12 Middle-East Corrosion Conference in Bahrain
February 3-6, 2008

"THERMAL INSULATION COATINGS AND CORROSION CONTROLS"

Much of what is known about ceramic compounds is limited to Space Travel Technology or minor R&D work performed by major corporations associated solely with their own raw materials.

Beginning in 1988, one company begun research to determine what type ceramic compound could perform to block the absorption of heat and therefore block heat transfer. As research continued, design characteristics became clear as to their crystalline structure, density and natural earth composition that would provide the best possible heat resistance and blocking ability.

Since form, size and type of compound had never been studied for the purpose of heat control in a commercial form, finding and testing individual ceramic compounds became the vocal point to find all possibilities available. Sources for the compound research ranged from industrial materials to exotic compounds from around the world. The range of the focus was held open to have no limitations in order to accommodate all possible earth or man made materials. As research developed, crystalline structures was noticed to contribute to a compound's ability to refract heat waves from both sun radiation and mechanical heat sources. Density was found to be a critical component in heat absorption and loading. Size was found to be extremely important in the effort to block particular radiation heat waves.

During the development period of research, in order to find the correct compounds, engineering studies were being performed to determine which radiation heat waves were the most concentrated representing the total heat load from sun radiation. From this research, ceramic compounds were selected to perform the blocking of these heat waves for the design of the coating. Designing a ceramic coating to block the studied heat waves provides the scope for blocking 100% of the "heat load" from these waves.

For any coating to be represented as a "reflective" coating that can block "heat" could mean that it only blocks solar or visual light which is on a part of the radiation heat received from the sun. Radiation heat is broken down into three separate engineered categories: UV, Visual Light (short wave) and Infrared (long wave). To represent any coating to be an "insulation" coating without blocking all three of these waves is not representing the scope of heat absorption and transfer.

In order to better understand the standard materials used for insulation and relate this to the new technology of ceramic heat blocking, a brief understanding is presented. Perception of insulation materials and how they actually function in real-life applications have changed dramatically over the past five to ten years.

The given parameters of BTU or W/mK heat transfer have been critically challenged according to how the numbers are interpreted by the standard nominal laboratory test procedures. The lab procedures established created unrealistic test parameters, such as determining a near "0" humidity environment, a single preset temperature (obviously established for the optimal heat resistance of air filled materials), and zero air flow. **The testing established for all air-filled insulation materials does not and will not relate in any practical way to the actual atmospheric conditions** in any of the environments known throughout the world.

Given the introduction of **ceramic compounds** created for the purpose of insulation more than twenty years ago, architects writing specifications have seen very positive results in their insulation affects. Since the ceramics are usually carried within resin systems having a low permeability, the effect of air flow that cancels the insulation impact on air filled materials is eliminated. The timing of heat transfer through air pockets is eliminated, and the effect of moisture load into the material (that immediately cancels the W/mK number and R Value) is eliminated as well. Air flow and moisture load are two elements that are present in all atmospheric conditions and immediately affect the performance of standard insulation materials. This means that any W/mK numbers and R Values calculated for these materials (fiberglass/rock wool, cellulose, etc) in laboratory testing are useless outside of the laboratory conditions. In addition to the negative affect convection (air flows) and humidity conditions will immediately have on these materials, the materials are compacted and compressed into position as they are installed. These traditional materials **are only effective** as presented by lab testing if installed at the full 6 inch (150mm) thickness and placed in the identical environment as tested. In all installations, the installer must compress the materials in order to force them into position. Generally, the wall cavity is 4" or 100 mm deep and 6" of the material is compressed into this area. This compression reduces the thickness (creating a higher density) upon which these materials were rated for a particular W/mK value, therefore reducing the effective insulation value placed in the wall or roof. As reported by the ASHRAE (**American Society of Heating, Refrigerating and Air-Conditioning Engineers)** code group in the U.S.; when fiberglass (one of the air filled materials) is used over metal structures or framing of any kind, **the R 21 value rated material is immediately reduced to a R value of 7.4** because the material does not and cannot effectively cover the metal surfaces, supports and connections to effectively provide the insulation value throughout the wall or roofing. (Traditional wood framing will conduct and transfer heat as well in a similar fashion, though the results are not quite as dramatic)

See the following charts produced in ASHRAE Code 90.1: Reference 2nd chart.

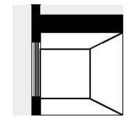


Table 402R Parallel Path Correction Factors for Metal Roof Trusses

Size of Members	Spacing of Framing (inches o.c.)	Insulation R-value	Correction Factor	Effective R-value
All	48	R-0	1.00	R-0
		R-5	0.96	R-4.8
		R-10	0.92	R-9.2
		R-15	0.88	R-13.2
		R-20	0.85	R-17.0
		R-25	0.81	R-20.3
		R-30	0.79	R-23.7
		R-35	0.76	R-26.6
		R-40	0.73	R-29.2
		R-45	0.71	R-32.0
		R-50	0.69	R-34.5
		R-55	0.67	R-36.0

Table 402S Effective R-values for Wall Insulation Installed Between Metal Framing

Nominal Framing Depth	Nominal Insulation R-value	Correction Factor	Effective R-value
4"@16"o.c.	R-11	0.50	R-5.5
	R-13	0.46	R-6.0
	R-15	0.43	R-6.4
4"@24"o.c.	R-11	0.60	R-6.6
	R-13	0.55	R-7.2
	R-15	0.52	R-7.8
6"@16"o.c.	R-19	0.37	R-7.1
	R-21	0.35	R-7.4
6"@24"o.c.	R-19	0.45	R-8.6
	R-21	0.43	R-9.0
8"@16"o.c.	R-25	0.31	R-7.8
8"@24"o.c.	R-25	0.38	R-9.6

The correction factors for metal framed walls may be used with metal studs of 16 ga. or lighter.

Table 402T Effective R-value of Fiberglass Batts Compressed in Various Depth Cavities ($h\text{-}ft^2\text{-}°F/Btu$)

Nominal Lumber Size	Actual Depth of Cavity	Insulation R-values at Standard Thickness													
		38C	38	30C	30	25	22	21	19	15	13	11	8	5	3
2" × 12"	11-1/4"	38	37												
2" × 10"	9-1/4"		32	30											
2" × 8"	7-1/4"		27		26	24									
2" × 6"	5-1/2"				21		20	21	18						
2" × 4"	3-1/2"						14		13	15	13	11			
2" × 3"	2-1/2"										10				
2" × 2"	1-1/2"										6.5	6.0	5.7		
2" × 1"	1/2"													3.2	3.0

The standard thicknesses are as follows: 10-1/4" for R-38C, 12" for R-38, 8-1/4" for R-30C, 9-1/2" for R-30, 8" for R-25, 6-3/4" for R-22, 5-1/2" for R-21, 6-1/4" for R-19, 3-1/2" for R-15, 3-1/2" for R-13, 3-1/2" for R-11, 2-1/2" for R-8, 1-1/2" for R-5 and 3/4" for R-3.

The 3rd chart (prior) exhibits how compression and compaction degrades the performance of standard insulation by decreasing the air voids and increasing the density within it, thus increasing heat load and heat transfer. Contributing to additional compaction and compression over time include age and gravity, as well as added weight from moisture, mold and mildew, and dust or dirt.

It has been learned from studies performed on testing procedures created for testing insulation materials, that results are adversely affected by atmospheric conditions when used in the field. Carefully chosen ceramic compounds are designed to work regardless of the atmospheric conditions found in all field applications. The ceramic compounds were chosen from extensive research on over 3200 compounds to determine which type of heat flow could be blocked. Ceramics selected were mixed with other effective compounds to provide a comprehensive reflection or block from the sum of each particular heating component. (UV, Visual Light, Infrared, Thermal Heat.)

The natural process of becoming dirty in field use has little to no effect on their performance because from the ceramic compound research, compounds were selected according to their ability to block specific heat sources. Radiation Heat Waves have particular “nano” wavelength measurements that must be blocked by using particular compounds and sizes. The ceramic compounds are designed and engineered to block specific waves regardless of the topical loading of dirt for the reason that heat waves can pass through thin, topical dirt deposits. As a representative sample of how the ceramic compounds should perform in the field and not have adverse effect on the performance due to normal weather cycles and dirt, the following gives a detail of the desired result.

Solar Reflectance Test After 15 Years

Reflectance Durability

- **User**

  Mr. Roger Kuntz, President of K-Teck
  Routel Box 69, Grainfield, Kansas 67737

- **Test Piece**

  The test piece was taken from a 15-year old roof in January 2006 where Super Therm was applied in 1989.

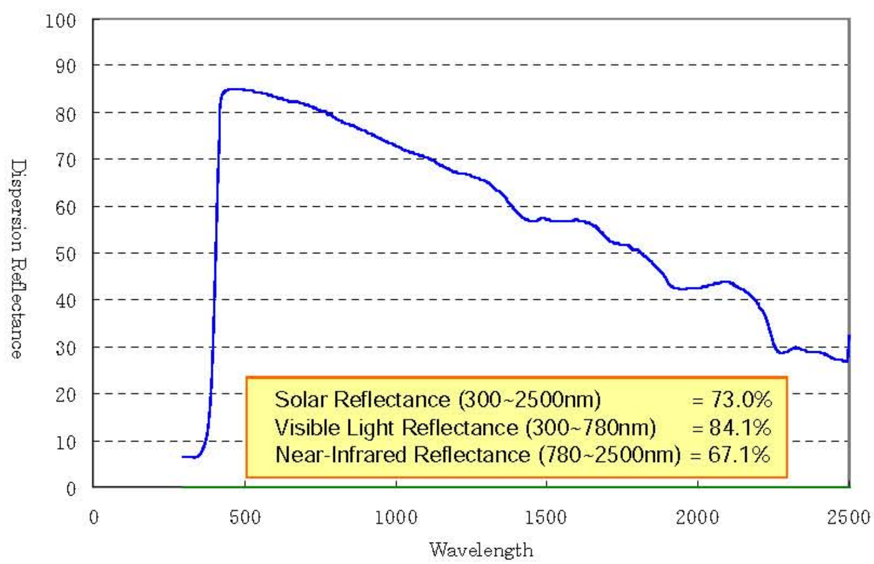
- **Climate Condition**

  K-Teck is a manufacturing facility located in Grainfield, Western Kansas. This area's climate is very severe with -21°C in the winter with snow and ice and with 38°C in the summer with sand storms and very strong sun radiation.

- **Solar Reflectance Test**

  Test Center: Building Material Test Center
  Test Method: Solar Reflectance Test JIS R 3106 (Reflectance Test on Plate Glass)

  Test Result :



- **Evaluation**

  This is an excellent result for a roof of a factory in extremely severe conditions to remain at 84.1% of visible light reflectance and 73% of total solar reflectance after 15 years. The reflectance of near infrared is 67.1% because the Super Therm® at that time did not contain the fourth ceramic which is designed to block infrared rays introduced in 2000. This fourth ceramic repels 65% of infrared, so the result with the current Super Therm® will be better.

THE STUDY BELOW WAS PERFORMED IN JAPAN TO DETERMINE THE TYPICAL REFLECTIVE LOSS OF HIGH REFLECTANCE COATINGS MARKETED IN JAPAN AND THE USA.

Reflectivity change due to aging of other reflective coatings

Twenty one high-reflectance coatings have been tested based on the JIS Standard as a part of the heat island mitigation effect investigation program by the city of Tokyo. The result of the newly applied product was publicly released prior, but the result after it aged has just been released in the “International Workshop on Countermeasures to Urban Heat Island” in a presentation “**Research on Cool Roof in Japan**” by Mr. Yasushi Kondo, PhD of Musashi Institute of Technology. Dr. Kondo is a researcher and authority in the high reflectance coating field.

There are many high-reflectance coatings in the market nowadays, but not enough research has been done on product quality. Therefore, it is difficult for users to select reliable products.

In the test performed by Dr. Kondo, the product No.13 had one of its highest reflectance in the new stage, but only after one and a half years (571 days) the reflectance had decreased by about 30%.

<Product No.13>

	Solar Reflectance (300~2500nm)		**Visible Light Reflectance** (300~780nm)		**Near-Infrared Reflectance** (780~2500nm)	
	New	571 days	New	571 days	New	571 days
White	80.8 →	**54.8**	85.2 →	**50.4**	82.1	61.4
Black	40.4 →	30.7	5.8 →	6.9	71.2	51.5

Test Method: JIS R 3106 (Reflectance Test on Plate Glass)

On the contrary to this test result, Super Therm®'s reduction in reflectivity after **15 years** was only **19.2%**. (92.2% - 73%=19.2%)
This result proves that Super Therm®'s durability in reflectivity is by far excellent.

Super Therm®

- The Solar Reflectance at the new stage was **92.2%** (Building Material Test Center)
- The Solar Reflectance **After 15 years** (K-Teck, Kansas)

	Solar Reflectance (300~2500nm)	**Visible Light Reflectance** (300~780nm)	**Near-Infrared Reflectance** (780~2500nm)
White	**73%**	**84.1%**	67.1%

Test Method: JIS R 3106 (Reflectance Test on Plate Glass)

- The reduction of solar reflectance in 3 years tested for the Energy Star Program by EPA was only **0.01%**.

In the insulation developments, blocking of radiated heat from sunlight is mainly for exterior surfaces. If the radiated HEAT LOAD trying to enter a structure can be reduced by 95%, it reduces the amount of heat available for transfer and, therefore, acts to control the conduction of heat. With considerably less heat load available for transfer, there is less heat available for conduction into the facility.   Because the HEAT LOAD is controlled and the majority blocked on the initial surface, no “R” value is either required or desired for this type of insulation material. Blocking the initial heat load is the “key” to controlling heat load and flow into or out of a building structure. The current insulation materials or “air-filled” materials depend solely on absorbing heat for a given period of time and then allowing it to transfer at a controlled rate into the building. These materials were **never designed to stop** the loading and transferring of the loaded heat.

Insulation also covers hot pipes, furnaces, boilers and all types of hot surfaces or circumstances to block the heat transfer. This type of insulation requires different ceramic blends for a coating to be effective in this type of requirement. To suggest that one type of ceramic can do all jobs of insulation regardless of the heat level, or whether there is a need to control hot surface conduction is nonsense. Different ceramic compounds carried by specific resin systems must be designed for their specific, different requirements.

Research was performed on all ceramic compounds to find the ones that could block heat transfer in a “catch and hold” method. Instead of trying to reflect or repel heat from a hot pipe surface back into the pipe, which would enjoy very limited success because of the physics involved (cooler heat cannot be thrown back to higher heat), ceramics were found that resisted the loading of heat on the pipe surface. The heat loading into the pipe surface from the interior of the pipe is stabilized due to a near equilibrium having been reached to match the interior heat level. This may increase the pressure inside the pipe or vessel because there is a reduced surface heat release causing the interior to actually contain more of the produced heat energy and, therefore, increasing the pressure, as found in steam pipes. When the heat is trapped, the pressure will increase, which will in turn elevate to higher temperature levels than previously experienced. The overall effect is a reduction in the fuel consumed to maintain the heat level inside the pipe or vessel because of the limited loss of heat off the surface.

Again, air-filled insulation materials cannot hold the initial surface heat load of the pipe or vessel. This heat has always migrates and is transferred to the cooler air side of the materials. Because these materials are thick, the heat release from the surface can dissipate within the three to six inches (75mm to 150mm) of standard batt insulation material wrapped around the pipe or vessel. When physically touched on the exterior side of this material, one cannot feel the amount of heat loss because your hand is being held structurally away from the heated surface by 3-6inches (75-150mm) by the batt insulation, rather than the warm air being cooled within the thickness of insulation itself. Again, since one does not feel the extreme heat, the idea that the material is insulating is assumed. Simply remove the 3-6 inches (75-150mm) of insulation material and hold your hand the same distance away from the pipe or vessel surface and you will find that it will be cooler than with the material in place. Why is this? Air.

Air, which is assumed to be the best insulation in the universe, is dissipating the heat so quickly in the distance from the pipe surface to your hand, that nothing is felt. Conduct an experiment. Hold a piece of notebook paper 3-6 inches (75-150mm) away from the pipe surface and using an Infrared heat gun, record the heat on the surface of the paper. It will be cooler than the standard insulation material. Why? Because the "air" is dissipating the heat quickly and the paper is not loading any of the heat. The air-filled insulation materials actually can act as a structure to hold your hand away from the hot surface so that you will not be burned, but in real insulation effect (considering moisture load and air movement inside the materials), the insulation utilized to actually hold heat without dissipation on the surface is very minimal.

With the development of products similar to the example of HOT PIPE COATING (HPC) and HOT SURFACE COATING (HSC), that have a different layering of ceramic compounds based on resisting absorption and the loading of heat and not reflection, the key to actually insulating the pipe or vessel was found to be fast, easy and extremely more effective. Unlike the air-filled insulation materials, it is not a measurement of how much or how fast the surface heat is dissipating through the material, thereby requiring great thicknesses. The effect is to resist the initial heat load in order to hold it on the surface of the pipe. This is **actual** insulation.

In the testing procedures of R or K values, the material is tested for its individual heat "resistance" performance value specific to that material. This BTU or W/mK is then divided into a particular thickness to find the relating R or K value. HPC and HSC both have been tested for these values. HSC is 0.071 W/mK per ASTM C 177 and/or 0.06 kcal/m-h-degC or 0.07 W/m-degC.

Thermal Conductivity of HPC is:

Mean temperature °C	Thermal conductivity W/(m.K)
-10	0.059
0	0.060
10	0.061
20	0.062
30	0.063
50	0.066
100	0.071
200	0.083
300	0.094
400	0.106
500	0.117

HPC was taken through a layering of heat levels to show the change in heat flow resistance in actual use, not in a lab. Doctorates in Europe ran the calculations from lab studies and related the findings to actual field use. “As all insulating materials, Hot Pipe Coating performs the best at low temperatures. Above a mean temperature of 350°C, its thermal conductivity passes 0.1 W/(m.K). The effect on the surface temperature and the heat loss of 1 meter run steel pipe thus depends on the temperature of the fluid in the pipe, the insulation thickness applied, the diameter of the pipe and the fact of the pipe hangs inside or outside. Only to illustrate the effect of Hot Pipe Coating, we calculated the reduction in heat loss per meter run for a steel pipe with an exterior diameter of 10 cm, hung in an environment with an effective temperature of 20°C. The pipe transports a 350°C hot fluid and is insulated with a 1 cm thick layer of Hot Pipe Coating. Without coating, the heat loss touches 3409 W/m. With Hot Pipe Coating it diminishes to 776 W/m, i.e. a decrease with 77.3%. The average thermal conductivity in the coating then reaches 0.088 W/(m.K)”.

In the testing and results for the air-filled materials such as fiberglass, rock wool and others, the W/mK number will appear only at the 23 C (73F) testing level. Their numbers will be in the range of 0.04. Compared to HPC (ceramic filled coating) at 0.062, these air-filled materials appear to show greater ability than that of HPC, but this is based purely upon lab performance without factoring air flow and humidity. Therefore, in actual use, these numbers are completely invalidated when air begins to enter and flow through the product, creating a faster release of the heat and causing the resistance to drop dramatically. At the same time, moisture begins to immediately load the material which carries heat at a very faster rate to the cool side. With the combination of air flowing into and through the material and the induction of moisture, this material cannot provide the presented W/mK value as of the day it is applied. On the other hand, the uniquely selected ceramic compound coatings can and will perform as stated because they were tested for water permeability to show the ability to resist moisture load and air flow. The ability to stabilize the environmental effects over the coating surface in which they operate allows these coatings to function as presented from testing results in the field through actual use and consistent performance. This is why the products will control “Corrosion Under Insulation” (CUI) by prohibiting the moisture load and air flows under the coatings to corrode the surfaces coated.

In as much as heat ALWAYS goes to cold, the purpose of reflective insulation has been to control (slow down) the transmission of heat. Specially selected reflective ceramic compounds keeps the heat from loading onto the protected surface. If it doesn't load, there is no need for traditional insulation. The properties of non-conductive insulation ceramics are completely different where they are required to not absorb the surface heat off of pipes or tanks and contain this heat on the surface of the pipe or tank to provide the insulation needed.

The new generation of ceramic designed coatings can provide insulation without being affected by moisture and air flow. They can contain the heat at the surface level and therefore resist heat loss from the surface and holding more heat on the interior of the pipe or tank. The closed film can help prevent moisture and air to enter the coating film and therefore provide for a dramatic decrease in corrosion under insulation which is a major cause of corrosion problems in the field.

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