SUPER THERM

Versus

R Value Insulation Myths

WHAT IS “R” RATING? // WHAT IS “K” RATING?
Why is the “K” value the most important value in finding heat conduction before finding the “R” rating?

PhD. Inn Choi’s comments (Ph.D. in Mechanical Engineering, advanced heat transfer and fluid mechanics, Research team in Owens Corning Fiberglass, Du Pont, Westinghouse and Pacific Northwest National Laboratory) noted in red.
The “R” value is simply the reciprocal of the “K” value.

Why are the values assigned to Fiberglass or any batt type or non-radiant blocking “insulation” material missing the third part of the three components (convection, conduction and radiation) that make an insulation material valid?

There is a reason that the people in responsible positions making the decisions on insulation are completely confused on true insulation values and the truths about fiberglass. Since the middle to late 70’s, the fiberglass manufacturers (Owens Corning) made a point to establish formulas and work the numbers to convince engineering, architect groups including the public that this new product was the answer to insulation by using their own newly derived numbers to prove the worth.

PhD. Inn Choi’s comments:
Fiberglass is missing the radiation part, which is significant. Other than the radiation, however, fiberglass is doing fine provided that the ‘air trapping’ function of fiberglass is not degraded. Unfortunately, the ‘air trapping’ function is easily degraded by tear, moisture, and air void inside the wool pack, thus making the formula invalid. So the key point here should not be attacking the formula itself which is derived in an ‘ideal’ condition. The critique should be more on the fiberglass becoming non-ideal very easily in the real world from moisture, mold and mildew accumulation.

Since the formulas and calculations were new to the industry and sponsored by unknown theories and respected engineers with high-level degrees, no one actually questioned the concept. After years, the concepts were accepted without question in the minds of decision makers throughout government, industry, city regulations and in the Universities. Due to this, there is little doubt we have encountered resistance from all these groups when we develop an insulation product that includes all three heat transfer components and in doing so exposes the inherent deficiency in the insulation concepts established by the fiberglass industry.

PhD. Inn Choi’s comments:

Again, the fiberglass concept is fine although it is limited by the missing radiation part. If there is any real misconception of formula, it is with foam insulation where a laminated foil sheets are used between pieces of foam material. The intent is to reflect the radiation. But in this case, all heat reaching the foil barrier is conductive and passes straight through making the barrier useless. The situation gets worse because the foil is in close contact with the material by lamination.

Fiberglass is an ‘air trapper’. Air is a very good insulator with a “K” value of only .16. The “K” value given for air describes the amount of heat which will travel directly through perfectly still, and dry, air. However, air used as an insulator never stays completely still. Instead it sets up an active circulation as one side of the containment chamber is heated. The heated air rises and the cold air falls. This circulation constantly exposes the colder air to the warm wall, thus increasing the delta T across that wall and greatly increases the rate of heat transfer through the chamber. This is where traditional insulation helps. In these materials the air is “trapped” on a great many small chambers called “cells”. While each cell still sets up its own convection current, heat transfer is reduced in direct proportion to the size of the cell. The smaller the cell, the greater the reduction in convection. The resistance from government and industry comes more from health hazard than from insulation effectiveness. This is not to say the insulation effectiveness is fine. It is not. Once installed, people just do not think about it.

We will now go through the concepts, expose the facts, see the truth in the arguments and look at the actual numbers established by the early formulas and how they are badly flawed by completely ignoring the third component of heat transfer. We went back to one of the engineers that worked on the team that developed the insulation concept for fiberglass. This concept was engineered on the fact that the parts of the heat transfer formula that could not fit into the formulas for fiberglass were simply ignored because the material could not and did not perform this important part of heat control and thus in effect ignored the idea that this third component was important at all to heat control and insulation. Oddly enough, this was accepted over time.

PhD. Inn Choi’s comments:

They didn’t ignore radiation. They just didn’t have a means of accounting for radiation. Besides, it was supposed to be an ‘inside’ insulation (not exposed to atmosphere) although we see fiberglass hanging outside everywhere these days.

The entire heat transfer concepts of involving conduction (thermal conductivity, thermal resistance, effective conductivity, etc.), convection (heat transfer coefficient for forced convection, natural convection, etc.), and radiation (emissivity, reflectivity, diffusivity, etc.) are not that complicated once the people involved in this understand the fundamentals of the heat transfer concept at its root. There is no myth in fiberglass Heat Transfer calculations. It is fairly simple because the third component of heat transfer was thrown out to determine the “R” value only because fiberglass cannot reflect. This alone reduces its validity in the total calculation of heat transfer.

PhD. Inn Choi’s comments:

Yes

“R” Rating Birth:

The “R” rating concept was developed specifically for the fiberglass material by Owens Corning in the middle to late 70’s in order to explain why the thickness was needed for fiberglass to work as an insulation material. The “R” rating is only used in the U.S. because the rest of the world uses the “K” factor value of how many BTU’s are transferred through a material per sq.ft. per hour per F. The “R” rating is a result of the calculation after the “K” value is determined. The “K” value must be known before any “R” value can be determined. The “K” value is the single most important value or number to be determined in finding insulation values of any material claiming to perform insulation.

PhD. Inn Choi’s comments:
Thermal conductivity is the measurement of the speed at which heat travels through a material through conduction. In the United States thermal conductivity (also referred to as the “K” value) is commonly expressed in terms of the number of BTUs of heat which will travel through one sq. foot of material which is one inch thick when there is one degree F temperature difference across the material (ie. Delta T). This expression is often stated as Btu/in/hr/sq.ft/oF. The lower the “K” value the better the thermal insulation. The term “R” value is frequently used to describe the performance of insulation materials. The “R” value is simply the reciprocal of the “K” value. Therefore, the higher the “R” value, the better the insulation quality.

Terminology used for heat transfer and how it applies:

Emittance is defined as the total energy emitted per second per unit area. The units of radiant emittance are watt/m2. High emmitance gives off more heat than low emmitance.

Emissivity is defined as the ratio of the radiant emittance of the body to the radiant emittance of the perfectly black body. The value of emissivity for perfectly black body is equal to one and for all other bodies the value of emissivity is always less than one.

Surface emissivity is affected by several variables, the most important of which are the geometric shape of the blackbody, the blackbody temperature, the surface emissivity and wavelength dependence. Additional refinements to the term “emissivity” may be made by defining it in terms of the wavelength of interest, changes due to temperature affects, etc. The simple concept of emissivity can very quickly become a very complex topic!

Mirror may reflect 98% of the energy, while absorbing 2% of the energy.

Blackbody surface will reverse the ratio, absorbing 98% of the energy and reflecting only 2%.

In real life, emissivity is in the range 0.8-0.9. This is because non-ideal surfaces get all sort of shapes, dirt, scars, colors, etc. All these contribute to make the surface’s emissivity go up.

The rougher a surface, the higher the emittance. Inversely, the smoother a surface, the lower the emmitance. As an example, bare metal has a very low emmitance. When it is oxidized, its emmitance jumps up significantly. SUPER THERM is not flat nor shinny, but has very high reflectivity and very low emissivity (a. for instance, if the heat source is outside (roofing or cold pipe) reflectivity should be greatest (or emissivity should be lowest), b. if heat source is inside (hot pipe), emissivity should be greatest (or reflectivity should be lowest). This is an important point!! For a hot pipe, we may want to make the surface more opaque by roughening the surface of SUPER THERM or top coat with a coating that has less reflectivity. This is a result of the unique blend of ceramics used in the makeup of the SUPER THERM which give a tremendous reflective series of ceramic heat reflectors covering the surface area that does not allow heat buildup and gives the mirror effect.

Fiberglass is an "air trapper". The glass wool traps air and that is all it does. As the fiberglass is more than 90% air, and the air moves around inside the fiberglass by natural convection, temperature tends to averages out in all directions.

So if you stick in a T/C, Thermometer, or RTD, in a fiberglass pack, all it does is to measure the bulk air temperature surrounding the sensor tip inside the fiberglass.

Fiberglass "surface" can not be clearly defined, i.e. you don't know where the surface start and where it ends - its all air!

PhD. Inn Choi's comments:
Usually the fiberglass is wrapped with sheets in order to protect the wool and control the wool pack thickness. Measuring the temperature of this sheet is also meaningless as it is just a place holder, not part of fiberglass insulation.
So in a strict sense, you can not really measure fiberglass surface temperature with a traditional contact-based method.

According to one of the participating engineers at the Owens Corning fiberglass lab, they embed T/Cs all over inside to get the bulk temperature and extrapolate the surface temperature that way, which is not accurate.
Even for IR temperature devices, the same dilemma exists for fiberglass as the surface characteristic required to validate IR temperature readings does not exist. Air cannot be a surface! Air is what is flowing over the surface when the temperature is measured.

PhD. Inn Choi's comments:
The fiberglass wrapper sheet is not part of fiberglass thus its surface temperature also means nothing.

Assessment of Insulation Effect and Measurement Drawbacks for Fiberglass
The topics below was addressed by PhD. Inn Choi, Ph.D. in Mechanical Engineering. Dr. Choi taught advanced heat transfer and fluid mechanics at Ohio State University and was one of the founding members of fiberglass research team in Owens Corning Fiberglass at Granville Research Center. Since then he worked at Battelle Memorial Institute, E. I. Du Pont De Nemours & Co., Westinghouse, and most recently at Pacific Northwest National Laboratory. During his tenure, he has published over 67 journal papers on various topics involving advanced fluid dynamics and heat transfer.
PhD. Choi worked with Professor Raymond Viscanta (W.F.M. Goss Distinguished Professor of Engineering in Purdue University and an international authority in Heat Transfer) to do projects at the Lafayette Physical Property Lab where SUPER THERM was tested for BTU heat conduction to find the "K" value to allow direct insulation comparison to fiberglass. These comparisons are detailed under the section of this training entitled **"SUPER THERM, test results to determine, "K" value and Lambda value."**

Taking measurements of surface temperature and why you should be careful of how Infrared devices work and how they read.

Examples of Misperception on Heat Transmission

A reprint of recent statements from a major oil company engineering department about their perception of how SUPER THERM works and performs. This perception is based in a deep seated blind acceptance of the1970's fiberglass general concept of how insulation works. These rules of insulation principles developed by Owens Corning are seriously limited as it does not take into account the contribution of radiation, which is the most significant component of heat transfer for insulation.

PhD. Inn Choi's comments:

Other than the radiation, fiberglass is not an ideal model to study heat transfer mechanism.

Fiberglass is an 'air trapper'. Air is a very good insulator with a "K" value of only .16. The "K" value given for air describes the amount of heat which will travel directly through perfectly still, and dry, air. However, air used as an insulator never stays completely still. Instead it sets up an active circulation as one side of the containment chamber is heated. The heated air rises and the cold air falls. This circulation constantly exposes the colder air to the warm wall, thus increasing the Delta T across that wall and greatly increases the rate of heat transfer through the chamber. In fiberglass insulation, the air is "trapped" on a great many small chambers called "cells". While each cell still sets up its own convection current, heat transfer is reduced in direct proportion to the size of the cell. The smaller the cell, the greater the reduction in convection.

As it is impossible to individually study the heat transfer in these cells, most heat transfer study for fiberglass is done experimentally using average quantity of temperatures and heat transfer rates. The measured values of heat transfer often reflect the values of air than fiberglass wool pack itself (air trapper). The fiberglass wrapper also plays a role here. Its function is to contain the fiberglass at a certain thickness. Depending on how it is squashed or pulled, its thickness varies. So there is no definite and reliable thickness one can use. Besides the wrapper material itself affects the heat transfer mechanism significantly. If measurements are made on the surface of fiberglass wrapper, the wrapper thermal properties, thickness, and how it bonds with fiberglass all affect the results.

Another problem is the degradation of the 'air trapping' function of fiberglass. During installation and in the actual usage, fiberglass wrapper is torn and allows the outside air and moisture migrates into the fiberglass wool pack. This not only invalidates the insulation standard established by the manufacturer but also makes the actual insulation performance seriously degraded. As an example, a small amount of moisture or externally induced air pocket can cut down fiberglass' R-value by more than 50% easily.

All these facts seriously affect the validity of any kind of heat transfer studies conducted with fiberglass sample. They skew all of the understanding about any insulation material and set standards based on limited facts of heat transfer. Since fiberglass cannot reflect and has no ability to resist radiation, the principles established for heat transfer are very much limited.

Most all insulation guidelines are currently build on fiberglass claims and calculations. These claims are short sighted, disputed and can easily be shown invalid. This, of course, leaves the engineering and architectural groups with a responsibility for determining true and accurate numbers to be used for quotations on insulation requirements for buildings and facilities nationwide and worldwide under their review. These misconceptions are exhibited by the engineering staff of the following major oil company. The quoted statements are directly from the energy engineer. Those statements were presented to Dr. Choi for rebuttal given pro or con according to the accurate heat transfer principles. His remarks are highlighted in red.

Example of Engineering Statements and Corresponding Rebuttals by PhD. Choi:

1. *"Based on Super Therm's ability to withstand radiant heat, it may be better suited to a) insulate cold objects than hot ones."*

a) 'Insulating cold object' is the wrong words by definition. Heat goes from hot to cold. The temperature difference ('Delta T') is the driving force to make the heat transfer occur. Insulation, by definition, is blocking the source (hot side) of this heat transfer. For a cold pipe, we say it is wrapped with insulation material - we don't say it is insulated, The heat goes outside in.

2. "*At ________, we have found in our tests that the surface temperature of Super Therm on a hot pipe (400 degrees F) {Note: they mean Hot Pipe Coating and not Super Therm,}was about 200 degrees F. At that temperature, a) convection becomes a problem even though the Super Therm may do b) a good job of not radiating the heat out."*

a) Convection involves the heat transfer by moving air current and conduction through air layer of infinitesimal thickness ('boundary layer') attached to the surface. This convection transfers heat from the pipe out to the surrounding ambient air. As pipe insulation material releases heat out of the pipe, convection helps, not hurts. It is not a 'problem'.

b) Nonsense. SuperTherm works by reflecting radiant heat back toward the source. It does not reflect conducted heat, nor can it reflect heat within a solid object. Also 'not radiating out' is not a good job. It is a bad job. For hot pipe, we want to radiate out the heat as much as we can.

3. "Overall, I agree that customers should look at total heat transfer by all three mechanisms - conduction, convection and radiation. You are right in saying that R-values and K-values are really measuring just the effectiveness of the insulation against conduction. They do not directly measure the effectiveness against convection and radiation. However,

a) ***if the surfaces of two different insulating materials were both at 200 degrees F when an air current of 15 mph is directed at them, the material with the better R-value will lose less heat due to its conductivity being lower. b) At the same time that material will see its surface temperature drop more than the materials with the lower R-value. c) So, in general, materials that do a good job at stopping conductive heat will also lose less heat to convection."***

a) Nonsense. For two materials with the same surface temperature, geometry, orientation and surface roughness, the convection heat loss is identical.

b) If the surface temperature is allowed to change with forced air blown over, the convection cooling on the surface will allow the low R material transfer heat out easier. Therefore the temperature will drop down.

c) For condition a), the surface temperature is same. In this case, convection has nothing to do with conduction. Conduction is strictly based on inner property (conductivity) of the material. Convection based on surface property (boundary layer) not material property (conductivity) except that the thin air film, the lower part of the air boundary layer, also conducts heat. Besides, the surfaces retaining the same surface temperatures means the conduction effect has already been manifested in the final temperature level.

4. *"The only problem I have with Super Therm is that a) I cannot prove that it's R-value is better than fiberglass or perlite or calcium silicate. b) The opposite seems to be true since the surface temperature of the Super Therm is always greater than that of these other insulation products. c) Therefore, one would also assume that Super Therm also allows more convective heat losses that these other products. d) The only question remaining is how important radiant heat losses are at these low temperatures."*

a) If R-value is measured without the contribution of radiation, this statement can be correct.

b) For hot pipe insulation, the goal is to preserve the energy of the fluid inside the hot pipe. Quite often, people make a judgment on the insulation effectiveness based on outside pipe temperature. This can be misleading. If a hot pipe is well insulated, the fluid inside the hot pipe will not lose heat as much. Thus, the fluid temperature will drop less. What this means is that the outside pipe temperature with better insulation material will be higher than that with the inferior insulation material.

c) When we see the surface temperature fixed, it means a steady state has been reached. What this means is that all heat transfer mechanism has been acted and balanced out. The resulting temperature is nothing but a manifestation of this balance. In the current hot pipe case, the surface temperature is more the outcome of work of conduction than convection.

d) SuperTherm is radiation reflector. So it won't emit radiation heat as much as black body like material. This problem can be easily taken care of by roughening the surface so that emissivity goes up. At the same time, it is important to consider the issue of protecting the surface from environment hazards such as UV, acid rain, and weathering. SuperTherm was designed to provide this protection.

The radiation heat transfer out of the surface is important at high temperatures. In a net shell, we can compare convection and radiation heat transfer by doing the order of magnitude comparison: Convection (T_{hot}-T_{cold}) and : Radiation (T_{hot}^4 – T_{hot}^4). In doing this, we have to make sure that we use absolute temperatures (absolute zero is when atoms almost stop motion and is -459°F) by adding 460°F to the temperatures.

The engineering group who made above statements need to understand the fundamentals of heat transfer mechanism before they make any meaningful test plans. Wrong concept -> wrong test protocol -> meaningless result.

This next section is PhD Choi's explanation of the R-Value and other values as used for fiberglass and then compared to SUPER THERM:

R-Value No More

The R-value is a number supposed to indicate a material's ability to resist heat loss. In reality, it is not. R-value by itself is a meaningless number. It does not represent the effectiveness of insulation. It was solely designed for fiberglass.

Fiberglass is an 'air trapper'. If high wind blows over it, the air can not be trapped, so R-value goes to zero. A fiberglass insulation having an R-value of 25 placed in an attic not properly sealed will allow the wind to blow through it as if there were no insulation. If it is immersed in water, R-value goes to zero. R-value is not even remotely part of the real world.

What is R-Value?

Then what is R-value? R-value is simply defined as R=1/(kA/d)=d/(kA). Since U=k/d, R=1/(UA)

	British Unit (US)	Metric Unit (Europe)
K: Thermal conductivity	Btu inch/hr sq.ft °F	W/cm °K
d: Insulation thickness	inch	cm
U: Conductance (Transmittance)	Btu/hr sq.ft °F	W/ sq.cm °K
A; Cross sectional area	sq.ft	sq.cm

R: Thermal resistance (R-value) hr °F/Btu °K/W

Please note that the actual number for R value is totally different depending on which units are used. It must be defined with units. As far as the units are consistent, it really doesn't matter what terminology we use. As an example, conductance is same as transmittance. But if you want to see whether people who use these words actually mean the same thing, you can check the units and see whether they are consistent. The same goes for K-value or ë (Lamda) value. If units are converted from British to metric units, we can easily see that it is the same thing.

R-Value is geometry dependent

R-value is thickness dependent

As you can see, R-value is directly proportional to thickness and inversely proportional to conductivity and cross area. This means that R-value depends not only on material but also on geometry. Therefore, if fiberglass insulation is squashed or flattened to 10% of its original thickness, the corresponding R-value is proportionally cut down to 10%.

R-value is cross-sectional area dependent

R-value is also cross-sectional area dependent. Usually most of the R-value lab test is conducted in a way that the insulation thickness is much less than its width or length. This is necessary to make the heat transfer one-dimensional. That is why the unit of thermal conductivity is often expressed in (Btu inch/hr sq.ft °F) instead of (Btu/hr ft °F), i.e. the cross-sectional area is in (sq.ft) and thickness is in (inches). If the insulation width or length retains the same order of magnitude as the thickness, the heat transfer becomes two-dimensional. Therefore a lab test based on one-dimensional heat transfer becomes useless.

Therefore using R-value as a material property without consideration of geometry (cross-sectional area and thickness) changes is irrelevant. In addition, the R-value for fiberglass heavily depends on air convection and presence of moisture as described next.

Fiberglass R-Value is convection and moisture dependent

ASTM R-value test not for real world

ASTM R-test was designed by a committee to give us measurement values that hopefully would be meaningful. However, the test does not account for air movement (wind) or any amount of moisture (water vapor). In other words, the test used to create the R-value is a test in non-real-world conditions. If a fiberglass is assigned an R-value of 3.5, it can achieve this R-value if tested in an absolute zero wind and zero moisture environment. And zero wind and zero moisture are not the real-world.

Fiberglass moisture problem

Even small amounts of moisture will cause a dramatic drop in fiber insulation's R-value. To avoid moisture problem, a vapor barrier may be used for fiberglass on warm side. However, seasonal change would switch the warm side around. If you put vapor barriers on both sides, however, it can make things worse. This is because moisture migrated through any tears in the barrier would be forever trapped inside the fiberglass..

Fiberglass convection problem

Air ventilation is another problem. Within fiberglass, air trapped in there continuously rotates by natural convection within many fiberglass cells. This convection problem becomes serious when a fiberglass is laid horizontally, e.g. on the floor of an attic. The convection is now generated by vertical temperature difference across fiberglass thickness. As hot air always rises vertically and then circulates back, this tendency will accelerate the convection through the fiberglass. If you use a barrier to prevent this convection, then it will trap water vapor and creates a condensation problem. The condensation problem will then cut down R-value drastically. At the same time, it will cause molds develop and damage wooden structures.

Why SuperTherm?

Totally reflect radiation

SuperTherm is most effective when coated on roofs. It reflects more than 90% of solar radiation to begin with. This ability alone is sufficient to beat fiberglass as the most effective heat barrier. Therefore debating the effectiveness of conduction heat transfer with R-value for the remaining 10% of energy input into a building is not practical. Besides, R-value comparison without taking real-world conditions into account is totally meaningless.

Prevent air penetration, free water, and moisture

In a nut shell, it is very likely that insulating the roof can handle more than half of the insulation needs for the entire building. This is because the primary heat transfer in nature always tales place vertically, i.e. hot air goes up and cold air comes down. Therefore roofing insulation is much more effective than sidewall insulation. By applying SuperTherm on top of roofs and, if necessary, in the attic, air penetration can be stopped, free water can be blocked, and moisture migration can be prevented.

Corrosion Protection

SUPER THERM will not allow corrosion to develop under it. The ceramics bond tight to the substrate surface preventing the passage of moisture, air and atmospheric conditions to affect the surface.

In all fiberglass wrapped pipes found in industrial or petrochemical plants, the pipes are all corroded when the fiberglass is removed. Fiberglass breaths the air, moisture and conditions into the air pockets and holds this mixture causing the surface of the pipes walls, etc. to corroded in a short amount of time. From industry testing, 1 ½ percent of moisture in fiberglass will kill 35% of it's effectiveness. 1 ½ percent is breathing on it. Most climates range from 40% to 80% humidity and given the ability to absorb this moisture, the fiberglass is worthless in a matter of days. It should be remembered also and related later in this report that the fiberglass "R" value was only established at 75 degrees F. In explanation as to why it was tested and certified at only the 75 degree temperature, the labs said that it is called **standardization**.

Owens Corning and ASTM decided when the tests were first developed that the material could be tested at one temperature and projected to all climates. This is totally false as related from the labs that do the testing. If the temperature is more than or less than 75 degrees F, the fiberglass reduces greatly in effectiveness. But this fact is not related to the industry and the "R 19" value stamped on the roll of 6 inch fiberglass is totally incorrect in any atmosphere or temperature other than 75 degrees F.

Summer & winter considerations

As far as SuperTherm being a radiation reflector, there is a question of seasonal changes. In summer time, heat goes into a building. In winter time, heat goes out of a building. To remedy this situation, my recommendation is to apply SuperTherm on the roof for blocking summer heat from outside, and on the attic floor for preventing winter heat loss from inside. With this double insulation, in summer, the roofing insulation effectiveness will increase significantly more. In winter, the attic will trap hot air from inside the building and will be able to prevent building heat loss significantly more.

For those that want a little more in depth formula calculations, this next pages are to get deeper into the formulations and figures:

Thermal Resistance Calculation

Assumption

One dimensional heat conduction with insulation of 1 sq.ft cross sectional area with 3 varying insulation thicknesses: 0.01", 1.0", and 10".

Definition

	British Unit(US)	Metric Unit(Europe)
k: Thermal conductivity	Btu inch/hr sq.ft °F	W/cm °K
d: Insulation thickness	inch	cm
U: Conductance	Btu/hr sq.ft °F	W/ sq.cm °K
A; Cross sectional area	sq.ft	sq.cm
R: Thermal resistance	hr °F/Btu	°K/W

Thermal Resistance Calculation based on BTU Units

k = 4.1628 (Btu inch/hr sq.ft °F)

U=k/d=4.1628 (Btu inch/hr sq.ft °F)/d (inches):

d= 0.01": U=416 (Btu/hr sq.ft °F)

d=1": U=4.16 (Btu/hr sq.ft °F)

d=10": U=0.416 (Btu/hr sq.ft °F)

If A= 1 sq. ft, then,

R=1/(UA) gives:

d=0.01": R=1/{416 (Btu/hr sq.ft °F) *1.0 (sq.ft)}=0.0024 (hr °F/Btu)

d=1.0": R=1/{4.16 (Btu/hr sq.ft °F) *1.0 (sq.ft)}=0.24 (hr °F/Btu)

d=10": R=1/{0.416 (Btu/hr sq.ft °F) *1.0 (sq.ft)}=**2.4 (hr °F/Btu)**

Thermal Resistance Calculation based on Metric Units

k= 0.006 (W/cm °K) (or =W cm/sq.cm °K)

U=k/d=0.006 (W/cm °K) /d (cm):

d=0.0254 cm: U=0.236 (W/ sq.cm °K)

d=2.54 cm: U=0.00236 (W/ sq.cm °K)

d=25.4 cm: U=0.000236 (W/ sq.cm °K)

If A=1 sq.ft=929 sq.cm, then,

R=1/(UA) gives:

d= 0.0254 cm: R=1/{0.236 (W/ sq.cm °K) *929 (sq.cm)}= 0.00456 (°K/W)

d=2.54 cm: R=1/{0.00236 (W/ sq.cm °K) *929 (sq.cm)}= 0.456 (°K/W)

d=25.4 cm: R=1/{0.000236 (W/ sq.cm °K) *929 (sq.cm)}= **4.56 (°K/W)**

Conversion for d=10" (or 25.4 cm) case

R=**4.56 (°K/W)** = 4.56(°K/W) * 1.8 (°F/°K) / 3.412 {(Btu/hr)/W} = **2.4 ((hr °F/Btu)**

Note

(a) Conductance (U) is different from thermal conductivity (k)
(b) R calculation involves k (thermal conductivity), d (insulation thickness), and A (cross sectional area): $R=1/(kA/d)=d/(kA)$.
(c) R value is different depending on which units are used. It must be defined with units
(d) R is directly proportional to thickness and inversely proportional to conductivity and cross area. This means that it is not a material property but a geometry-dependent property. Therefore using R-value as a material property (for coating) is irrelevant.

TEST RESULTS

to determine
"K" value and Lambda value

TEST #1

for BTU and K value of heat flow through a wall unit:

"ASTM C-236 Guarded Hot Box Test"

Test requested by Bombardier Transportation and Engineering Group.

Testing performed by VTEC Laboratory, Inc. and National Certified Testing Laboratories.
This test is used to establish R value for fiberglass and other batt materials as determined from these results.
Control is the fiberglass test density board of 3 inch thickness.
Result of applying SUPER THERM over the standard fiberglass test density board.

3 inch high-density **fiberglass board tested**: **K = 0.52**

10 mils **SUPER THERM** tested: **K = 0.31** One coat facing heat source.
68% improvement based on the 0.21 improvement against the fiberglass control board compared to the one coated side control board (0.31) (.21 divided by .31). Based against the .52 fiberglass is 40% improvement.

20 mils **SUPER THERM** tested: **K = 0.21.** One coat on each side of board (heat source and cold side) total of 2 coats or 20 mils
Conductance value of 0.21 (K-value)(BTU/in/sq.ft./hour/ F)
148% improvement based on the 0.31 improvement against the fiberglass control board.

Also noted: The testing for fiberglass is conducted at 75 degrees F (24 C) to achieve the best results for the fiberglass materials. SUPER THERM is designed to work more efficient the higher the temperature and differences of temperatures between substrates by using reflection in conjunction with conduction which the fiberglass is not designed to do.

TEST #2

BTU conduction test to determine the BTU conduction block performance for SUPER THERM.
ASTM E-1461-92 Thermal Diffusivity

ASTM E-1269 Specific Heat

BTU value measurement testing of SUPER THERM alone as a single coating film at 100 C or 212 F.

Metal Plate was tested without the coating to allow 367.20 BTU/sq.ft./hour/F to Pass through.

SUPER THERM was tested in one coat at 14.9 mils over the metal plate and allowed 3.99 BTU/sq.ft./hour/F to pass through.

ASTM E 1269 Specific Heat and ASTM E-1461-92 Thermal Diffusivity used to find these results.

This result of 3.99 BTU/sq.ft./hour/F for only the coating film will be analyzed below.

NOTE: The metal plate was deducted out of the results for the SUPER THERM to allow the value for SUPER THERM to be strictly on the coating film alone.

SUPER THERM

K = 0.101

Explanation of usage of terms and application:

K value indicates the amount of heat (in BTUs) that will flow in one hour through a substrate surface in one sq.ft.of a uniform material for one inch thickness (25mm) for one hour and each degree F of temperature difference from one side (heat side) of the material to the other side (cold side).

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Batt insulation material testing and K value determinations.

The assumption is made that if the batt (glass wool or rock wool) is increased in thickness, the K value would remain the same as to the original thickness meaning that as the thickness increases the R rating would automatically increase in effectiveness. The lower the K value, the more effective the insulation material is in resisting the heat flow.

In reality, the only way this could possibly work would be to have the insulation material in a controlled environment without the influence of humidity, air pressures and weather changes. All of the weathering factors load moisture into the batt type insulation materials to immediately reduce the K value by large percentages. K value can reduce in batt type insulation materials by 35% with only 1.5% moisture entering into the material.

Comparison #3

Best fiberglass K value compared to SUPER THERM.

Lambda Value:

Owens Corning states in their insulation materials that their best high density Fiberglass insulation for pipes has a K value of 0.23 at 200 degrees F giving a

LAMBDA Value of 0.034.

SUPER THERM tested at 212 degrees F has a K value of 0.101 giving a

LAMBDA Value of 0.015.

Finished Results:

K factor at 75 degree and 200 degree // Lambda number:

ASTM C-236 Guarded Hot Box

75 F (24 C) base temperature

Fiberglass testing for establishing insulation values at **75 degree F (24 C)**: **"K" = .52 per 2.5cm (1 inch)**
SUPER THERM test at **75 degree F (24 C)** at one coat: **"K" = .31 per .025cm**
SUPER THERM test at **75 degree F (24 C)** at two coats: **"K" = .21 per .050cm**

[At 75 degrees (two coats) K = 0.21]

ASTM E-1269 Specific Heat / ASTM E-1461-92 Thermal Diffusivity

200 F - 212 F (93 C - 100 C) base temperature

SUPER THERM test at **212 degree F (100 C)**: **"K" = 0.10 per .025cm**
Fiberglass (Best hot pipe density) at **200 degree F (93 C)**: **"K" = 0.23 per 2.5cm**

[At 212 degrees F (one heavy coat) K= 0.10]

Based on pure BTU heat conduction testing for the "coating film alone", the true "K" factor result is:

K = 0.10

R = 1/K or 10

Based on pure conduction without the radiation factors and reduced convection heat, one can simply double the thickness, as in fiberglass by adding inches of thickness to increase the R value, to achieve a R 20 value.

Additional Charts and References:
Lambda Expression

European R value system is based on the Lambda expression of insulation numbers.
Taken from Table 16 of the European heat cross reference chart
1 BTU/in/sq.ft/hour/F (K value) = 0.144 W/mK

SUPER THERM K value (0.101) expressed in Lambda.
Lambda = K X 0.144 W/mK
Lambda = 0.101 X 0.144
Lambda = 0.015 W/mK Based upon 0.0149" thickness.

European Lambda statistics on standard insulation materials as tested **for 1" (2.5cm)** minimum thickness:.

Polyurethane Foam = 0.028 W/mK	per 2.5cm
Polystyrene board = 0.035 W/mK	“
Polystyrene expanded = 0.040 W/mK	“
Minerale Wool/ Fiberglass = 0.040 W/mK	“
Perlite = 0.055 W/mK	“
SUPER THERM = 0.015 W/mK	**per 0.025 cm**

The European R rating chart is a different expression of R value than calculated for the US.
Examples:
Above from the listing of lambda values-

- Polyurethane foam is 0.028
- For any material having 0.028 lambda value
  - 1 inch (2.5cm) R = 0.89
  - 9.6 inch (24cm) R = 8.57
- Minerale Wool is 0.040
- For any material having 0.040 lambda value
  - 1 inch (2.5cm) R = 0.63
  - 9.6 inch (24cm) R = 6.00

Since the chart does not give below 0.020 W/mK to the SUPER THERM value of .015 W/mK, and the chart is based on one inch (25mm or 2.5cm) thickness, a calculation can be made to determine the European R value as performed by the guidelines followed above for the U.S. “R” value by reducing the tested thickness of the SUPER THERM and find the corresponding European R value.

Below is a reprint of a Comparison Chart for Transmission of heat (Conduction, Convection and Radiation) developed by Glacier Bay heat properties: Per inch (25mm or 2.5cm) thickness and one foot square for certain insulation materials. SUPER THERM was not part of this

chart but was added by Superior for comparison based on the comparative tested numbers from laboratory results.

Material	**Conductivity ("K")**	**Insulation ("R")**	1 inch **Per 2.5cm**
Copper	2712.00	.00037	"
Aluminum (6061)	1160.00	.00086	"
Aluminum (5052)	960.00	.00104	"
Lead	245.00	.004	"
Stainless Steel (316)	113.00	.00885	"
Glass	5.00	.20	"
Polyester FRP (hand laid)	.48	2.08	"
Polyethylene Foam	.43	2.33	"
Wood (dry)	.33	3.03	"
Polyester FRP (pultruded)	.31	3.26	"
Glass Wool	.29	3.45	"
Polystyrene (expanded)	.28	3.57	"
Cork Board	.27	3.70	"
Polystyrene (extruded)	.21	4.80	"
PVC (Klegecell)	.21	4.80	"
Polyurethane Foam	.17	5.88	"
Air	.16	6.25	"
SUPER THERM	.10	10.00 **(per .025cm)**	**10mils***
Barrier Ultra-R	.02	50.35	"
Total Vacuum	.004	250.00	"

- Using the standard R=1/K for standard calculation of the "R" does not apply.
- SUPER THERM is applied by 1/1000 inch measurements.

Foil Barriers and their use as a sandwich to try and increase the insulation ability of another insulation materials such as foam, bubble packs or boards. Because the foils do have density as per their metallic construction, they will absorb heat. The more density a material has the more heat it can absorb and hold. Metal versus paper. The metal in the sun will absorb and hold heat. A piece of paper will absorb some heat but hardly be noticed.
Also, a metallic material must be bright and polished to effectively continue to reflect heat radiations and Infrared. As a reprint of this chart shows, the materials lose their ability to reflect after only 6 months and in other cases a year. As the metal oxidizes, it loses all its ability to reflect effectively.**
** glacierbay.com/ Heat Properties report

A reprint of the chart below gives the infrared radiation reflectivity (emissivity) of some common materials:

Material	**Condition**	**Reflectivity**
Aluminum	Bright	90-95%

	Anodized	45%
	Oxidized	70-80%
Brass	Bright	97%
	Oxidized	39%
Chromium	Polished	92%
Copper	Bright	95%
	Oxidized	22%
Steel	Polished	45%
	Oxidized	15%
Nickel	Polished	95%
	Oxidized	5%
Paint	White	10%
	Black	14% (in this case, a black body can block infrared better than a white body because it can absorb radiation.)
Rubber		6%
Water		8%

—

SUPER THERM	**99.5%** JIT testing performed in Japan in the Window films reflectivity testing to Repeal Infrared radiation (Long Wave). JIT (Japanese Institute of Technology)

What is the significance of Infrared??
As testing performed by the California COOL ROOF Program found**, heat transfer** into facilities of any design were as follows:

UV	3%
Visual light spectrum	40%
Infrared radiation	57%

SUPER THERM blocks 99.5% of Infrared.

Comment about the American “R” value status:

The most important number for insulation measurement is the “K” factor to determine heat flow and insulation effectiveness. The “R” rating is based on this number and the R value is only relating to

“conduction” and not the other two heat transfer measurements The “K” number is the number requested by the Architects and insulation requirements.
When we say that 10 mils (10/1000 inch) of SUPER THERM gives a K value of 0.10 and this relates to a R value of 10 for this one coat, then you must realize that this R factor does not consider the “reflectivity” factor of the SUPER THERM (92% of sunlight and 99.5% of Infrared radiation). All testing for insulation materials does not have reflectivity in the formula of the test procedure because none of the other insulation materials such as fiberglass, rock wool, foam and others of same type do not and cannot reflect heat therefore not in the test procedure.

Can we say that the additional R 9 would come from reflectivity? I think yes. Reflectivity would stop the surface from heating and therefore reduce the surface heat build up and reduce the conduction rate.
We could say that another coat of 10 mils would give an R 20 by the normal progression established by the current insulation formula of increased thickness for interior measurements since we do not have the advantage of sunlight reflection. Although, Infrared radiation is present on all interior heating sources and this is what is radiating through the air. SUPER THERM will block this radiation and prevent this heat loss on interiors.

Fiberglass and other thick materials are evaluated on an inch basis and you must add inches to attain any R 19 value such as 8 – 10 inches to gain this level of insulation R 19 value if the temperature is 75 degrees F.

In the basic testing for the fiberglass in the C236 (Guarded Hot Box) test, the K value is .52 per inch which calculates to an R value of 1.92. This would take 9.9 inches to make R 19. How can they claim 6-8 inches to be R 19 when the testing does not support this.

In their best hot pipe fiberglass make up from their materials book, the K value is 0.23. This would calculate to an R 4.34 per inch. This would mean 4.38 inches would give you an R 19 value. Of course, this is the hot pipe density material not used for construction. This K value of 0.23 is the best they have.

It is understood that all the testing used for batt insulation materials does not have reflection as one of the factors in the numbers. Why, because reflection was never considered in the test establishment because batt materials cannot reflect.

When reflection (one of the main three types of heat gain) is added into the mix to determine insulation effectiveness, SUPER THERM can achieve the R 19 easily.

Conclusion of all the information, statements and understandings presented:

A reprint of PhD Inn Choi on the summation of all of this is listed below for a good conclusion to all we have discussed. The basic sense I have arrived at is that the "R" rating type of insulation judgment was developed strictly for fiberglass, rock wool and other thick insulation batt type materials. The testing procedures are good tests, but for the materials that it judges, even the researchers state it is not good, but the only way at the time to appraise it.

PhD Inn Choi:

I am a marketing consultant for SPI for the world market. I usually respond only to questions asked by our distributors or by Mr. Pritchett, President of SPI. I usually do not deal with questions directly asked by end-users. In this case, however, I am making an exception and giving you my answer to your question below as I consider your question is important. You may respond to me with your feedback for this particular issue
Yours,

Inn Choi

R-Value Myth Revisited

The R-value is a number supposed to indicate a material's ability to resist heat loss. In reality, it is not. R-value by itself is a meaningless number. It does not represent the effectiveness of insulation. It was solely designed for fiberglass.

Fiberglass is an 'air trapper'. If high wind blows over it, the air can not be trapped, so R-value goes to zero. A fiberglass insulation having an R-value of 25 placed in an attic not properly sealed will allow the wind to blow through it as if there were no insulation. If it is immersed in water, R-value goes to zero. R-value is not even remotely part of the real world.

What is R-Value?

Then what is R-value? R-value is simply defined as $R=1/(kA/d)=d/(kA)$. Since $U=k/d$, $R=1/(UA)$

	British Unit(US)	Metric Unit(Europe)
k: Thermal conductivity	Btu inch/hr sq.ft °F	W/cm °K
d: Insulation thickness	inch	cm
U: Conductance (Transmittance)	Btu/hr sq.ft °F	W/ sq.cm °K
A; Cross sectional area	sq.ft	sq.cm
R: Thermal resistance (R-value)	hr °F/Btu	°K/W

> *Please note that the actual number for R value is totally different depending on which units are used. It must be defined with units. As far as the units are consistent, it really doesn't matter what terminology we use. As an example, conductance is same as transmittance. But if you want to see whether people who use these words actually mean the same thing, you can check the units and see whether they are consistent. The same goes for K-value or ë (Lamda) value. If units are converted from British to metric units, we can easily see that it is the same thing.*

R-Value is geometry dependent

R-value is thickness dependent

As you can see, R-value is directly proportional to thickness and inversely proportional to conductivity and cross area. This means that R-value depends not only on material but also on geometry. Therefore, if fiberglass insulation is squashed or flattened to 10% of its original thickness, the corresponding R-value is proportionally cut down to 10%.

R-value is cross-sectional area dependent

R-value is also cross-sectional area dependent. Usually most of the R-value lab test is conducted in a way that the insulation thickness is much less than its width or length. This is necessary to make the heat transfer one-dimensional. That is why the unit of thermal conductivity is often expressed in (Btu inch/hr sq.ft °F) instead of (Btu/hr ft °F), i.e. the cross-sectional area is in (sq.ft) and thickness is in (inches). If the insulation width or length retains the same order of magnitude as the thickness, the heat transfer becomes two-dimensional. Therefore a lab test based on one-dimensional heat transfer becomes useless.

Fiberglass advantage in R-test

Fiberglass is in a tremendously advantageous position to get the highest R-value possible as it can be arbitrarily stretched out to increase the thickness and, at the same time, to contain the maximum amount of air (very effective insulator) in it. And most fiberglass R-value test is usually done at its maximum inflated state. Solid materials such as insulation paints do not have this luxury. In fact, every thing goes against them because the thickness is inherently small compared to fiberglass. As an example, if a coating of 8 mil (0.2 inch) thickness is compared with fiberglass of 8 inches thickness for R-value comparison, fiberglass is already 40 times higher in R-value than the coating regardless the material properties. This is already given even before the test!

In spite of this advantage fiberglass has, it has several many drawbacks when applied in the real world. The R-value for fiberglass heavily depends on air convection and presence of moisture as described next. Even more important, it can not reflect radiation heat transfer.

Fiberglass R-Value is convection and moisture dependent

ASTM R-value test not for real world

ASTM R-test was designed by a committee to give us measurement values that hopefully would be meaningful in real world. However, the test does not account for air movement (wind) or any amount of moisture (water vapor). In other words, the test used to create the R-value is a test in non-real-world conditions. If a fiberglass is assigned an R-value of 3.5, it can achieve this R-value if tested in an absolute zero wind and zero moisture environments. And zero wind and zero moisture are not the real-world.

Fiberglass radiation problem

Fiberglass is more than 90% porous. Therefore, when exposed to the sun, it will absorb most of radiation energy. This will work totally against what fiberglass was designed for – preventing heat flow. If a barrier is used, it is no more fiberglass that we are testing. Therefore, fiberglass itself can not be used to prevent radiation heat transfer - its function is confined to retarding only conduction heat flow. However, if fiberglass barrier is coated with an insulation coating such as SuperTherm to reflect radiation, the combined insulation effect will improve significantly.

Fiberglass convection problem

Air ventilation is another problem. Within fiberglass, air trapped in there continuously rotates by natural convection within many fiberglass cells. This convection problem becomes serious when a fiberglass is laid horizontally, e.g. on the floor of an attic. The convection is now generated by vertical temperature difference across fiberglass thickness. As hot air always rises vertically and then circulates back, this tendency will accelerate the convection through the fiberglass. If a barrier is used to prevent this convection, then it will trap water vapor and creates a condensation problem. The condensation problem will then cut down R-value drastically. At the same time, it will cause molds develop and damage wooden structures.

Fiberglass moisture problem

Even small amounts of moisture will cause a dramatic drop in fiber insulation's R-value. To avoid moisture problem, a vapor barrier may be used for fiberglass on warm side. However, seasonal change would switch the warm side around. If you put vapor barriers on both sides, however, it can make things worse. This is because moisture migrated through any tears in the barrier would be forever trapped inside the fiberglass...

Do Heat Gain/Loss test, not R-Value test

Include radiation heat transfer

In real world, it is the heat transfer prevention that really matters. In summer time, it is the contribution of radiation that primarily heats up a building. Therefore radiation needs to be taken into account as the most important heat transfer mechanism followed by conduction and convection, the order of significance depending on the environment. Therefore a realistic test must be conducted based on heat gain/losses when all three different heat transfer mechanism, i.e. radiation, convection, and conduction are present. Unfortunately, fiberglass R-value test was primarily designed for conduction only.

Do heat gain/loss test or HVAC energy consumption test

In order to take into account the three heat transfer modes, the most practical approach is to take a large scale heat gain/loss test for a building. One way of doing this is to measure the heat gain/loss on the exposed surfaces such as roofs and walls. For more practical purposes, one may instead compare HVAC power requirements between the case with insulation and the case without, or between the case with fiberglass insulation and with insulating coating. SuperTherm was used in Japan extensively and now enjoys 70% of the insulation paint market. A large number of data exist accumulated over the years that show more than 80% reduction in HVAC power usages in various plants.

SuperTherm R-value equivalent with radiation

If a large scale test is difficult, one may try to use a small scale hot box test where all three heat transfer modes are taken into account. If radiation is included, we will be able to show that SuperTherm is much more effective than fiberglass because more than 90% of radiation heat is reflected back to the environment. For people who are stuck with R-value concept and must convert everything into R-value, it is also possible to convert radiation heat transfer into R-value equivalent. This is not easy as radiation is proportional to 4-th power of absolute temperature. But it can be done just to demonstrate that SuperTherm's R-value equivalent with radiation can be as high as fiberglass. If the radiation level is high, SuperTherm's R-value equivalent with radiation may even exceed the fiberglass even when SuperTherm's thickness is 40 times less than the fiberglass.

Why SuperTherm?

Prevent solar radiation

SuperTherm reflects more than 90% of solar radiation. Therefore it is most effective when applied outside a building. This ability alone is sufficient to beat fiberglass as the most effective heat barrier. Therefore debating the effectiveness of conduction heat transfer with R-value for the remaining 10% of energy input into a building is not practical. Besides, R-value comparison without taking real-world conditions into account is totally meaningless.

Prevent air penetration, free water, and moisture

By applying SuperTherm on outside walls and, if necessary, at various spots that contain cracks, leaks, holes, air penetration can be stopped, free water can be blocked, and moisture migration can be prevented.

Summer & winter considerations

As far as SuperTherm being a radiation reflector, there is a question of seasonal changes. In summer time, heat goes into a building. In winter time, heat goes out of a building. To remedy this situation, my recommendation is to apply SuperTherm outside a building to prevent summer heat from outside, and on inside walls for preventing winter heat loss from inside. With this double insulation, the building will remain very cool in summer and very warm in winter.