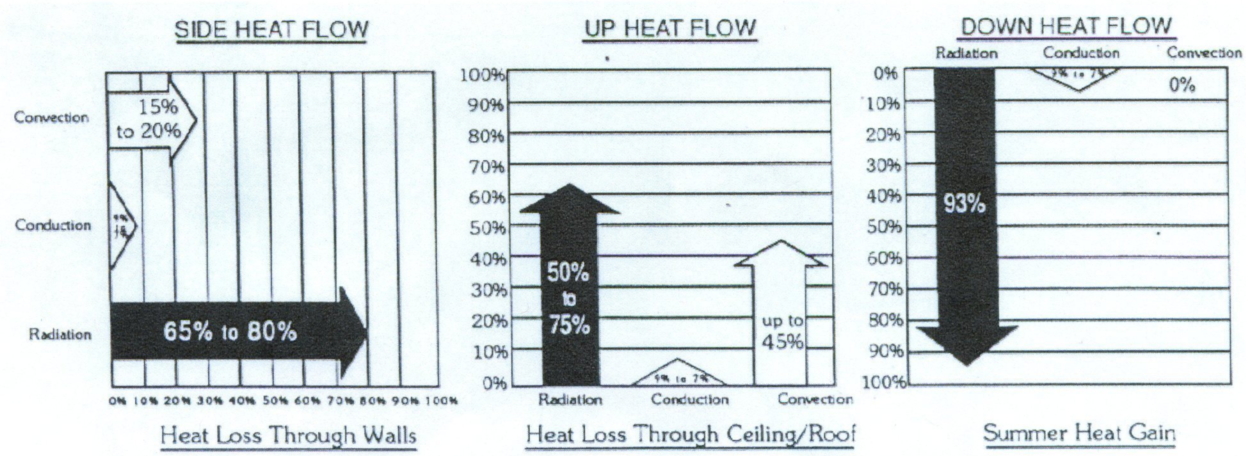
HEAT GAIN / LOSS IN BUILDINGS

**THERE ARE THREE MODES OF HEAT TRANSFER:
CONDUCTION, CONVECTION, AND RADIATION (INFRARED).**

Of the three, radiation is the primary mode of heat transfer; conduction and convection are the secondary and come into play only as matter interrupts or interferes with radiant heat transfer. As the matter absorbs radiant energy, it is heated, develops a difference in temperature, and results in molecular motion (conduction in solids) or mass motion (convection in liquids and gas).

All substances, including air, building materials, such as wood, glass and plaster, and insulation obey the same laws of nature; they do TRANSFER heat. Solid materials differ only in the rate of heat transfer, which is affected by differences in: density, weight, shape, permeability and molecular structure. Materials which transfer heat slowly can be said to RESIST heat flow.

Direction of heat transfer is a very important consideration to understand where to apply Pro-Tek/USA Insulating -Reflective Ceramic Coatings. Heat is **radiated** and **conducted** in all directions, but **convected** primarily upward. The figures below show modes of heat loss in houses and buildings. **<u>In all cases, radiation is the dominant mode.</u>**



<u>CONDUCTION</u> is direct heat flow through matter (molecular motion). It results from actual PHYSICAL CONTACT of one part or of one body with another. For instance, if one end of an iron rod is heated, the heat travels by conduction through the metal to the other end. It also travels to the surface and is conducted to the surrounding air which is another, but less dense, body. An example of conduction through contact between two solids is a cooking pot on the solid surface- of a hot stove. The greatest flow of heat possible is where there is direct conduction between solids. Heat is always conducted from **warm to cold**; never from cold, to warm, and always moves via the shortest and easiest route.

In general, the more dense a substance, the better conductor it is. Solid rock, glass and aluminum, being very dense are good conductors of heat. Reduce their density by mixing air into the mass, and their conductivity is reduced. Because air has low density, the percentage of heat transferred by conduction through air is comparatively small.

<u>CONVECTION</u> is the transport of heat within a gas or liquid, caused by the actual flow of the material itself (mass motion). In building spaces, **natural convection heat flow is largely upward**, somewhat sideways, not downwards. This is called free convection. For instance, a warm stove, person, floor, wall, etc., loses heat by conduction to the cooler air in contact with it. This added heat activates (warms) the molecules of the air which expand, becoming less dense and rise. Cooler, heavier air rushes in from the side and below to replace it. The popular expression "hot air rises" is exemplified by smoke rising from a chimney or a cigarette. The motion is turbulently upward, with a component of sideways motion. Convection may also be mechanically induced, as by a fan. This is called forced convection.

RADIATION is the transmission of electromagnetic rays through space. Radiation, like radio waves, is invisible. Infrared rays occur between light and radar waves, (between the 3 - 15 micron portion of the spectrum). Henceforth, when we speak of radiation, we refer only to infrared rays. Any material with a temperature above absolute zero (-459.7 F.), emits infrared radiation, including the sun, icebergs, stoves or radiators, humans, animals, furniture, ceilings, walls, floors, etc. All objects radiate infrared rays from their surfaces in all directions and in a straight line, until they're reflected or absorbed by another object. Traveling at the speed of light, these rays are invisible, and they have **NO TEMPERATURE**, only **ENERGY**. Heating an object excites the surface molecules, causing them to give off infrared radiation. When these infrared rays strike the surface of another object, the rays are absorbed and only then is heat produced in the object. This heat spreads throughout the mass by conduction. The heated object then transmits infrared rays from exposed surfaces by radiation, if these surfaces are exposed directly to an air space.

EMISSIVITY AND ABSORPTANCE

The amount of radiation emitted is a function of the **EMISSIVITY** factor of the source's surface. EMISSIVITY is the rate at which radiation (EMISSION) is given off. Absorption of radiation by an object is proportional to the absorptivity factor of its surface which a reciprocal of its emissivity. Although two objects may be identical, if the surface of one were covered with a material of 90% emissivity, and the surface of the other with a material of 5% emissivity, there would result a drastic difference in the rate of radiation flow from these two objects

Materials whose surfaces do not appreciably reflect infrared rays, for example, paper, asphalt, wood, glass and rock, have an absorption rate from 80% to 93%. **Most materials used in building construction - - brick, stone, wood, paper, regardless of their color, absorb infrared radiation at a rate of about 90%.**

Pro-Tek/USA's Ceramic - Reflective - Insulating- Coatings **(CRICS[SM])** have the ability **NOT TO ABSORB**, but **REFLECT, 90 -95%** of the infrared rays striking it.

REFLECTIVITY AND AIR SPACES

In order to retard heat flow by conduction, walls and roofs are built with internal air spaces. Conduction and convection through these air spaces combined represent only **20% to 35%** of the heat which pass through them.

In both winter and summer, **65% to 80%** of the heat that passes from a warm wall to a colder wall or through a ventilated attic does so by **radiation.**

The value of air spaces as thermal insulation must include the character of the enclosing surfaces. The surfaces greatly affect the amount of energy transferred by radiation, depending on the material's absorptivity and emissivity and are the only way of modifying the total heat transferred across a given space.

The importance of radiation cannot be overlooked in problems involving ordinary room temperatures !

The following test results illustrate how heat transfer across a given air space may be- modified. The temperature differences of the hot and cold surfaces are 70 °F and 32 °F, respectively. In all cases the walls are made of wood, and similar building materials:

CASE 1. UNINSULATED WALL SPACE			CASE 2. THE SAME WALL SPACE EXCEPT that the inner surfaces were lined with sheets of aluminum foil, a reflective material.			CASE 3. 2 COATS of Pro-Tek/USA Insulating Reflective Ceramic Coating (90-95% EMISSIVITY)		
Outside 32°F	**Inside 70°F**	**Heat Flow by:**	**Outside 32°F**	**Inside 70°F**	**Heat Flow by:**	**Outside 32°F**	**Inside 70°F**	**Heat Flow by:**
	←7 BTU's	**Conduction**		**←14 BTU's**	**Conduction**		**←12 BTU's**	**Conduction**
	←←30 BTU's	**Convection**		**←30 BTU's**	**Convection**		**←25 BTU's**	**Convection**
	←←←70 BTU's	**Radiation**		**←35 BTU's**	**Radiation**		**←2 BTU's**	**Radiation**
	107 BTU's			**79 BTU's**			**39 BTU's**	
The surfaces of ordinary building materials, including ordinary bulk insulation have a radiation or emissivity rate of about 10%, a heat absorption rate of over 90%. Air has low density, so conduction is slight (only 7 BTU's.) Convection currents transfer 30 BTU's.			Note the drastic drop in heat flow by radiation, from 70 BTU's to 35 BTU's Conduction rises from 7 to 14 and convection is unchanged. The original total heat loss of 107 BTU's drops to 79 BTU's.			Heat loss by radiation drops from case 1. The 2 coats of interior coating retard convection so that its flow falls 16%. The coating film acts as a vapor barrier reducing the convection of heat. Conduction is reduced by 2 BTU's; from 14 BTUs to 12 BTU's. The total heat loss drops 63% as compare to case 1.		
Results are different in all applications. The following data is a result of this particular experience and circumstance that can be widely generalized. .								

Reflection and emissivity by surfaces can ONLY occur in SPACE. The ideal space is any dimension 3/4" or more. Smaller spaces are also effective, but decreasingly so. Where there is no air space, we have conduction through solids. When the reflective surface material is attached to a ceiling, floor or wall, that particular surface ceases to have radiant insulation value at the points in contact. Therefore, when installing FOIL INSULATION it has to be stretched sufficiently to insure that any inner air spaces are properly opened up and that metal does not touch metal. Otherwise, conduction through solids will result at the point of contact. **This particular detail makes the foil materials fail by their design.**
In the space vehicle Columbia, tiles are imbedded with ceramic bits, which reflect heat before it can be absorbed.

HEAT LOSS THROUGH AIR

There is no such thing as a "dead" air space as far as heat transfer is concerned, even in the case of a perfectly airtight compartment such as a thermos bottle. Convection currents are inevitable with differences in temperature between surfaces, if air or some other gas is present inside. Since air has some density, there will be some heat transfer by conduction if any surface of a so called 'dead" air space is heated. Finally, radiation, which accounts for 50% to 80% of all heat transfer, will pass through air (or a vacuum) with ease, just as radiation travels the many million miles that separate the earth from the sun.
Ceramic Insulating Coatings, with their reflective properties can block the flow of radiation. They are impervious to water vapor and convection currents, and reflects 90 % plus of all radiant energy, which strikes its air-bounded surfaces.

The performance of Pro-Tek/USA's Insulating-Reflective Ceramic Coatings are unsurpassed for upward rising winter heat.

HEAT LOSS THROUGH FLOORS

Heat is lost through floors primarily by radiation (up to 93%). When **Pro-Tek/USA's** Ceramic - Reflective - Insulating-Coatings **(CRICS℠)** are applied in the ground floors and crawl spaces of cold buildings, it prevents the heat rays from penetrating down; reflecting the heat back into the building, thereby warming the floor surfaces.

CONDENSATION

Water vapor is the gas phase of water. As a gas, it will expand or contract to fill any space it may be in. In a given space, with the air at a given temperature, the amount of vapor that can be suspended is limited. Any excess will turn into water. The point just before condensation commences is called 100% saturation. The condensation point is called dew point. CONDENSATION FORMS WHENEVER AND WHEREVER VAPOR REACHES DEW POINT.

VAPOR LAWS

1. The higher the temperature, the more vapor the air can hold; the lower the temperature, the less vapor.
2. The larger the space, the more vapor it can hold; the smaller the space, the less vapor it can hold.
3. The more vapor in a given space, the greater will be its density.
4. Vapor will flow from areas of greater vapor density to those of lower vapor density.
5. Permeability of insulation is a prerequisite for vapor transmission; the less permeable, the less vapor transfer.

The average water vapor saturation point is about 65%. If a room was vapor-proofed, and the temperature was gradually lowered, the percentage of saturation would rise until it reached 100%, although the amount of vapor would remain the same. If the temperature were further lowered the excess amount of the vapor for that temperature in that amount of space would fall out in the form of condensation. This principle is visibly demonstrated when we breathe in cold places. The warm air in our lungs and mouth can support the vapor, but the quantity is too much for the colder air, and so the excess vapor for that temperature condenses and the small particles of water become visible in front of the mouth.

In conduction, heat flows to cold. The under surface of a roof, when cold in the winter, extracts heat out of the air with which it is in immediate contact. As a result, that air drops in temperature sufficiently to fall below the dew point (the temperature at which vapor condenses on a surface). The excess amount of vapor for that temperature that falls out as condensation or frost, attaches itself to the under side of the roof. Water vapor is able to penetrate plaster and wood readily. When the vapor comes in contact with materials within those walls having a temperature below the dew point of the vapor, they form moisture or frost within the walls. This moisture tends to accumulate over long periods of time without being noticed, which can cause building damage and batt insulation waterlogged and ineffective.

To prevent condensation, a large space is needed between outer walls and any insulation which permits vapor to flow through. Reducing the space or the temperature converts vapor to moisture which is then retained. The use of separate vapor barriers or insulation that is also a vapor barrier are alternative methods to deal with this problem. ***Ceramic Coatings are the only product on the market that solves this problem, as it is insulation and vapor barrier in one!.***

TESTING THERMAL VALUES

R-FACTOR is the rate of heat flow, measured in BTUs in one hour through one sq. ft. area of ceilings, roofs, walls or floors, including insulation (if any) resulting from a 1°F temperature difference between the air inside and the air outside.

MEMORY JOGGER: U = BTUs flowing in ONE hour, through ONE sq. ft. for ONE degree change.
R-FACTOR or RESISTANCE to heat flow is the reciprocal of U; in other words, 1/K. The smaller the K-Factor fraction, the larger the R factor, the better the insulation's ability to stop conductive heat flow.

Note: Neither of these factors include radiation or convection flow.

There are at present two kinds of techniques generally used by accepted laboratories to measure thermal values: The guarded hot plate and the hot box methods. The results obtained seem to vary between the two methods. Neither technique simulates heat flow through insulation in actual everyday usage. Thermal conductivity measurements as made in the completely dry state in the laboratory will not match the performance of those same insulations under actual field conditions. Most mass type insulating materials become better conductors of heat when the relative humidity increases because of the absorption of moisture by the insulator. **(Try keeping you feet warm in a pair of wet socks.)** Therefore, mass insulations, which normally contain at least the average amount of moisture which is in the air, are first completely dried out before testing. In Pro-Tek/USA's Insulating-Reflective Ceramic Coatings, there is no moisture problem. Ceramic Coatings are one of the few insulating materials that are not affected by humidity and, consequently, its insulating value remains unchanged from the "bone dry" state to very high humidity conditions. The R-Value of a mass type insulation is reduced by over 35% with only a 11/2 % moisture content. (ie. from R13 to R 8.3). The moisture content of insulation materials in homes typically exceeds 11/2% !

IN SPITE OF THE ADVANCES MADE BY SPACE TECHNOLOGY IN INSULATION SYSTEMS BASED ON UNDERSTANDING AND MODIFYING THE EFFECTS OF RADIATION, NO UNIVERSALLY ACCEPTED LABORATORY METHOD HAS YET BEEN DEVELOPED TO MEASURE AND REPORT THE RESISTANCE TO HEAT FLOW OF CERAMIC INSULATING COATINGS. UNTIL SUCH A METHOD THAT WILL SATISFY RIGOROUS LABORATORY DEMANDS IS DEVISED, WE MUST BE CONTENT TO MAKE OUR JUDGEMENTS ON THE BASIS OF COMMON SENSE AND EXPERIENCE. THERE ARE MANY DIFFERENT TYPES, GRADES, AND QUALITIES OF PRO-TEK/USA CERAMIC REFLECTIVE INSULATING- COATINGS (**CRICS**SM) DESIGNED FOR A VARIETY OF APPLICATIONS. MATCHING THE CORRECT COATING TO THE SPECIFIC JOB IS EXTREMELY IMPORTANT TO PERFORMANCE.