Monitoring Heat Flow Across Omni Block Masonry Units Via Thermocouples

Abstract

Omni Block, Inc. desires to determine real world thermal performance of its patented and uniquely designed insulated masonry units. While the industry has relied on ASTM C-236 and then more recently on ASTM C-1363 thermal resistance test result data to predict product thermal efficiency in building performance, far too often laboratory test results do not properly equate to actual real world thermal performance.

Due to the current laboratory test result data, the building industry falsely presumes that conductive materials will not offer valuable and positive thermal performance. The industry solely relies on the Guarded Hot Box Test (ASTM C-1363), and it has not only become the standard to measure R-Value (resistance to heat flow), but has become the instrument to predict building thermal efficiency. However, the Guarded Hot Box bypasses and virtually eliminates real world physical principles that should be included: thermal mass, thermal lag, and the thermal flywheel effect. Additionally, the Guarded Hot Box tests the resistance to heat transfer in a "steady state". The "real world" is not a steady state. Climate change is dynamic in every location globally and this is not addressed in the laboratory.

Masonry has thermal mass properties that can positively affect a building's thermal performance if properly structured, managed, and protected. If used improperly, thermal mass can have significant negative effects on a building's thermal performance. Proper heat flow analysis will greatly assist in determining how best to structure, manage, predict, and protect thermal mass.

Thermal mass products actually conduct heat, albeit very slowly. They slowly resist heat transfer by the slow absorption and cooling of heat. Therefore, one should not expect a conducting material like masonry to perform well on a resistance test like the Guarded Hot Box. This current testing does not completely or accurately evaluate the thermal performance of thermal mass products. A resistance test on a conductive material is the wrong test. An analogy would be that one would not measure air volume with a liquid measuring cup. This leaves the industry professional and ultimately the consumer with potentially inaccurate information from which to base their design, construction, and purchasing decisions.

Hypothesis

The Omni Block CMU is a uniquely designed masonry unit. Its construction includes off-set and constricted cross webs that effectively reduce and impede heat flow. The middle lineal wall(s) increases the thermal mass and thermal lag. Thermal lag can be defined as the time that it takes the exterior temperature of a building to become the interior temperature without supplemental temperature air conditioning. The design of the block creates unique cells that are internal to the block. These cells are filled with uniquely designed and patented Expanded Polystyrene (EPS) foam inserts. The Omni Block envelope walls that create the conditioned interior spaces can be left exposed. If a finish is desired, they are not furred, insulated and or covered with sheetrock; rather, they are skim-coated with regular sheetrock compound directly over the surface of the block, then texture-coated exactly the same as all the other interior partition sheetrock walls. The thinly-coated block provides an exposed effective thermal mass surface. It is the combination of the delayed heat transfer and extended thermal path (combined to create increased thermal lag), insulation within the block cavities, and the exposed thermal mass that has provided consumer realized thermal efficiencies that far outweigh the limited suggested and restrictive R-value measurement.

Since R–Value by definition, is the inverse of the time rate of heat flow through a body from one of its bounding surfaces to the other surface for a unit temperature difference between the two surfaces, **under steady state conditions**, per unit area, it is our hypothesis that the current ASTM C-1363 resistance test is an inaccurate test for masonry.

Our hypothesis is supported by the fact that hundreds of homes (and a growing number of commercial and institutional buildings) have been built with Omni Block and these buildings thermally perform exceedingly well in all climate zones. It is very important to note that they all perform much better than very similar buildings built with lightweight materials that have higher tested R-Values achieved via ASTM C-1363.

It is permissible for lightweight or heavyweight building materials to be layered to increase total wall assembly R-value. When masonry block is layered to increase the total wall R-Value, the results seem to be consistent at first look. But further assessment provides results that are actually unexplainable and actually illogical in "real world" settings. Please refer to the adjacent Table. Notice that the increase in R-Value from the 4″ block to the 8″ block is 0.3 and from the 8″ block to the 12″ is 0.1. These differences are hardly distinguishable and may only be numerically distinguished by a "rounding" up or down or a margin of error. When one considers that the generally accepted R-Value of "ice" is 1.0 per inch (how this value was derived is a mystery) the tested R-Value of a 12″ CMU block is 10.7 LESS than 12″ of ice.

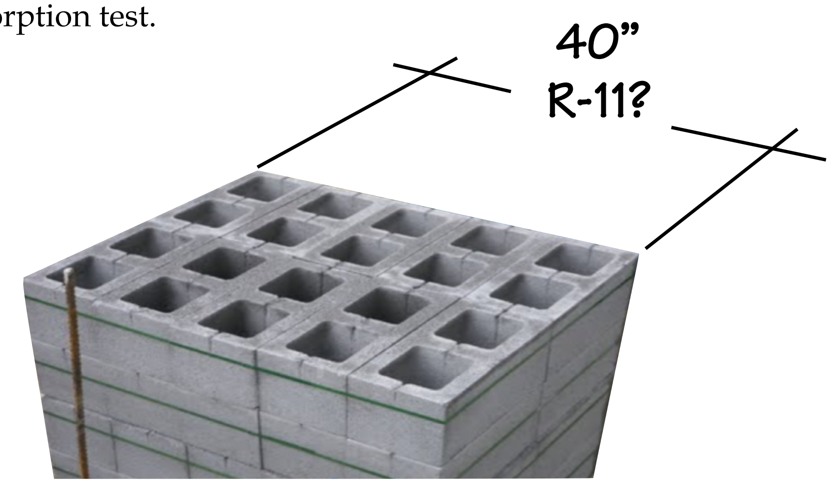
Current Industry Assumption

BLOCK THICKNESS	DENSITY	R-VALUE	NUMBER OF BLOCK LAYERED TO ACHIEVE A 48" THICK WALL	TOTAL R-VALUE
4" BLOCK	105 LB	1.9	12	R-22.8
8" BLOCK	105 LB	2.2	6	R-13.2
12" BLOCK	105 LB	2.3	4	R-9.2

Source: National Concrete Masonry Association (NCMA) TEK 6-2B (Abbreviated)

Further analysis of the above Table presents information that creates the question, how can the 4" block, with the lowest individual R-Value, be layered 12 times to form a 48" overall wall thickness, but achieve the highest total wall R-Value? The masonry industry has spent hundreds of thousands of dollars trying to derive accurate and reliable thermal tables when thermal mass is part of the wall assembly. The actual monitoring of installed Omni Block via thermocouples will provide accurate and reliable "real world" performance data rather than laboratory testing results. The accurate data will prove that current industry relied upon R-Values for masonry are not indicative of its thermal performance.

The Table above further supports our hypothesis that the face shell ("shell" is the industry's term for the face of a block) that is exposed in the ASTM C-1363 test chamber absorbs heat, virtually the same, whether it is a 4" block, 8" block, or a 12" block. It is an absorption test.



8x8x16 105 lb density equals R-2.2 (NCMA TEK 6-2B)
A wall 5 block thick x R-2.2 = R-11

Scope

Technology available today allows for real world data to be assimilated and shared with the industry including design professionals, builders, HVAC contractors, and consumers. The intent is to use thermocouples, strategically placed on the face and within an Omni stretcher unit; then strategically place those stretcher block units within the constructed walls of buildings at all four directional exposures (north, east, south, and west). The thermocouples are mechanically connected to a circuit board whereby each thermocouple is uniquely identified with an output measured in degrees Fahrenheit. The output datum is then sent to "the cloud" in a readable json format which enables the Omni Block web designer to compile and present the data on Omni Block's web site 24/7. The data must be stored indefinitely so that verifiable performance can be compared to actual ambient air temperatures in the various climatic zones of the monitored buildings over time. This information then can be used to anticipate and predict heat/cooling loads on not only a building, but the building's rooms according to directional exposure.

All 7 climate zones will have monitored buildings.

The methods and equipment utilized for the exercise must provide results that are scientific and "above reproach".

The required deliverable is to provide "kits" that allows Omni Block personnel to assemble the Omni Block stretcher units and standard CMU units with thermocouples, and monitoring devices that can be sent to general contractors or masons for upcoming construction projects.

Strategy and Cost

In order to accomplish the exercise potentially an arduino programmer might be the skill set that can achieve the combination of software and hardware necessary. Cost is yet to be determined. Duplicating the monitoring system should be very inexpensive and may ultimately be offered to the consumer at an economical price. The programmers' expertise and experience should expedite the implementation and provide un-biased third-party professionalism. There are Omni Block buildings that are preparing to start construction, so the sooner that the monitoring process is realized and the equipment is determined and procured, the sooner the data can be collected.

Determine Thermocouple Type

There are various types of thermocouples. The thermocouple required must:

a) be thermally sensitive and possess the ability to measure to .1° F temperature fluctuation.
b) be small in physical size, which allow it to be mechanically adhered to various block wall locations with minimal adhesive, and allow the normal installation of the Omni Block foam inserts within the block.
c) consist of wire leads that are insulated because the thermocouples will be placed up to 8′ from the monitoring board and measurement device. The wiring must not be affected by other heat sources from the thermocouple placement to its measurement.

Determine Measurement Receptor Type

The type of measurement receptor is a key component in the accuracy of the exercise. The measurement receptor must:

a) accurately register thermal data sent to it.
b) be relatively small is physical size. These receptors will be located on the interior walls of living spaces. It is therefore desirable that the wires that run to the receptor (within the interior of the block walls) and the receptor are contained in an integral electrical box or a surface mounted plastic box that is unobtrusive and inconspicuous.
c) be battery operated with significant operable life. It must have a battery life icon indicating the amount of battery life that is possesses.
d) have a low cost. There will be a minimum of four (4) locations per building.

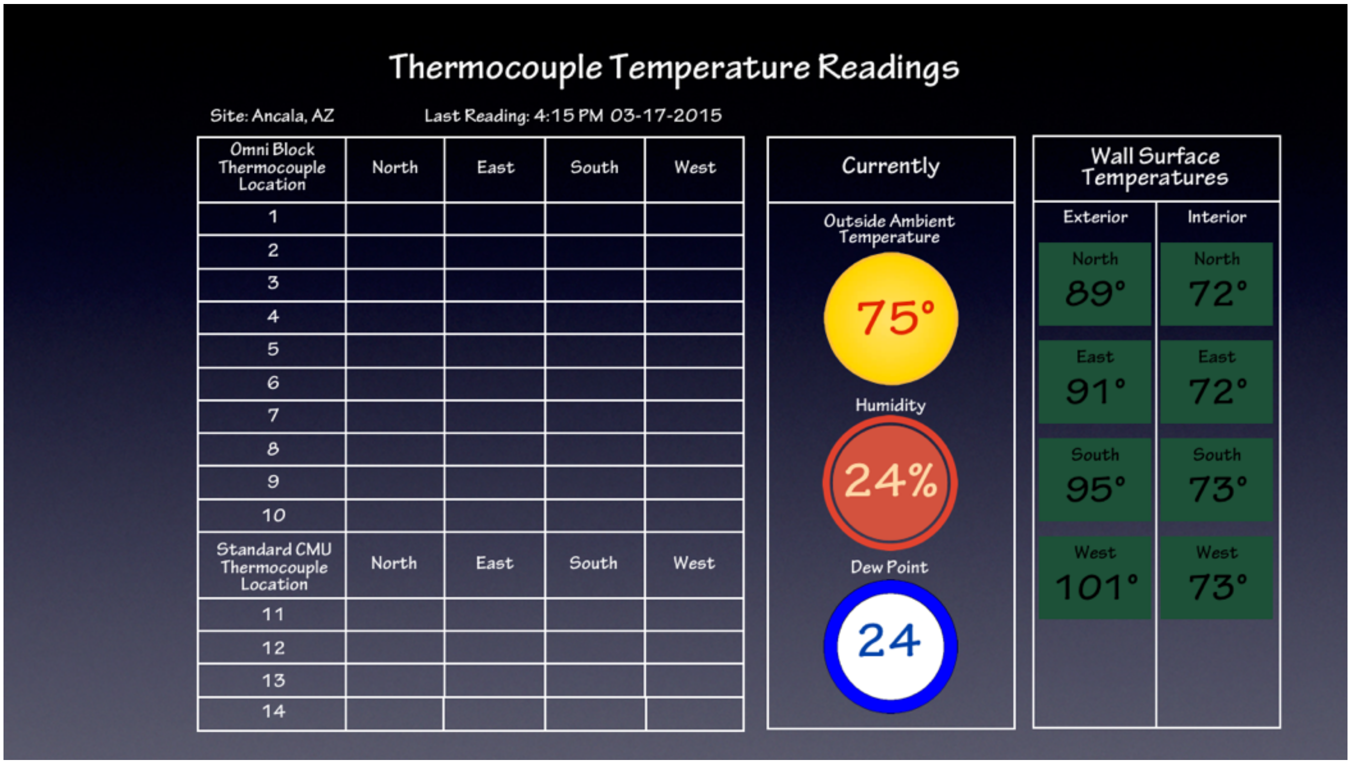
Requirements to Deliver Data

Our web designer has reviewed this project and has determined that the data and temperature must be supplied in a json format along with a unique ID identifier for each device (thermocouple).

Presentation

The web designer will display data results in a **modern and user friendly user interface** that makes it a pleasure to view and access (see following page).

Security - use SALTS (encrypt the string as it is being sent) and HTTPS to encrypt the traffic naturally.



Dashboard Sample

Advanced Data Reporting and History

In addition to present data display the ability to give a more thorough review and data access to the Omni Block Thermocouple units is derived by the following:

> Give the ability to see a **full history** of the Omni Block Thermocouple unit data reports for a more complete comparison and analysis.

> Build automated **PDF reports** so that users can compile and print a report of there Omni Block masonry units for better accessibility and engagement of data content.

> Enable **CSV export** options to be able to retrieve and use data in reporting documents and analysis.

> Give the ability to set data point history retrieval based on a certain set of criteria.

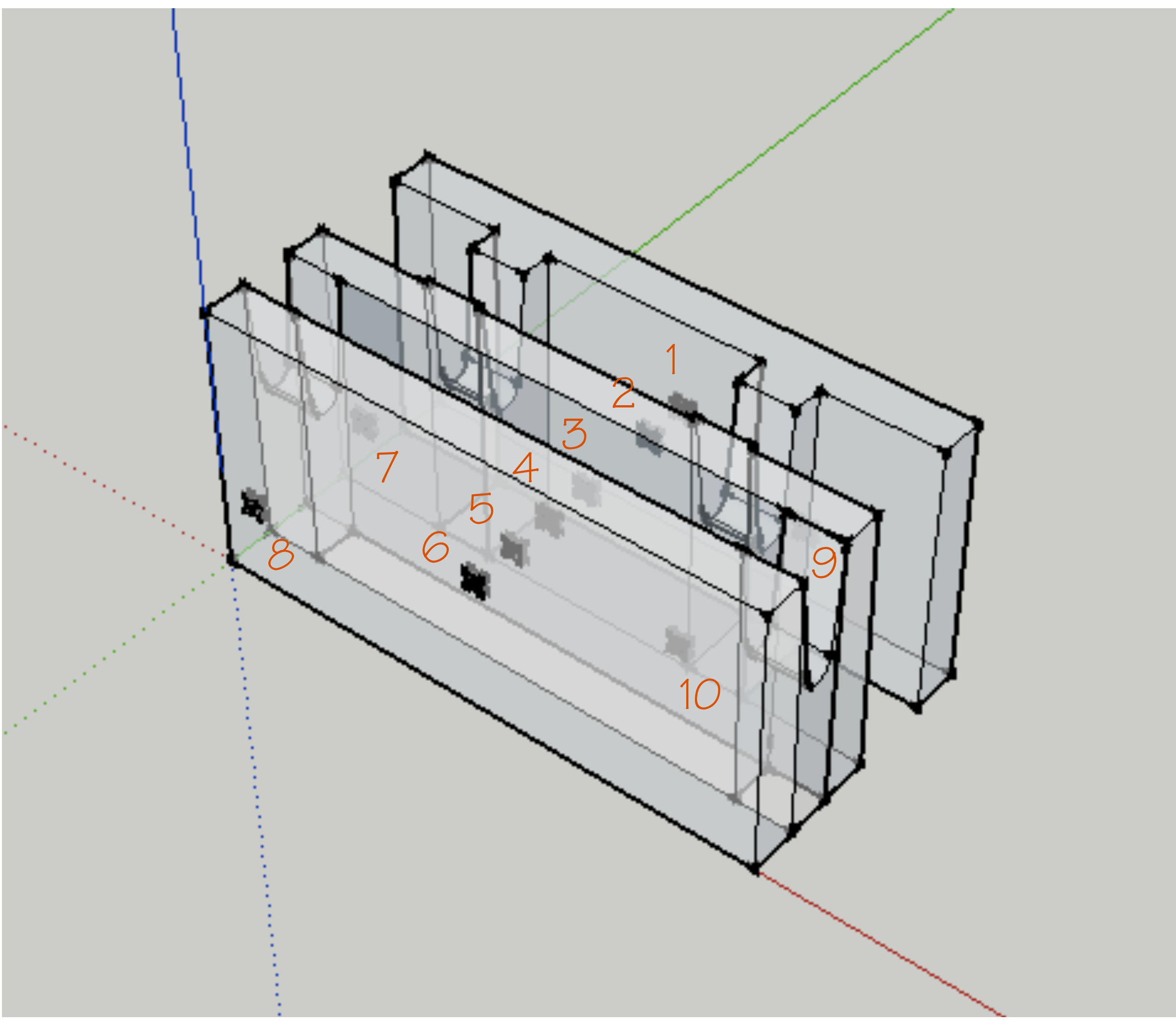
> Create separate PSD's for the mobile/tablet **interface**.

> Enable several different types of **view points** to see hourly, daily and monthly averages and reports.

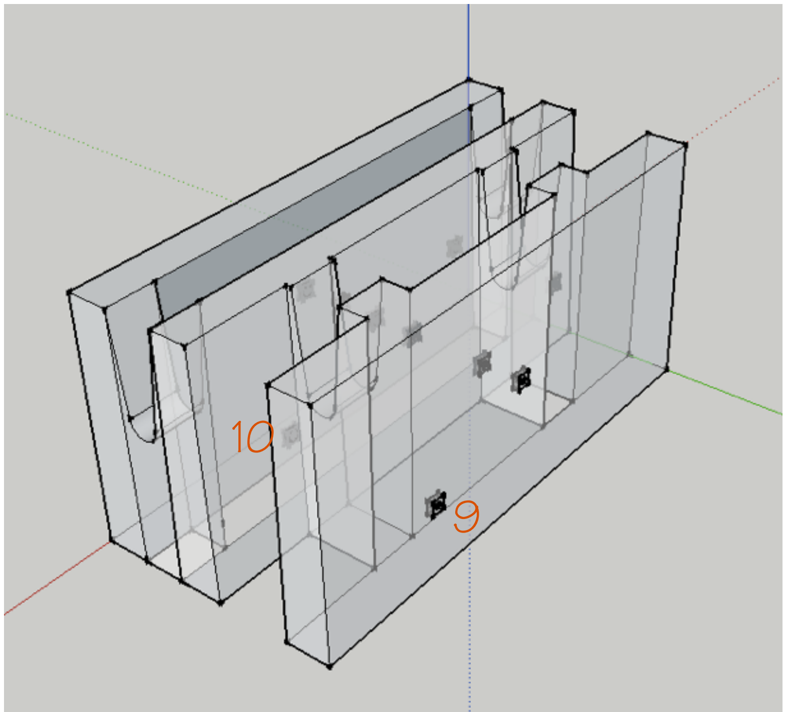
Thermocouple Placement

The below schematic shows an Omni stretcher block with ten (10) strategically placed thermocouples. The middle of each individual block face contains a thermocouple, located on a horizontal plane, account for six of the thermocouples. The purpose of this placement strategy is to be able to determine the heat gain/loss across each block face and each foam insert at the center of the block. These measurement locations minimize the affect that mortar joints would have the temperature.

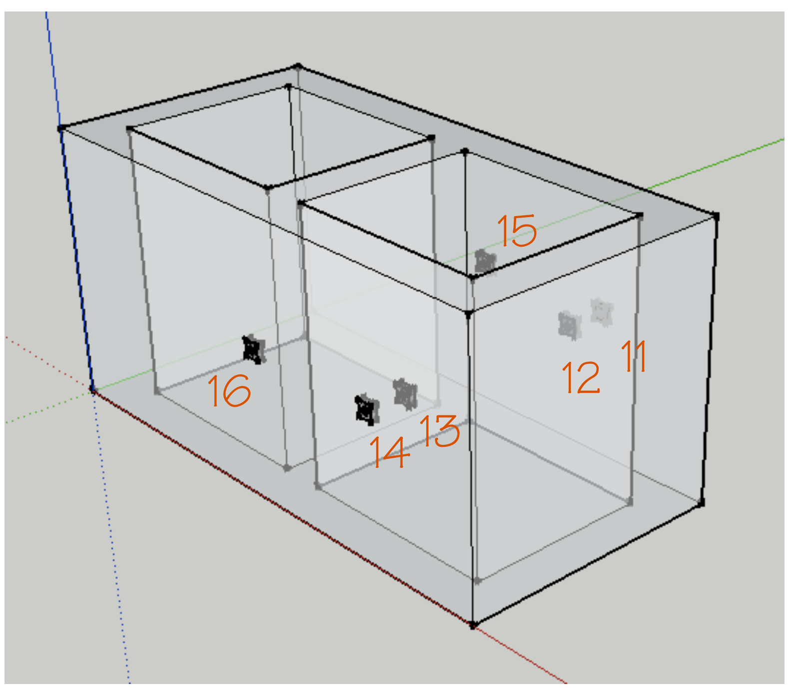
Thermocouples #7 and #8 would be placed on a horizontal plane in order to determine the heat gain/loss at exterior cavity cross webs. The cross web measurement would be at the exterior face shell surface to the middle lineal wall interior face shell.



The schematic below depicts thermocouples #9 and #10, located on a horizontal place that would measure from the exterior middle lineal wall surface to the face surface of the interior face shell. This placement would measure the heat gain/loss at the interior cross web.



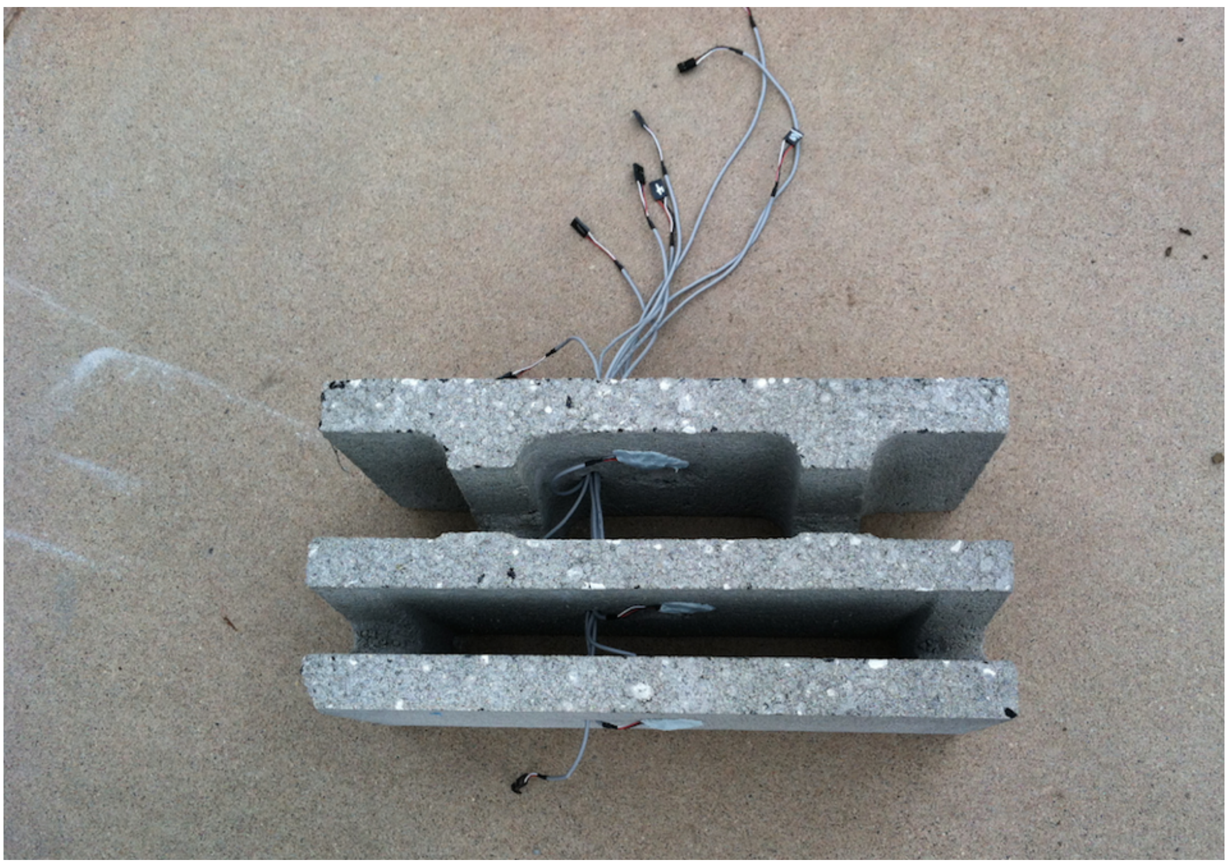
The schematic below shows a standard CMU with six (6) thermocouples. Four of the thermocouples (#11, #12, #13, #14) are placed on each side the interior and exterior block face shell surfaces in the center of cavity void on a horizontal plane to determine the heat gain/loss of each face shell and the cavity void.



Thermocouples #15 and #16 are located on a horizontal plane at the center cross web of the standard CMU. This placement will minimize the affect of the mortar joints. The similar placements of #1 and #2 of the Omni stretcher and #11 and #12 of the standard CMU will serve as "control" measurements and should be identical (within a yet-to-be-determined tolerance) with each other.

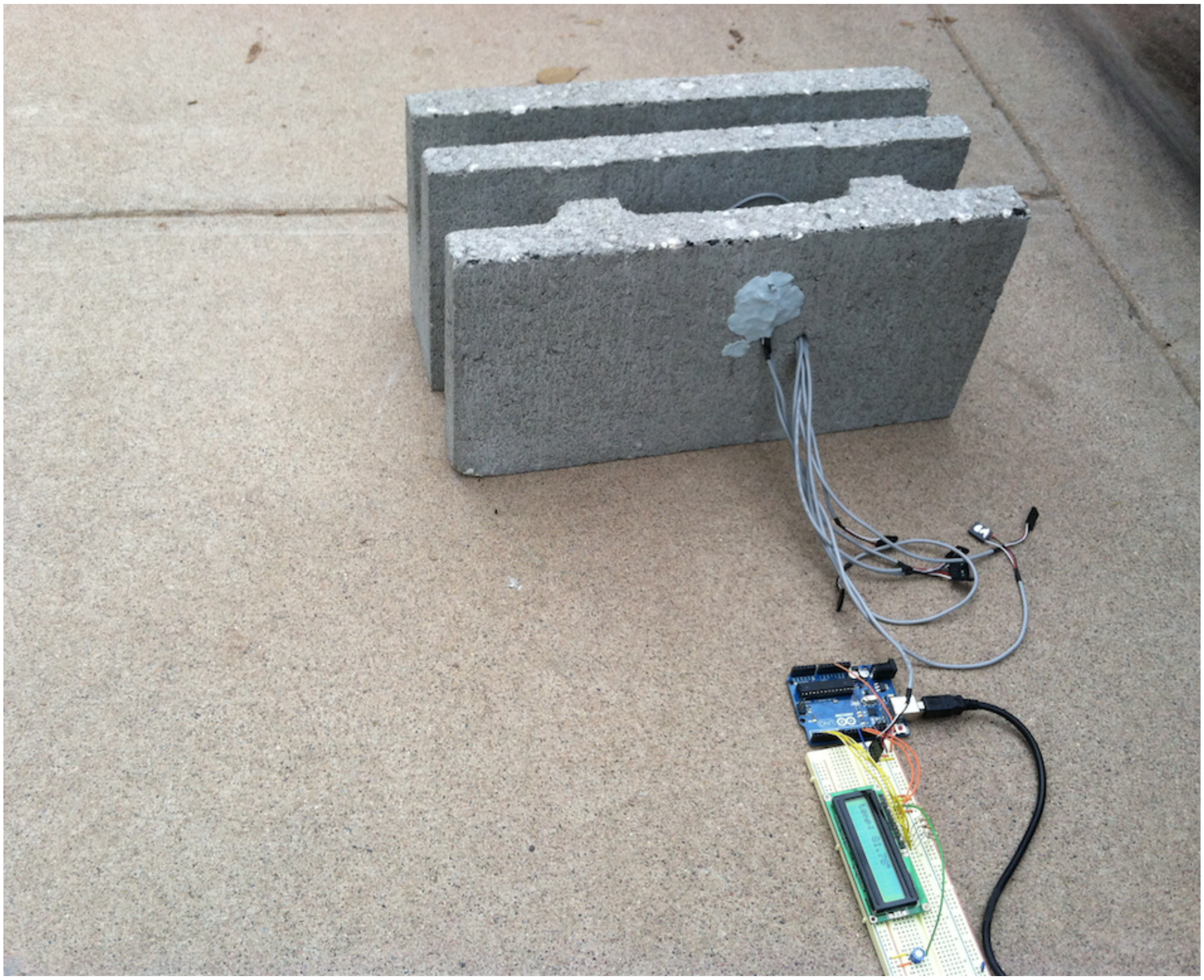
Conceptual Work

Experimental work has been done on a prototype. Currently no specific information is available on any of the thermocouples, digital gauge, or circuitry that is pictured herein.



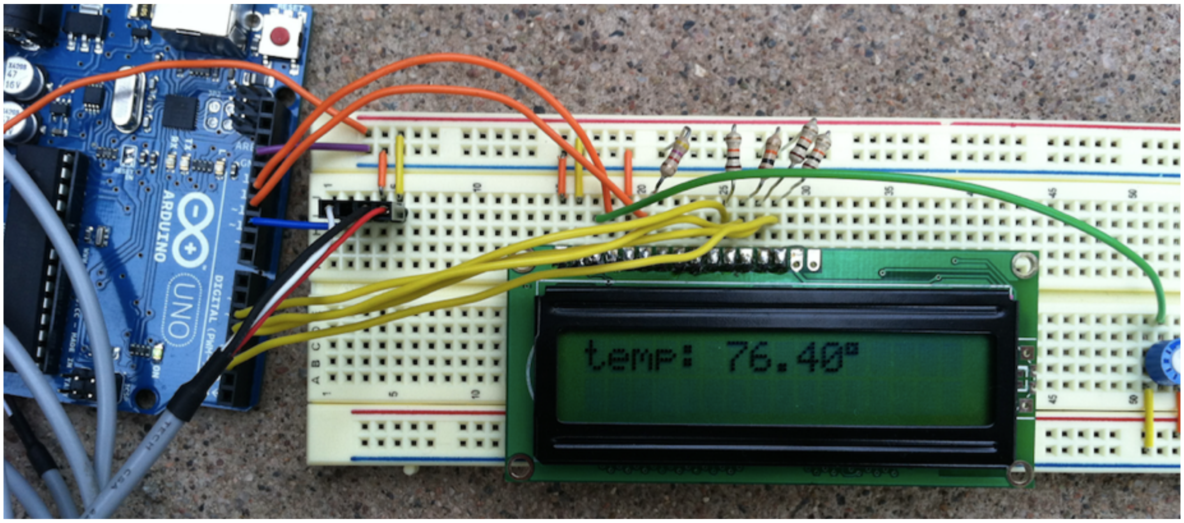
The above photo shows an Omni Block that has thermocouples affixed with an adhesive. The wiring has female terminals attached.

The below photo shows the apparatus connections. The female terminal is matched with a male terminal that is mounted to the circuit board. The prototype digital temperature gauge and has multiple read-out capability (10 required). This gauge is connected to a data device that can deliver the data to a server.

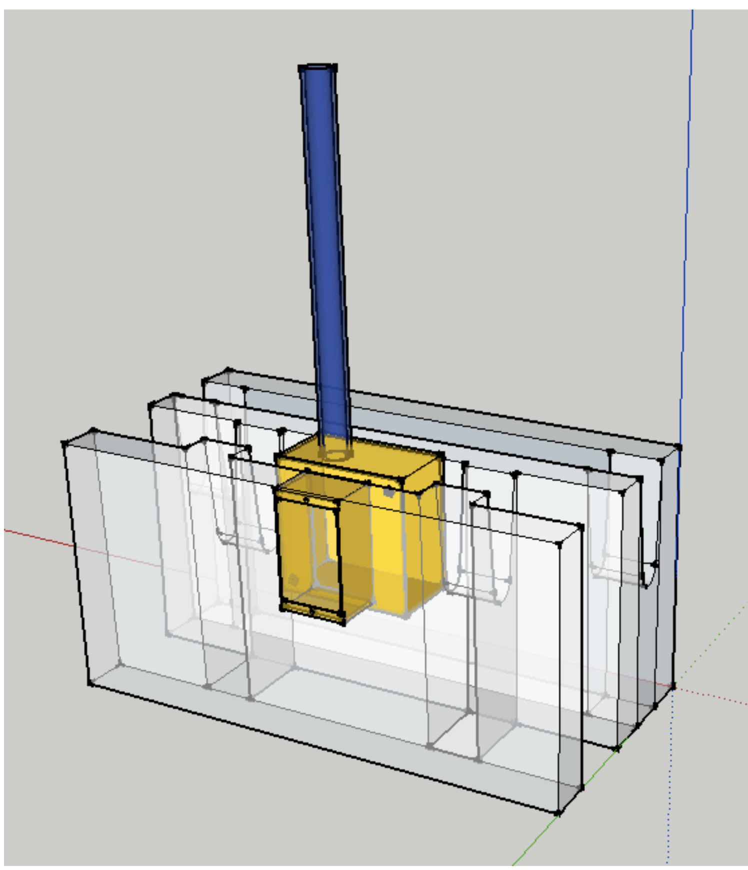


Note the wiring grouping shown in the photo above that protrudes out the middle of the block would not occur in this planned scope.

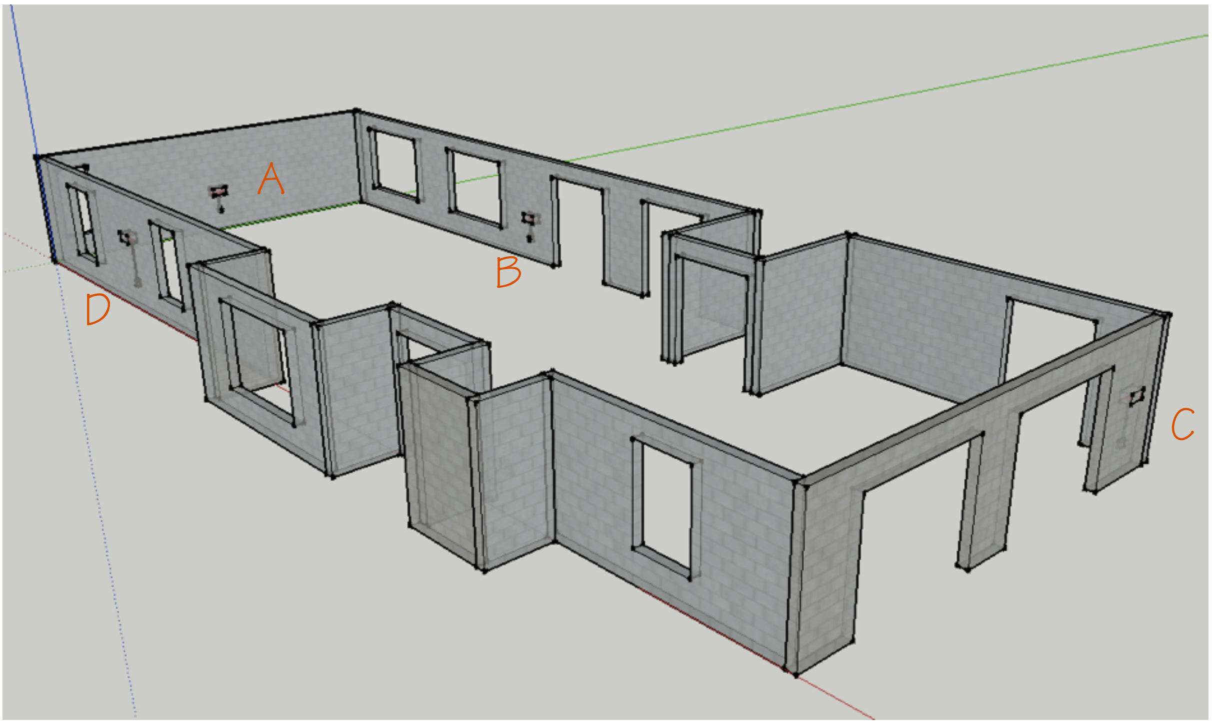
The below photo depicts the circuit board, temperature gauge, and circuitry.



As previously mentioned, these photos are of the prototype. It is desirable to reduce the size of the prototype to allow the entire monitoring components and gauge to be mounted in a standard electrical box within the block as shown below. The circuit board can be housed in the block cavity or in an electrical box as illustrated below. A conduit from the thermocoupled block to a lower block is available. The block cavity overall size is 5″w x 8″ h x 2.5″ d.



The below photo depicts a typical thermocouple building placement. The block, with specific thermocouples, is placed directly above the electrical box and conduit. All four directional exposures A, B, C, and D (north, east, south, and west respectively) would facilitate a greater understanding of heat gain/loss of a building. It may ultimately indicate where additional insulation or thermal mass is required to achieve maximum thermal efficiency.



Summary

This process could change how the industry thermally rates products. Laboratory test results of any product assume that those products are installed in the field as prescribed during the test procedure. This assumption is an inherent problem when relying solely on test results. Contractors do not always install products correctly. Real world thermal results as determined via thermocouple monitoring will provide considerably more reliable data.