('mat8').propertyGroup('def').func('cs').set('extrap',
'const');
model.material('mat8').propertyGroup('def').addInput('temperature');
model.material('mat8').set('family', 'water');
```

```
model.material.create('mat9');
model.material.remove('mat8');
model.material.remove('mat9');

model.param.set('T_trans', '0[degC]');
model.param.descr('T_trans', 'Transition temperature');
model.param.set('dT', '1[K]');
model.param.descr('dT', 'Transition interval');
model.param.set('lm', 'lm_original');
model.param.descr('lm', 'Latent heat of fusion');
model.param.set('lm', '3.3350E5[J/kg]');
model.param.set('rho_ice', '918[kg/m^3]');
model.param.descr('rho_ice', 'Density of ice');
model.param.set('cp_ice', '2052[J/kg/K]');
model.param.descr('cp_ice', 'Specific heat capacity of ice');
model.param.set('k_ice', '2.31[W/m/K]');
model.param.descr('k_ice', 'Thermal conductivity of ice');
model.param.set('rho_water', '997[kg/m^3]');
model.param.descr('rho_water', 'Density of water');
model.param.set('cp_water', '4179[J/kg/K]');
model.param.descr('cp_water', 'Specific heat capacity of water');
model.param.set('k_water', '0.613[W/m/K]');
model.param.descr('k_water', 'Thermal conductivity of water');
model.param.remove('lm');
model.param.set('lm_original', '3.3350E5[J/kg]', 'Latent heat of fusion');
model.param.set('lm', 'lm_original');
model.param.descr('lm', 'Latent heat of fusion');
model.param.descr('lm_original', 'Latent heat of fusion, original');

model.material.create('mat8');
model.material('mat8').name('Water');
model.material('mat8').propertyGroup('def').set('heatcapacity', '');
model.material('mat8').propertyGroup('def').set('ratioofspecificheat',
'');
model.material('mat8').propertyGroup('def').set('thermalconductivity',
'');
model.material('mat8').propertyGroup('def').set('heatcapacity',
{'cp_water'});
model.material('mat8').propertyGroup('def').set('ratioofspecificheat',
{'1'});
model.material('mat8').propertyGroup('def').set('thermalconductivity',
{'k_water'});
model.material('mat8').propertyGroup('def').set('density', {'rho_water'});
model.material.create('mat9');
model.material('mat9').name('Ice');
model.material('mat9').propertyGroup('def').set('density', '');
model.material('mat9').propertyGroup('def').set('heatcapacity', '');
model.material('mat9').propertyGroup('def').set('ratioofspecificheat',
'');
model.material('mat9').propertyGroup('def').set('thermalconductivity',
'');
model.material('mat9').propertyGroup('def').set('density', {'rho_ice'});
model.material('mat9').propertyGroup('def').set('heatcapacity',
{'cp_ice'});
```

```
model.material('mat9').propertyGroup('def').set('ratioofspecificheat',
{'1'});
model.material('mat9').propertyGroup('def').set('thermalconductivity',
{'k_ice'});

model.physics('ht2').feature('phc1').set('dT_pc1_2', 1, 'dt');
model.physics('ht2').feature('phc1').set('dT_pc1_2', 1, 'dT');
model.physics('ht2').feature('phc1').set('L_pc1_2', 1, 'lm');
model.physics('ht2').feature('phc1').set('MaterialPhase1', 1, 'mat8');
model.physics('ht2').feature('phc1').set('MaterialPhase2', 1, 'mat9');
model.physics('ht2').feature('porous1').set('Cp', 1, 'cp_water');
model.physics('ht2').feature('porous1').set('rho', 1, 'rho_water');
model.physics('ht2').feature('porous1').set('k_mat', 1, 'from_mat');
model.physics('ht2').feature('porous1').set('k_mat', 1, 'userdef');
model.physics('ht2').feature('porous1').set('k', {'k_water' '0' '0' '0'
'k_water' '0' '0' '0' 'k_water'});
model.physics('ht2').feature('porous1').set('rho_mat', 1, 'from_mat');
model.physics('ht2').feature('porous1').set('rho_mat', 1, 'userdef');

model.result('pg12').run;

model.physics('ht2').feature.move('phc1', 5);

model.material('mat8').selection.set([3]);

model.physics('ht2').feature('porous1').set('k_mat', 1, 'from_mat');
model.physics('ht2').feature('porous1').set('rho_mat', 1, 'from_mat');
model.physics('ht2').feature('porous1').set('Cp_mat', 1, 'from_mat');
model.physics('ht2').feature('porous1').set('gamma_mat', 1, 'from_mat');
model.physics('ht2').feature('porous1').set('SolidMaterial', 1, 'mat1');
model.physics('ht2').feature('porous1').set('SolidMaterial', 1, 'mat5');
model.physics('ht2').feature('porous1').set('SolidMaterial', 1, 'mat4');

model.result('pg12').run;

model.probe('bnd1').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg12').run;
model.result('pg1').set('window', 'graphics');
model.result('pg1').run;
model.result('pg1').set('window', 'graphics');
model.result('pg1').set('windowtitle', 'Graphics');
model.result.export('tbl5').run;

model.sol('sol1').feature('t1').set('maxstepgenalpha', '30');

model.probe('bnd1').genResult('none');
model.probe('bnd2').genResult('none');
```

```
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg12').run;
model.result.export('tbl5').set('filename',
'C:\Users\gfreeman501\Desktop\2d Model DataV3.csv');
model.result.export('tbl5').run;

model.param.set('lm_original', '3.3350E10[J/kg]');

model.probe('bnd1').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;

model.physics('ht2').feature('phc1').selection.set([]);
model.physics('ht2').feature('phc1').selection.named('sel2');
model.physics('ht2').feature('phc1').selection.set([]);
model.physics('ht2').feature('phc1').set('editModelInputs', '1');
model.physics('ht2').feature('phc1').set('minput_temperature_src', 1,
'root.mod1.T3');
model.physics('ht2').feature('phc1').selection.set([3]);

model.param.set('lm_original', '3.3350E5[J/kg]');

model.physics('ht2').feature('phc1').featureInfo('info').set('ht2.k_effxx'
, 0, {'(1-theta_p)*ht2.kxx+theat_p*k_p'});
model.physics('ht2').feature('phc1').featureInfo('info').set('ht2.k_effyy'
, 0, {'(1-theta_p)*ht2.kyy+theta_p*k_p'});
model.physics('ht2').feature('phc1').featureInfo('info').set('ht2.C_eff',
0, {['ht2.rho*ht2.Cp*(1-theta_p)+theta_p*rho_p*c_concret'
native2unicode(hex2dec('200b'), 'Cp1252') 'e']});

model.param.set('c_concrete', '750[J/kg/K]');

model.physics('ht2').feature('phc1').featureInfo('info').set('ht2.C_eff',
0, {['(ht2.rho*ht2.Cp*(1-theta_p))+(theta_p*rho_p**c_concret'
native2unicode(hex2dec('200b'), 'Cp1252') 'e)']});
model.physics('ht2').feature('phc1').featureInfo('info').set('ht2.C_eff',
0, {['ht2.rho*ht2.Cp*(1-theta_p)+theta_p*rho_p**c_concret'
native2unicode(hex2dec('200b'), 'Cp1252') 'e']});

model.probe('bnd1').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');
```

```
model.physics('ht2').feature('phc1').featureInfo('info').set('ht2.C_eff',
0, {['ht2.rho*ht2.Cp*(1-theta_p)+theta_p*rho_p*c_concret'
native2unicode(hex2dec('200b'), 'Cp1252') 'e']});

model.probe('bnd1').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');

model.physics('ht2').feature('phc1').featureInfo('info').set('ht2.C_eff',
0, {'ht2.rho*ht2.Cp*(1-theta_p)+theta_p*rho_p*c_c'});

model.param.remove('c_concrete');
model.param.set('c_c', '750[J/kg/K]');

model.probe('bnd1').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');

model.param.set('theta_p', '0.965');

model.probe('bnd1').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');

model.param.set('k_p', '1.78[W/m/K]');
model.param.set('theta_p', '0.965[1]');
model.param.descr('theta_p', 'volume percent concrete');
model.param.descr('k_p', 'thermal conductivity of concrete');
model.param.set('rho_p', '2400[kg/m^3]');
model.param.descr('rho_p', 'density of concrete');

model.probe('bnd1').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');

model.physics('ht2').feature('phc1').featureInfo('info').set('ht2.k_effxx'
, 0, {'(1-theta_p)*ht2.kxx+theta_p*k_p'});

model.name('Heat_Convention 2D_ GLCC_air.mph');

model.physics('ht2').feature('phc1').set('MaterialPhase2', 1, 'mat8');

model.param.set('dT', '0.1[K]');

model.probe('bnd1').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');

model.sol('sol1').runAll;
```

```
model.result('pg1').run;
model.result('pg12').run;

model.param.set('dT', '1[K]');

model.probe('bnd1').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result('pg1').set('allowtableupdate', true);
model.result('pg1').set('renderdatacached', true);
model.result('pg12').run;

model.material('mat4').propertyGroup('def').set('density', {'2200'});

model.probe('bnd1').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');

model.param.set('rho_p', '2200[kg/m^3]');

model.probe('bnd1').genResult('none');
model.probe('bnd2').genResult('none');
model.probe('bnd3').genResult('none');
model.probe('bnd4').genResult('none');

model.sol('sol1').runAll;

model.result('pg1').run;
model.result.export('tbl5').set('filename',
'C:\Users\gfreeman501\Desktop\2d Model DatV5.csv');
model.result.export('tbl5').run;

out = model;
```

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