

# UNUSUAL BEHAVIOR OF RADIANT BARRIER MATERIALS IN FIRE CAUSATION

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## ABSTRACT

This paper will discuss a relatively new product that is becoming very widely used in residential structures and that recently has been discovered to present serious new dangers of fire causation. The paper will specifically focus on the unusual properties and characteristics as well as some most unusual “behaviors” of the product that create the new and serious fire dangers.

## INTRODUCTION

While there are many different specific causes of fire, in general, the ignition sources of structure fires can usually be divided into relatively few general classifications. In fact, the ignition sources of most structure fires fall into two primary categories. Most structure fires throughout history could be said to be the result of some sort of “machine malfunction” or some sort of “human malfunction”. Machine malfunctions include ignition sources such as over-heated motors, cracked heating elements, and electrical short circuits. Human malfunctions include ignition sources such as dropped cigarettes, un-attended cook stoves, and heating devices placed too close to combustibles.

While historically most fire ignition sources have been relatively common, as new technologies enable ever more advanced and exotic products, we are seeing new and more unusual fire ignition scenarios. An example is the situation we have with Corrugated Stainless Steel Tubing (CSST). CSST used as gas lines in residential structures were unexpectedly discovered to be susceptible to being ruptured by lightning. A rupture releases flammable gas, which of course is easily ignited. Clearly, CSST presents a new and additional fire risk in structures where it is used. Recently, another new fire ignition source has been discovered that is even more unusual and more dangerous than CSST. Reflective radiant barrier products are extremely popular, widely used, and appear to everyone to be perfectly safe. However, the construction of the product incorporates a very unique set of properties that enable some “strange” behaviors during certain fire ignition scenarios.

## OVERVIEW OF RADIANT BARRIER PRODUCTS AND THEIR USE

Reflective radiant barrier products are relatively simple building materials that can be used in home or building construction. The products include a layer of reflective material (usually a form of aluminum foil) to reflect thermal heat energy. When placed in an attic space of a house, the products reduce the amount of summer solar heat that enters the house through the roof and in the winter months, the products can reduce the amount of inside heat that escapes to the outside. With all of the “green” initiatives in play today, everyone is very conscious of saving energy. The addition of reflective radiant barrier products in residential structures is a very simple and cost-effective method of facilitating significant energy savings, especially when the products are installed at the time of construction. The energy saving potential of radiant barrier products is broadly marketed. As a result, the number of residential structures that contain these products has sky-rocketed within the last decade. There are a number of municipalities (such as Frisco, Texas) where ordinances have been adopted that require

essentially every new house constructed to include these products. Effective in 2012, the federal government's own "Energy Star" program added the use of reflective radiant barriers as a factor in determining the eligibility of a structure for the Energy Star rating. In light of the benefits and extreme wide use of reflective radiant barrier products, it is very unfortunate that it has been discovered to be dangerous.

At this time, it seems that three forms of reflective radiant barrier products are most common. One common form of radiant barrier material is a "sandwich" of aluminum foil and plastic laminated together and then packaged in rolls of various sizes. This material can be stapled to the underside of the roof structure or it can be rolled onto the attic floor. This form of the material is often used to "retrofit" a house with radiant barrier. A second form of radiant barrier material is actually a paint that includes aluminum particles. The paint can be used during initial construction or as a retrofit. The third and most widely used form of radiant barrier material is standard 4' x 8' roof sheathing with a layer of foil material laminated to the under-side. This form of the product is often simply called "radiant barrier sheathing" or it is referred to by the acronym "RBS". The RBS material is most commonly used for initial construction because it requires no additional effort during construction. It is installed exactly the same way as normal roof sheathing.



Figure 1 – Typical Radiant Barrier Sheathing Installation as the Roof Deck ([www.norbord.com](http://www.norbord.com))

While there are several different forms of radiant barrier products, the form most commonly encountered in fire investigation has been the radiant barrier sheathing (RBS) form. The rest of this paper will specifically focus on the RBS form of the material.

At first look, radiant barrier sheathing (RBS) seems like a great product and it is difficult to see how it could present any danger. After all, in the most commonly used form, it is primarily just a **layer of aluminum foil glued onto paper which is then glued onto the underside of standard roof sheathing**. However, careful study, testing, and field observation have revealed a unique combination of physical, thermal, and electrical properties that manifest in some strange and highly dangerous behaviors in the locations where the RBS material is most frequently installed.

Before beginning a discussion on the details of the RBS material properties, it is first necessary to understand in general how RBS material causes fires.

## HOW RADIANT BARRIER SHEATHING CAUSES FIRE

In very simple terms: *fires are caused when the aluminum foil of the RBS material becomes energized by electricity!*

When electrical current flows through any material that has electrical “resistance”, heat is generated. That is how all common electrical heating devices work (cook stoves, toasters, water heaters, etc.).

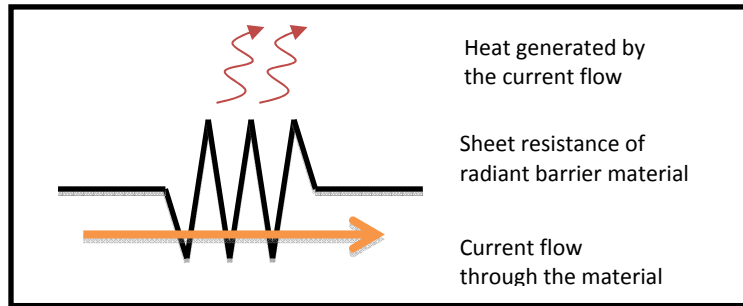


Illustration 1

Aluminum is an electrical conductor. All conductors have a certain amount of electrical resistance. If enough electrical current flows through that resistance, heat is generated. If enough heat is generated and there is ignitable material close by, a fire very often results.

It turns out that a roof deck made with RBS material has just the right unique combination of physical structure, conductivity, resistivity, and ignition temperature to make it extremely effective at “igniting” when it is energized by electricity – ESPECIALLY if the source of that electricity is lightning.

## PHYSICAL PROPERTIES OF RBS MATERIAL ARE THE KEY TO THE DANGERS

The simple construction of RBS material is shown in Photo 1 below. Also, values of the key physical properties of the materials used are shown in Table 1 below. Construction of the RBS starts with a thin layer of aluminum foil (approximately 0.01 millimeters thick). The foil is glued to a thin layer of paper and then the foil and paper sandwich is glued to a standard sheet of oriented strand board (OSB). The aluminum is what provides the excellent “conductivity” property of the material. The thin physical form of the aluminum is what creates the “resistive” property. The construction of a roof deck (with all sheathing sheets in contact with each other) creates one massive conductive, yet somewhat resistive, plane on the underside of the roof.

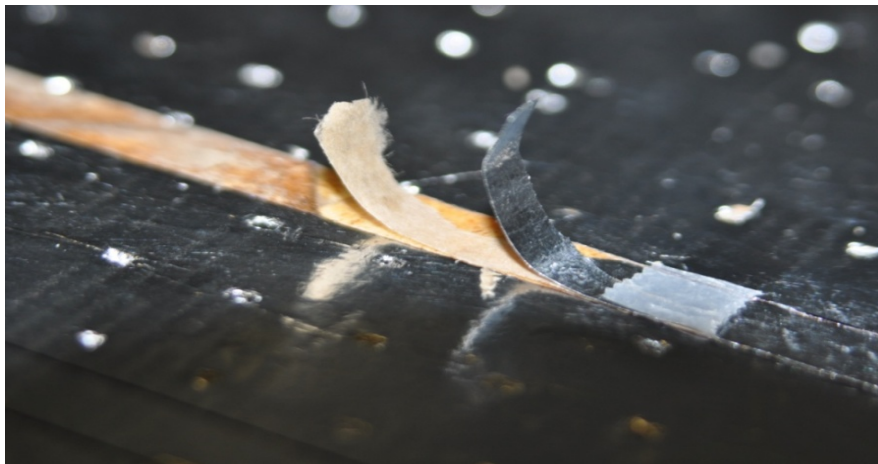


Photo 1 – Physical Construction of RBS Material (OSB, Paper, and Aluminum Foil)

Table 1 – Values of Key Properties of RBS Materials

Material Property	Approximate Value
Thickness of Aluminum Sheet	0.01 millimeter <sub>1</sub>
Conductivity of Aluminum	65% of copper <sub>2</sub>
Velocity of Electrical Voltage in Aluminum	290 million meters per second <sub>2</sub>
Resistance of RBS Aluminum Sheet	4.5 milliohms per square <sub>1</sub>
Current Density Required to Melt Aluminum	200 amps per square millimeter <sub>1</sub>
Melting Temperature of Aluminum	1200 degrees F <sub>2</sub>
Thickness of Paper	0.02 millimeter <sub>1</sub>
Auto Ignition Temperature of Paper	450 degrees F <sub>2</sub>
Piloted Ignition Temperature of Wood	600 degrees F <sub>2</sub>
Piloted Ignition Temperature of Styrofoam	650 degrees F <sub>2</sub>

<sub>1</sub> = value measured by McDowell Owens  
<sub>2</sub> = approx. value averaged from several published sources

**COMBINED RBS MATERIAL PROPERTIES AND INSTALLATION METHODS CREATE A PERFECT ENVIRONMENT FOR FIRE CAUSATION**

1. The aluminum on RBS products is an excellent conductor of electricity. Of the non-precious metals on the earth, only copper is a better conductor than aluminum. Electrical current in aluminum travels at just below the speed of light. If the roof gets energized by electricity at any point, the entire roof within a few nanoseconds is energized and current can flow anywhere and everywhere.
2. Because the aluminum on RBS material is very thin, it has a relatively high sheet resistance (approximately 4.5 milliohms per square). When the current density in the material reaches approximately 200 amps per square millimeter, the material begins to heat rapidly because of the sheet resistance property.
3. As a result of roof installation methods, the aluminum sheets of adjacent roof sheathing sheets are in electrical contact in only a few locations (usually where the metal sheathing support clips are located). This results in current “funneling” when electrical current flows from sheet to sheet. As a result of the current funneling, current densities of greater than 200 amps per square millimeter are easily achieved.
4. Aluminum does not melt until the temperature reaches approximately 1200 degrees F. The glue and paper laminated to the aluminum ignite at approximately 450 degrees F. At the flame temperatures of the burning paper, glue, and wood, the thin aluminum foil itself burns.
5. Because some form of thermal insulation is always included in a typical attic, eave vent channels are also included to prevent blockage of the attic eave vents by the insulation. The eave vent channels used today are made of styrofoam or paper. These vents channels are always located between rafters, which is exactly where sheathing clips are located.
6. When electrically energized RBS material ignites near a metal sheathing clip, the vent channels are immediately ignited as well. These channels are perfect conduits for carrying the flame up further into the attic.

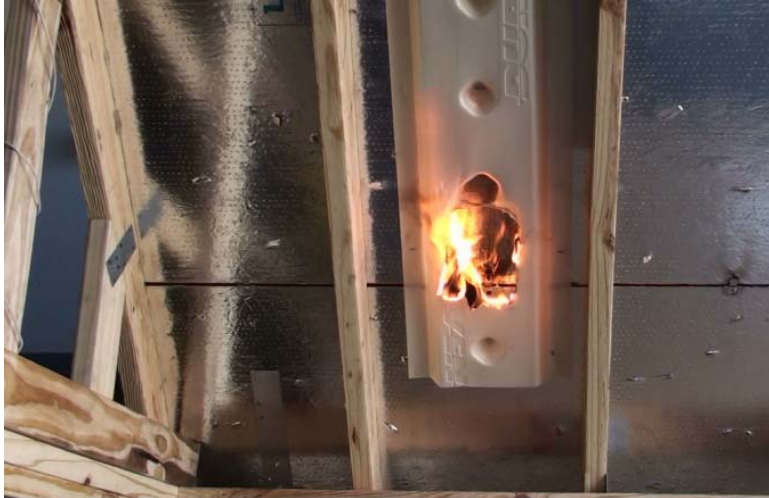


Photo 2 - Styrofoam Eave Vent Channel Ignited by Electrically Heated RBS Material

The exact voltage and/or current applied to RBS material are not important. The only thing that matters is the CURRENT DENSITY level at any point as the current flows through the material. RBS material is readily ignited with 120 volts through a 20-amp breaker. Most of the McDowell Owens lab testing was done using a 12-volt battery. In the lab, we have ignited RBS material with as little as 3.0 amps and 0.78 volts and in demonstrations, it has been ignited many times using a 1.5-volt penlight battery.

#### **THE LOCATION OF RBS INSTALLATION MAGNIFIES THE PROBLEM**

The location where RBS material is installed is a major factor in why it presents such a large overall danger. In a typical installation, the entire roof of the house is RBS and therefore, the entire bottom of the roof deck is aluminum foil. The attic is where most or all of the electrical wiring is routed in many structures, therefore there are obviously opportunities for the RBS to become energized by contact with the utility wiring. More significantly, on the roof, the RBS material is in the perfect location to be struck by lightning. If lightning strikes a house with an RBS roof, the RBS material is almost guaranteed to be energized by the lightning. However, what may be the absolute worst result of the location of the installation is that there is evidence **the RBS material in a roof structure may actually “attract” lightning**. We realize this will sound like an outrageous claim to many people, so the basis for the claim is explored in detail below.

#### **WHAT IS THE EVIDENCE THAT RBS ATTRACTS LIGHTNING?**

Generally, the initial reaction to this suggestion that radiant barrier sheathing attracts lightning is that it sounds outrageous. At first, the idea seemed far-fetched to the investigators at McDowell Owens as well. Then the different pieces of evidence began to fall into place. The initial thoughts about the possibility that RBS might be attracting lightning were triggered by comments in a newspaper article:

*“Firefighters in a Central Texas city say they’ve seen an increase in house fires caused by lightning...Round Rock Fire Department Assistant Chief Billy Wusterhausen says house fires caused by lightning strikes are becoming a lot more common...He can’t explain why, but he did say all the homes hit fit the same profile...”*

(Excerpt from article “Lightning Storms A Potential Cause for House Fires” on KEYE TV website – [www.weareaustin.com](http://www.weareaustin.com))

The comments by Chief Wusterhausen about “homes with the same profile” caused McDowell Owens investigators to reflect on the fact that most (more than 90%) of the lightning involved house fires they had investigated over the last couple of years had been in houses with RBS roofing. Furthermore, on many occasions, the fires were in neighborhoods that included houses without RBS roofing, but the houses with RBS seemed to be the ones that were struck by the lightning. These facts caused investigators to begin looking at the issue from a theoretical point of view. An in-depth theoretical analysis of lightning and electrical field theory is beyond the scope of this paper; however, at least an overview of the subject is required.

Lightning is basically a huge electrical “arc” or discharge between an electrical charge in a cloud and an electrical charge on the earth. Regions of electrical charge in thunderclouds are created by wind currents. The extremely strong electrical fields generated by these regions of charge induce “equal but opposite” regions of charge at ground level. When the amount of charge and the strength of the fields become large enough, a lightning bolt occurs that tends to “discharge” the regions of charge.

The details of the physics involved in determining the exact point where lightning will strike are extremely complex; however, the general principles involved are reasonably straight-forward.

Coulomb’s Law tells us that the strength of the electric force between two regions of charge is directly proportional to the product of the magnitude of the charges and inversely proportional to the distance between the charges. In mathematical form:

$$F \propto \frac{qxq'}{d^2}$$

Gauss’s Law essentially tells us that the strength of the electrical fields in the region vary in a manner similar to the electrical force. From these relationships, the following can be concluded:

If the amount of charge in either of the two regions is increased or if the charges are moved closer together, then the strength of the electric fields between the two regions will be increased.

The addition to a house of the large aluminum sheet of an RBS roof effectively adds a large capacitor plate which stores extra charge at a location above the ground. Additional charge that is also at a location closer to the clouds should definitely tend to increase electric field strength in the region of the house.

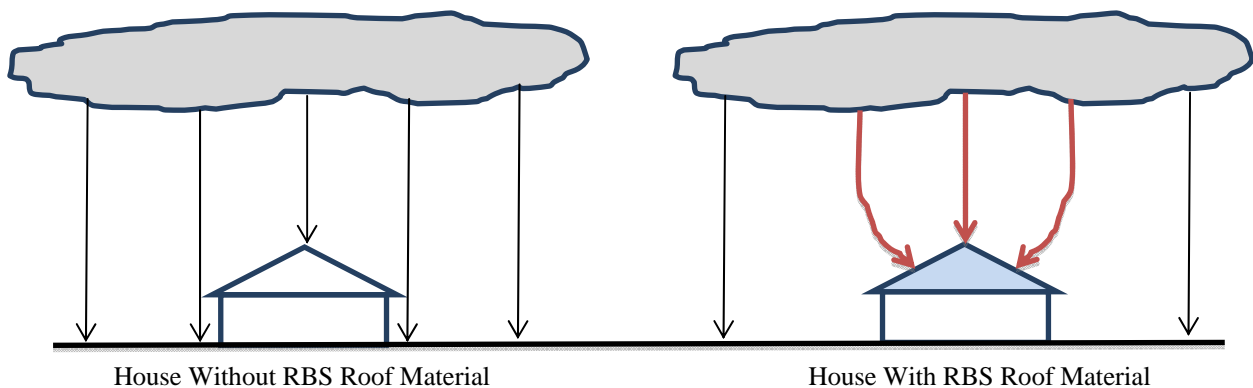
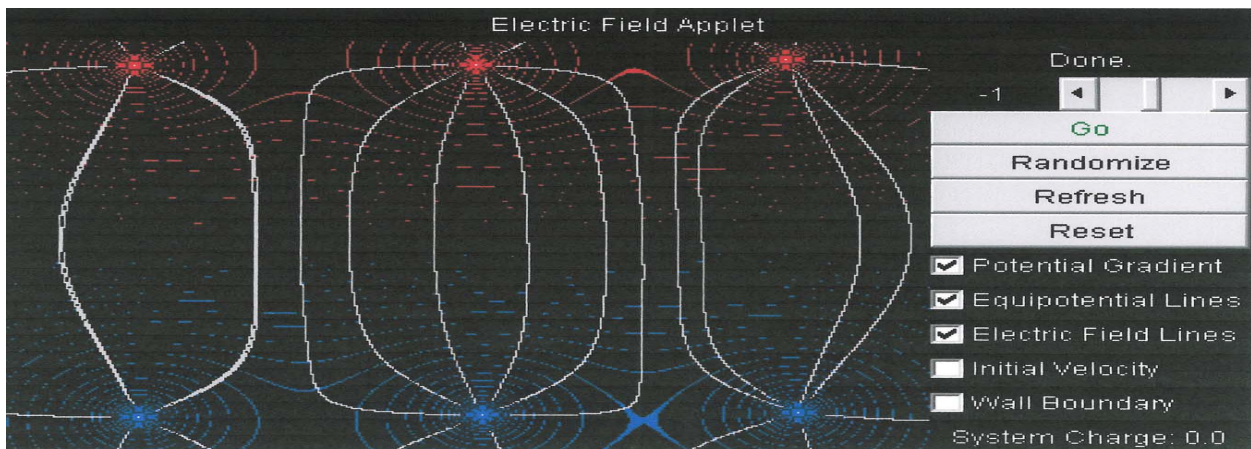


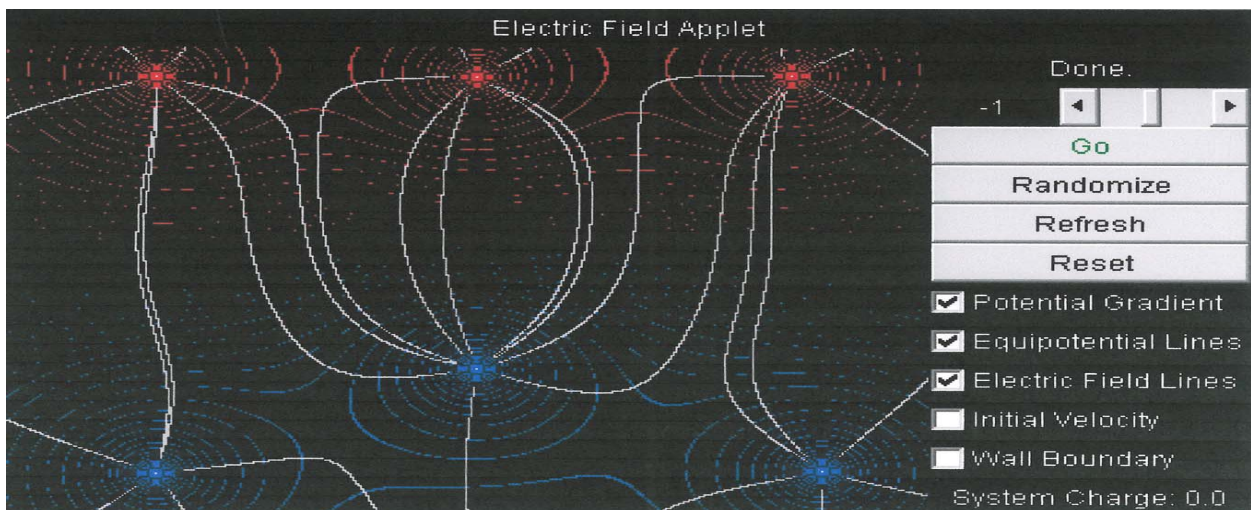
Illustration 2 – Effect of RBS Material on Cloud-to-Ground Electric Field Lines

Illustration 2 above depicts the key effects of the presence of the RBS roofing that are predicted by Coulomb's and Gauss's law. The extra capacitance created by the aluminum "capacitor plate" stores additional charge while at the same time making the effective distance between cloud charge and ground charge shorter. Coulomb's law tells us that both of these effects tend to increase the strength of the electric force, which in turn "concentrates" the electric fields.

After the review of the theory of electric forces and fields, the next logical step was to model the effects of RBS material. Computers can be used to model more complex scenarios; however, sometimes the results can be cluttered and difficult to interpret. A simple scenario is illustrated in the outputs of an electric field applet from Caltech. Model Output 1 depicts a relatively uniform E-field distribution created by uniform charge distribution at ground level. Model Output 2 depicts the effects on the E-field distribution when a small amount of charge at a single location is moved "up" (closer to the cloud). Clearly, the results with the computer model are consistent with the predictions of the theory.



Model Output 1 – E-fields with Uniform Charge Distribution at Ground Level  
(<http://www.cco.caltech.edu/>)



Model Output 2 – E-fields with a Point Charge Moved "Up" Slightly (as with an RBS Roof)  
**Note That More Field Lines Converge at the Same Location**  
(<http://www.cco.caltech.edu/>)

After computer modeling, the final step in investigating the issue of lightning attraction was to “physically” model the situation. Two small house models were constructed – one with a RBS roof and one with a standard roof. The models were placed below a 400,000-volt Van De Graph generator. The electrical discharge (small lightning?) travelled from the generator source to the RBS roof versus the non-RBS roof essentially 100% of the time as shown in the time-lapse Photo 3 below.



Photo 3 – 400,000 Voltage Discharge (miniature lightning?) Selects the RBS Roof Every Time

**In Summary, There are Five (5) Reasons That Make us Tend to Believe RBS Material Attracts Lightning.**

1. Independent fire investigators on the front line of structure fires (such as Chief Wusterhausen) have observed that there has been an increase in lightning caused structure fires in houses of similar and newer construction.
2. McDowell Owens field investigations of lightning involved structure fires have revealed that a disproportionate number of these fires have been in houses with RBS roofs.
3. A review of the principles of physics (such as Gauss’s Law and Coulomb’s law) indicates that the presence of RBS will modify the electric fields in a way that will tend to increase the possibility of a lightning strike.
4. Computer model simulations agree with the predictions of the scientific theory.
5. Actual physical scale model simulations also completely agree with and support the theoretical predictions.

Final confirmation that radiant barrier sheathing attracts lightning will require one of two things that are not yet available. First, and most desirable, would be a statistically valid set of data containing properly adjusted numbers of lightning strikes to houses with RBS versus houses without RBS. Also possible is a full scale field lightning test of structures with and without RBS. Hopefully, one of these two things will be available in the future; however, until one is available, all presently available evidence clearly says that an RBS roof DOES attract lightning.



## IF LIGHTNING IS INVOLVED, WHY ISN'T IT THE CAUSE OF THE FIRE?



### God and Mother Nature Have Been Getting a Bad Rap!!

Historically (and especially before CSST), if lightning was involved in a structure fire, the “cause” was often dismissed as an “act of God” or an “act of nature”. We now know that in many cases, God and Mother Nature had very little to do with it. Lightning may provide the energy for ignition, but it is very often not the “cause” of ignition. Just because a source provides the energy does not mean it caused the fire. In all electrical appliance fires, the utility company provides the energy, but the utility company did not cause the fire. The failed appliance product conducting the current where it should not and then using the current in a way it should not is the actual cause of the fire.

A question that is frequently asked about a lightning involved RBS caused fires is: “how do you know that the lightning wouldn’t have caused a fire anyway?” The answer is simple: **it didn’t!** During investigations, we confirm that the lightning did not cause the fire in the following way. First, we identify the lightning strike point and confirm the fire did not originate there. Next, we identify the current exit point to ground and confirm the fire did not originate there. Then, we find conclusive evidence that the RBS material was in fact energized by lightning and we find the actual point of origin in a location where there is nothing but RBS material. If the fire originated on the RBS material in a location where there is NO OTHER source of ignition heat, the only reasonable conclusion is that the RBS material caused the fire. The lightning may have provided the energy, but the RBS material caused the fire. Without the actions of the RBS material, there would have been no structure fire. The RBS material collects the current from the lightning, the RBS material conducts the current to the location suited for fire origination, the RBS material generates the heat of ignition, and then the RBS material becomes the first ignited material. All the lightning does is provide the energy just as the utility company does in electrical appliance caused fires.

### THE COMBINED STRANGE BEHAVIORS OF RADIAINT BARRIER SHEATHING ROOFS CREATE A PERFECT STORM FOR FIRE CAUSATION

1. Reflective radiant barrier material requires no human supplied energy source. All available evidence says that RBS roofs **“attract” and collect lightning energy.**
2. When energized electrically, RBS material **transports the energy** to optimal locations for ignition of an attic fire.
3. Through resistive electrical heating, the RBS material utilizes the energy and **generates the heat** necessary for ignition.

4. When adequately heated, the radiant barrier itself **becomes the first ignited material**.
5. Finally, after ignition, the radiant barrier **accelerates fire progression** by focusing and concentrating the heat from the fire by “reflecting” the heat energy down onto wood structures in the attic.

**How much more effective can a fire ignition source be?**

### **BIG NEW CHALLENGES FOR FIRE INVESTIGATORS**

Another area where radiant barrier sheathing fires are unusual is in the evidence seen by the fire investigator. It has been said that an RBS fire investigation is **NOT YOUR FATHER’S FIRE INVESTIGATION**. In an RBS fire, there are effects and patterns that will be seen **ONLY** in an RBS fire. For example, all investigators at some point have been told that if multiple ignition sources are discovered for a structure fire, at least the possibility of arson should be considered. In the case of RBS fires, we often see multiple points of origin - sometimes many points of origin.



Photo 4 – Typical Evidence Observed in a Radiant Barrier Sheathing Fire Investigation  
**Note That There are Actually Three “Ignition” Points in This Photo**

In RBS involved fires, there will be electrical damage patterns that are not seen in any other type of fire. For example, there will sometimes be “arc flash” damage patterns. An electrical arc flash can generate temperatures of tens of thousands of degrees.



Photo 5 – A Large Arc Flash Pattern Where Extremely High Temperatures Were Generated

## **SUMMARY**

Radiant barrier sheathing (RBS) is an extremely efficient ignition source for structure fires and it exhibits some most unusual (even strange) behavior patterns. A roof constructed with RBS material appears to actually attract lightning. When energized electrically, an RBS roof conducts electrical energy to every square inch of the roof and along the way generates temperatures of at least 1200 degrees Fahrenheit in many locations. The RBS material becomes the first ignited material and multiple points of fire origin are common. If a house with an RBS roof is struck by lightning, the probability of a resulting attic fire is estimated by McDowell Owens to be roughly 80%. Furthermore, the RBS material accelerates the progression of an ignited attic fire by reflecting and concentrating the heat.

Because radiant barrier sheathing has become and continues to be very widely used in new home construction, radiant barrier caused structures fires will almost certainly become a much larger problem for fire investigators in decades to come.

## **ABOUT THE AUTHORS**

Mr. Ronald Simmons, P.E., C.F.E.I., is an Electrical Engineer employed by McDowell Owens Engineering. He studied engineering at California State Polytechnic University and for more than 15 years worked as an electronics system design and test engineer at Intel Corporation. Mr. Simmons has conducted dozens of radiant barrier involved fire investigations and has completed numerous lab test studies on the properties and behavior of radiant barrier products.

Mr. Eric Benstock, P.E., IEng., C.F.E.I., received a Bachelor of Science in Mechanical Engineering from the University of Houston. He has been an investigator and consulting engineer with McDowell Owens Engineering since 1995. He was appointed Director of Operations in 2001. In addition, he is a member of the Institute of Fire Investigators (MIFireE), UK.