ASHRAE Illinois Chapter

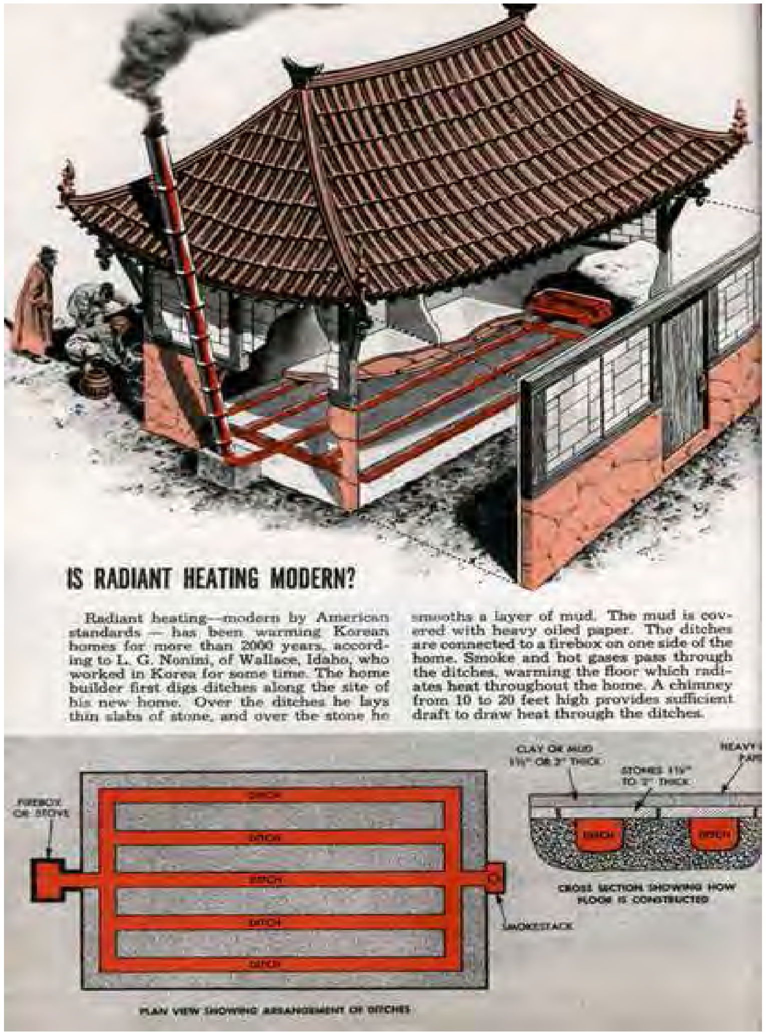
November 12 Monthly Meeting

Brian M. Ford

# *Innovation and Its Role in the Evolution of Radiant Heating and Cooling Systems.*

# Agenda

- Evolution of Radiant Heating & Cooling Systems through the ages
- Emergence of Radiant Panels
- Recent Innovations & Looking Forward



IS RADIANT HEATING MODERN?

Radiant heating—modern by American standards — has been warming Korean homes for more than 2000 years, according to L. G. Nonini, of Wallace, Idaho, who worked in Korea for some time. The home builder first digs ditches along the site of his new home. Over the ditches he lays thin slabs of stone, and over the stone he smooths a layer of mud. The mud is covered with heavy oiled paper. The ditches are connected to a firebox on one side of the home. Smoke and hot gases pass through the ditches, warming the floor which radiates heat throughout the home. A chimney from 10 to 20 feet high provides sufficient draft to draw heat through the ditches.



*[Popular Mechanics](#)*
Issue: [Sep, 1949](#)

# Chinese Kang & Dikang

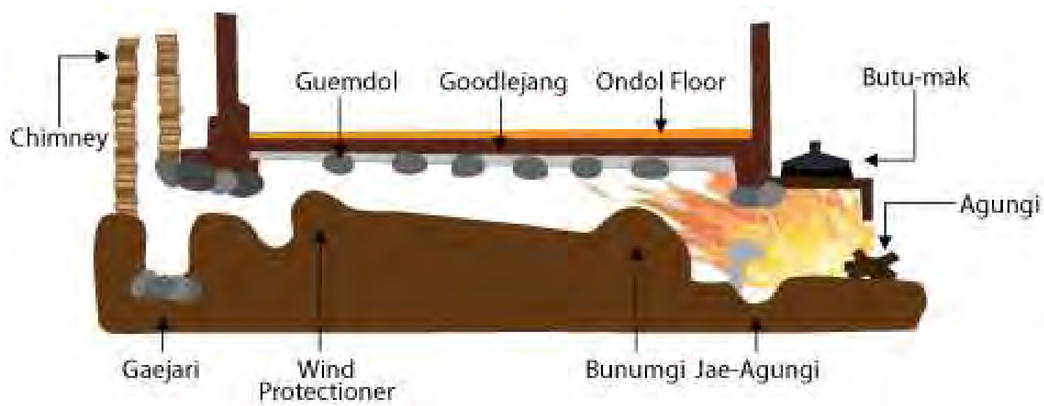
- The **Chinese kang (bed-stove)** is said to be derived from the concept of a heated bed floor called a *huoqiang* found in China in the Neolithic period, according to analysis of archeological excavations of building remains in Banpo Xi'an. However, archeleogical sites in Shenyang, Liaoning, show humans using the heated bed floor as early as **7,200 years ago**.
- Typically, **a *kang* occupies one-third to one half the area the room,** and is used for sleeping at night and for other activities during the day. **A kang which covers the entire floor is called a dikang (literally "ground kang").**

# Chinese Kang & Dikang

- "The interior of an inn". In illustration in H.E.M. James book. It is followed by a couple of pages where he described an inn in the Hunjiang River valley east of Tonghua, in an area that was very much a "frontier" of Chinese settlement. **Note a long *kang* (bed-stove) along the wall, shared by the guests.**

# Korean Ondol

- An **ondol**, also called **gudeul**, in **Korean** traditional architecture, is underfloor heating which uses direct heat transfer from wood smoke to the underside of a thick masonry floor. The earliest use of ondol has been found at an archaeological site in present-day North Korea. A Bronze Age archaeological find, 1000 BC, discovered in Unggi, Hamgyeongbuk-do, in present-day North Korea



# Roman Hypocaust

- A **hypocaust** (Latin *hypocaustum*, Greek *hypocauston*) was an ancient **Roman system of underfloor heating.**
- The word derives from the ancient Greek *hypo* meaning "under" and *caust-*, meaning "burnt"

Villa gallo-romaine de Vieux-la-Romaine, près de Caen, Basse-Normandie, France.

# Roman Hypocaust

- Other examples of "hypocausts" can be found in **Pakistan** (Mohenjo-daro 2600 BC), the **Republic of Georgia** (Dzalisa, 200-400 BC), **Jordan** "caldarium" (hot room), **Syria** and in **Spain** (Castile) where they are called "Gloria"
- **Problems;** *energy inefficient (whole forests were lost) labor intensive (constantly need to be tended)*
- **Innovation;** ***heated large areas from a central fire.***

Qusayr 'Amra, Jordan caldarium dome

# Early Radiant Cooling

- **Water circulation;** wealthy residents of ancient Roman cites pumped cool water from aqueducts into their villas and apartments.
  - **The water circulated through pipes installed in the walls, lowering room temperatures on hot summer days**.

- **Snow and Ice;** According to legend, several heat-averse roman emperors had snow hauled down from the mountaintops to cool their summer villas.  It is also said that the eighth century
  - **Persian caliph Al-Mahdi, packed the double walls of his Baghdad palace with imported snow and ice**

# Early Hydronic Cooling

- The Lotus Mahal (1540). Water flows through intricate channels along the walls to take away heat from the interior.
- **Innovation; *hydronic radiant and evaporative cooling***

The Lotus Mahal, Hampi, Karnataka, India

# Earth Coupled Cooling

- **Göreme** was inhabited as early as circa 1800 to 1200 B.C.  Located on a high, dry plateau in the middle of **Turkey**, the region is one of **hot, dry summers and cold, sometimes snowy, winters**.

- **Innovation;** ***the famous cave dwellings use Earth Coupled technology to help condition their living space.***

For more than a thousand years, people have made their homes in the soft rock of Cappadocia.

Elkep Evi Cave House - Urgup

# Early Hydronic Heating

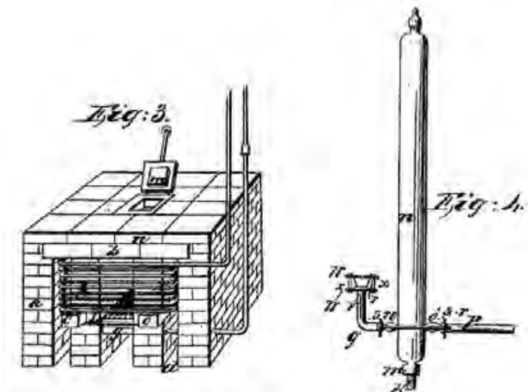
- 1700 Russian engineers had started designing **hydrologically based systems for central heating**. The Summer Palace (1710–1714) of Peter the Great in Saint Petersburg provides the best remaining example.

Saint Petersburg, Russia. Summer Palace of Peter I in the Summer Garden.

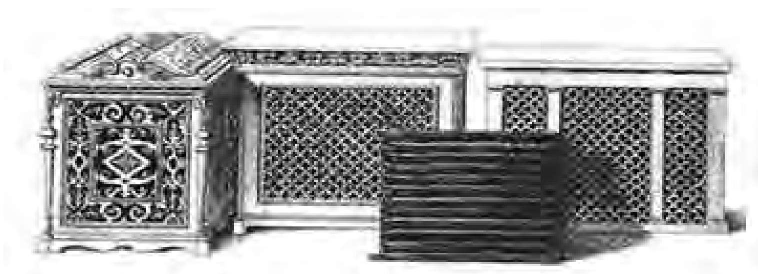
# Development of the Radiator

- **1831** American inventor *Angier Marsh Perkins (1799-1881)* was granted a patent in Britain for a boiler and expansion tube know as the ***Perkins Steam Heater***. This, however ran at massively high pressure, and was not suitable for domestic settings.

- **1841** Perkins developed a lower pressure system ***Perkins Hot Water Apparatus*****,** and an understudy of his*, Joseph Nason*, took what he had learnt and moved back to New York in 1842 and the *Walworth & Nason* company was established. This was the early beginnings of what was to become the ***American Radiator Co*****.**




Details of furnace and expansion tube from US Patent 888 by AM Perkins, August 20 1838



*High pressure hot water heating coil & decorative coil cases. [Patent Apparatus for Warming and Ventilating Buildings, AM Perkins, London 1840]*

# Willis Carrier

- **In 1902 Willis Carrier would build the first air conditioner to combat humidity problems inside a printing company and in 1917 the first documented theater to use air conditioning made its debut at New Empire Theatre in Montgomery, Alabama.**
- **Innovation; *removal of humidity (latent load) and increased comfort***

**1902:** With human comfort the last thing on his mind, a young mechanical engineer completes the schematic drawings for what will be the first successful air-conditioning system.

# Emergence of Radiant Ceilings

- **1907**, **Arthur H. Barker, a British professor, discovered that small hot water pipes embedded in plaster or concrete formed a very efficient heating system**.
- Subsequently, **"panel heating"** was used in Europe in conventional buildings, on the open terraces of many sanatoriums, and in an open-air roofed pavilion at a British World Fair

# Toledo Blade December 22, 1914

Business -:- Markets -:- Industry

PAGE 18 TOLEDO, OHIO, FRIDAY, DECEMBER 22, 1944

**Today In Toledo**

By FRANK SHELDON

**Radiant Heating Benefits Stressed**

RADIANT heating for homes, factories, schools, office buildings and most other structures to be built after the war is not a dream but a generally accepted probability," George Coffey, field service engineer of the Chicago division of A. M. Byers Co., Pittsburgh, told members of the Heating, Ventilating and Air Conditioning Society of Toledo at a dinner meeting in the Willard Hotel, last night.

Mr. Coffey affirmed that radiant heating, unlike many of the promises for postwar homes, already has achieved more than 1,000 successful installations in all types of structures built in this country before and during the war, including one in Toledo.

"Radiant heating will be adopted," Mr. Coffey stated, "because it makes possible substantial fuel savings and provides greater comfort than any other heating system yet devised."

The most common installations, he said, consist of wrought iron pipe coils located either in the floor or ceiling. The principle involved was explained as follows:

"Most people think that a heating system delivers heat to an individual to keep him warm. Actually, this is an error. The body generates its own heat. A heating system is a device for controlling the rate at which the body cools off. In order to be comfortable in cool weather we cannot consistently lose more than a certain amount of heat per hour without experiencing sensations of chill or cold. Radiant heating, by heating a large area such as a floor or ceiling, radiates this warmth to all other surfaces in the room. When room surfaces are warm, heat loss from the body is under proper control."

**Carrier Shares In Brisk Bulge**

Gains Reach 2 Points With New Tops Set

War Time Record of Texas Co. Stock

**Grains Improve, Offerings Light**

Wheat Extends Gains In Early Dealings

*1914 HVACS Dinner Meeting*

"Radiant heating will be adopted", Mr. Coffey stated, "because it makes possible substantial fuel savings and provides greater comfort than any other heating system yet devised"

Wrought iron pipe coils in floors and ceilings!

# Influence of Frank Lloyd Wright

- **1905** Frank Lloyd Wright travels to Japan where he **experiences an ondol heated home**. He later incorporates various early forms of radiant heating in his projects.
- **1937 Frank Lloyd Wright installed radiant panel heating in the Johnson Wax Building.** By 1940, “Architectural Record” reported the existence of eight such installations in different types of buildings in the US: four residences, a church, a high school, an office building, and an airplane hangar.
- **1937** Frank Lloyd Wright designs the **radiant heated** Herbert Jacobs house, the first Usonian home.
- **Innovation;** ***use of efficient hydronic in-slab radiant system***

# Influence of William Levitt

- **1945** American developer William Levitt builds large scale developments for returning GI's. **Water based (copper pipe) radiant heating used throughout thousands of homes.**
- **1947** "Levittown" houses **sold for between $6,995 and $8,000** with monthly payments as low as $57, a low price even by 1947 standards.
- Levittown proved successful. By **1951**, it and surrounding regions included **17,447 homes** constructed by Levitt and Sons.


# Early Problems with Radiant Cooling

- Radiant heating installations are easily converted into **radiant cooling** installations by running cold water through the radiant panels. Most of the early cooling ceiling systems developed in the **1930s** failed, however, because **condensation often occurred in cooling mode**.
- Subsequent **studies showed that this problem could be avoided if the radiant system was used in conjunction with a small ventilation system designed to lower the dew-point of the indoor air**. This combination proved successful in a department store built in 1936-1937 in Zürich, Switzerland, and in a multi-story building built in the early 1950s in Canada. (LBL)
- **Problem**; condensation
- **Innovation**; ***early DOAS system***

# 1953 Alcoa Building, Pittsburgh

- A **radiant heating and cooling system is contained in the ceiling structure**, freeing the window space under the exterior walls from radiators or air conditioning units, and **providing an additional 15,000 ft2 (1400 m2) of rentable space**.
- **Innovation; *radiant ceiling created extra room space***

Former world headquarters for the Aluminum Company of America.

Built in 1953, it was meant to showcase the Metal of Tomorrow.

# 1960 Kaiser Building

- Completed in 1960 the Kaiser Building in Oakland, is equipped with a **radiant cooling** system. A study conducted in 1994 showed that this system does not perform to the satisfaction of the occupants: it fails to provide acceptable thermal comfort.

- **The study demonstrated that the failure of the system is due to the design of the building (single-pane windows with aluminum frames, a large façade facing west), to a gradual increase of personal computers and office equipment over time, and to the relatively low cooling power of the radiant panels employed. (LBL)**

- **Problem**; building envelope, low cooling power

- **Innovation;** ***opportunity for increased cooling power, higher water temp, faster reaction time***

# 1962 Shell Centre, London

- Radiant cooling panel technology is used in both of the 27-storey Shell Buildings by the Thames in London.
- **Water from the Thames was pumped through a heat exchanger to cool all the ceilings totaling a massive 1.9 million sq ft.** Shell's London headquarters became Europe's first fully sealed air-conditioned building and, to date, this is still the world's largest chilled ceiling system.
- **Innovation;** ***geothermal (river water) used for "high temperature" cooling***

# 1962 Shell Centre, London

- A technical evaluation considered a number of alternative systems of air conditioning; radiant ceiling with either low or high air pressure distribution, double-duct, induction or fan-coil. The choice by the design-contractor G N Haden was a **chilled water radiant ceiling system**, a decision endorsed by the client's advisory consultant, C S Leopold of Philadelphia, for the following reasons:

  ***"The main advantage of radiant cooling lies in the fact that less space is required for pipes to transfer heat by water than for ducts to transfer heat by air. The cost of pumping water is a small fraction of the cost of delivering air for the same heat transfer. The air supply may be substantially reduced to that required for ventilation and humidity control and approximately half the cooling load."***

- ***Innovation;*** ***decoupling of sensible and latent to reduce plenum space and increase energy efficiency***

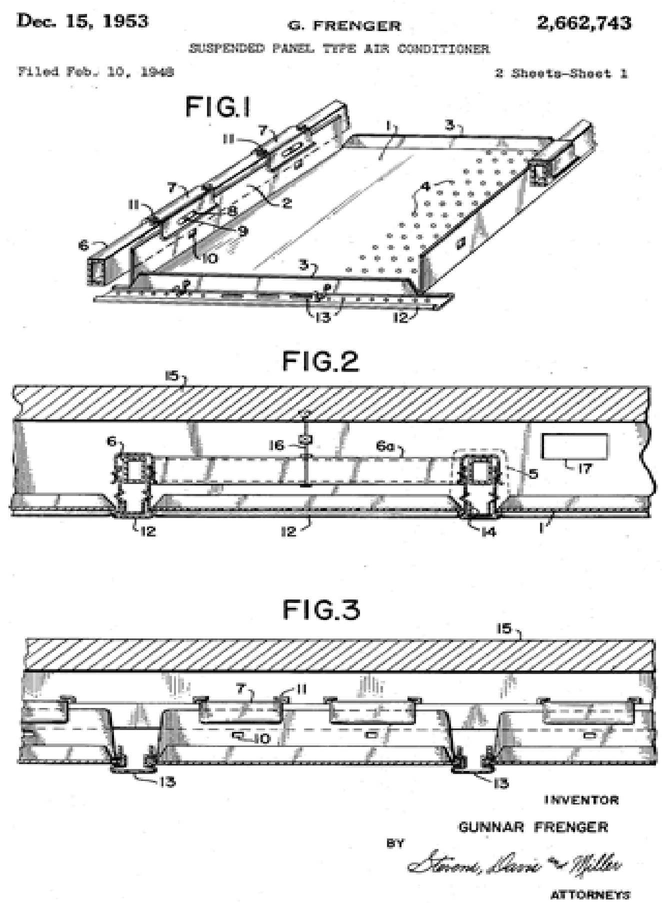
# Radiant Panel History


- **1915** Dr. C.F.Burgess founds Burgess Laboratories in Madison, WI.
- **1926**, Burgess announced that his Laboratories would investigate the phenomena of sound to improve the acoustical properties in auditoriums.
- **1929** R. F. Norris of C.F. Burgess Lab develops perforated metal acoustic panels.
- **1948** Norwegian inventor, Gunnar Frenger, came to the United States with a complicated system for an **acoustical radiant heating ceiling**. Burgess-Manning took an option on Frenger's proposed license and after a thorough investigation became the United States licensee.

# Frenger 1953

- <u>Suspended panel type air conditioner US 2662743 A</u>

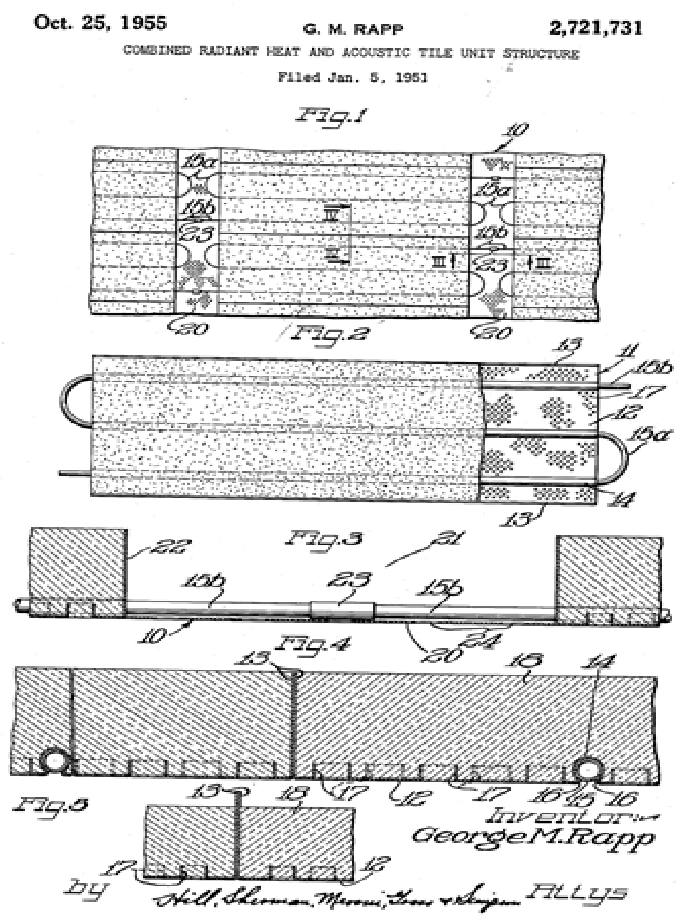
| | |
|---|---|
| Publication number | US2662743 A |
| Publication type | Grant |
| Publication date | Dec 15, 1953 |
| Filing date | Feb 10, 1948 |
| Priority date ⓘ | Oct 21, 1947 |
| Inventors | Gunnar Frenger |
| Original Assignee | Gunnar Frenger |



# Rapp 1955

- Combined radiant heat and acoustic tile unit structure
  US 2721731 A

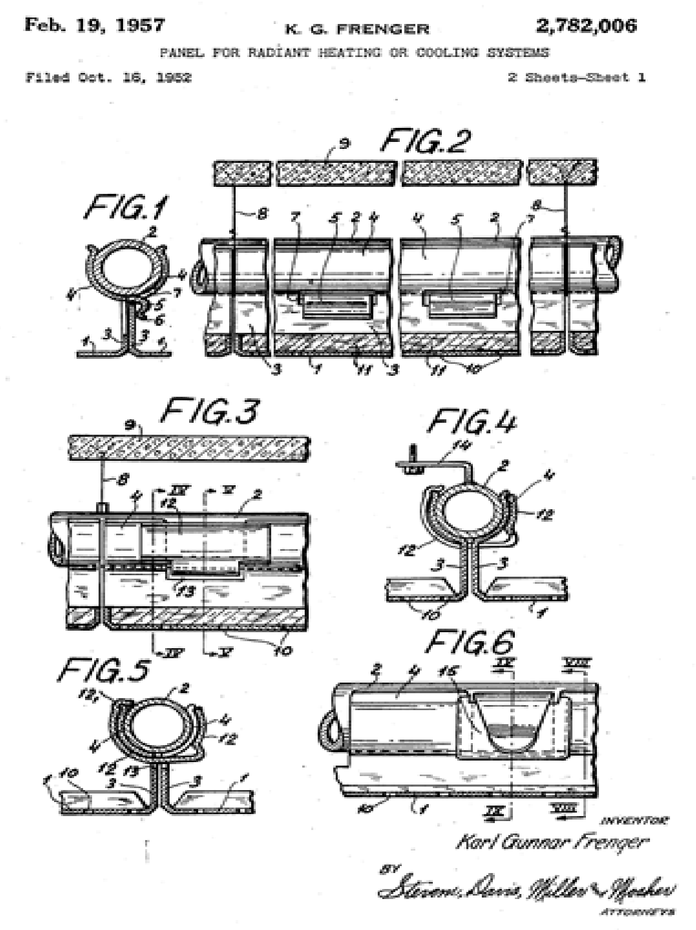
| | |
|---|---|
| **Publication number** | US2721731 A |
| **Publication type** | Grant |
| **Publication date** | Oct 25, 1955 |
| **Filing date** | Jan 5, 1951 |
| **Priority date** ? | Jan 5, 1951 |
| **Inventors** | Rapp George M |
| **Original Assignee** | Houdaille Hershey Corp |



# Frenger 1957

- Panel for radiant heating or cooling systems
  US 2782006 A

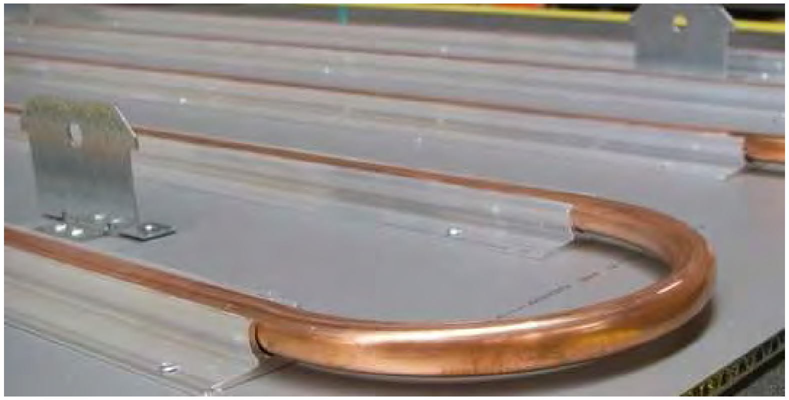
| | |
|---|---|
| Publication number | US2782006 A |
| Publication type | Grant |
| Publication date | Feb 19, 1957 |
| Filing date | Oct 16, 1952 |
| Priority date | Oct 20, 1951 |
| Inventors | Gunnar Frenger Karl |
| Original Assignee | Gunnar Frenger Karl |



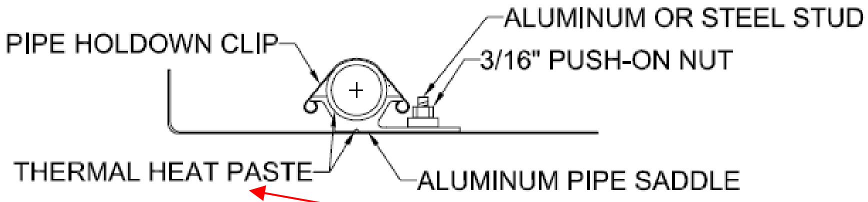
# Innovation “Drivers”

- Product differentiation
- Competitive advantage
- Continuous improvement
- Increased performance
- Reduced weight
- Cost reduction (product, operating and lifetime costs)
- Improved acoustic properties
- Simplified manufacturing process (decrease complexity)
- Application of emerging technologies

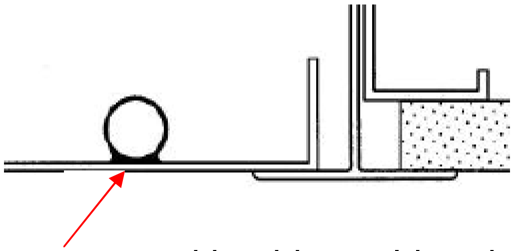
# Conventional Configurations for Thermal Transfer from Tubing to Metal Panels



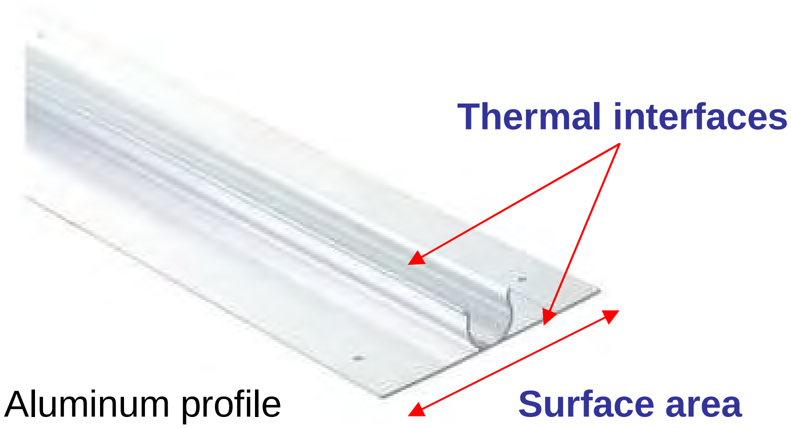
4 or 6 pass copper meander tube panel




**Innovation;** improve thermal interface and increase surface areas

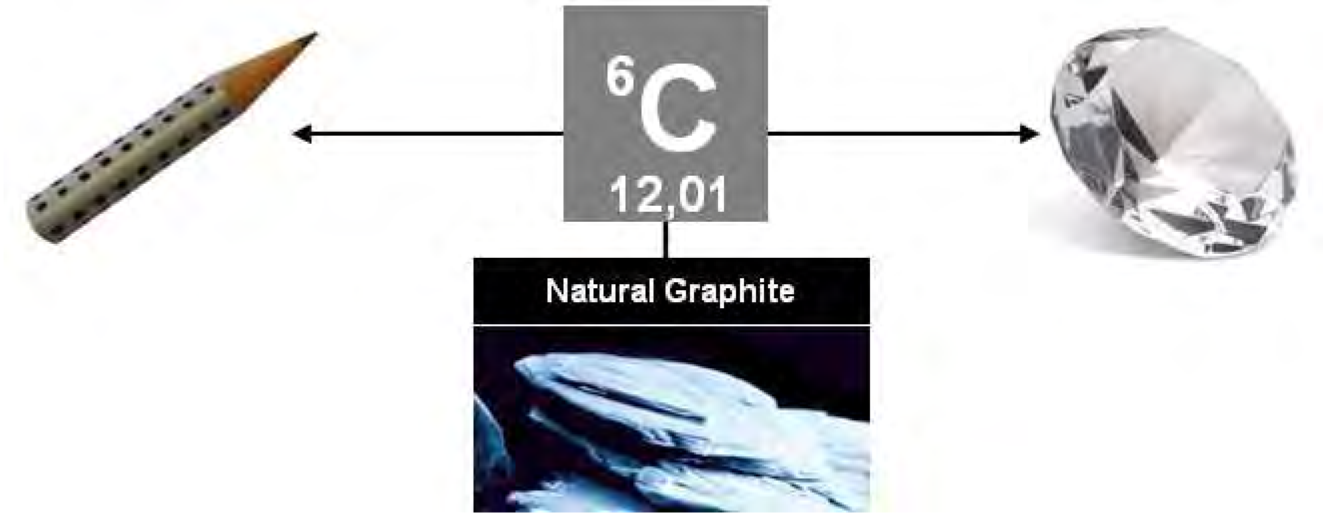


Spot contact with tubing soldered directly to metal panel



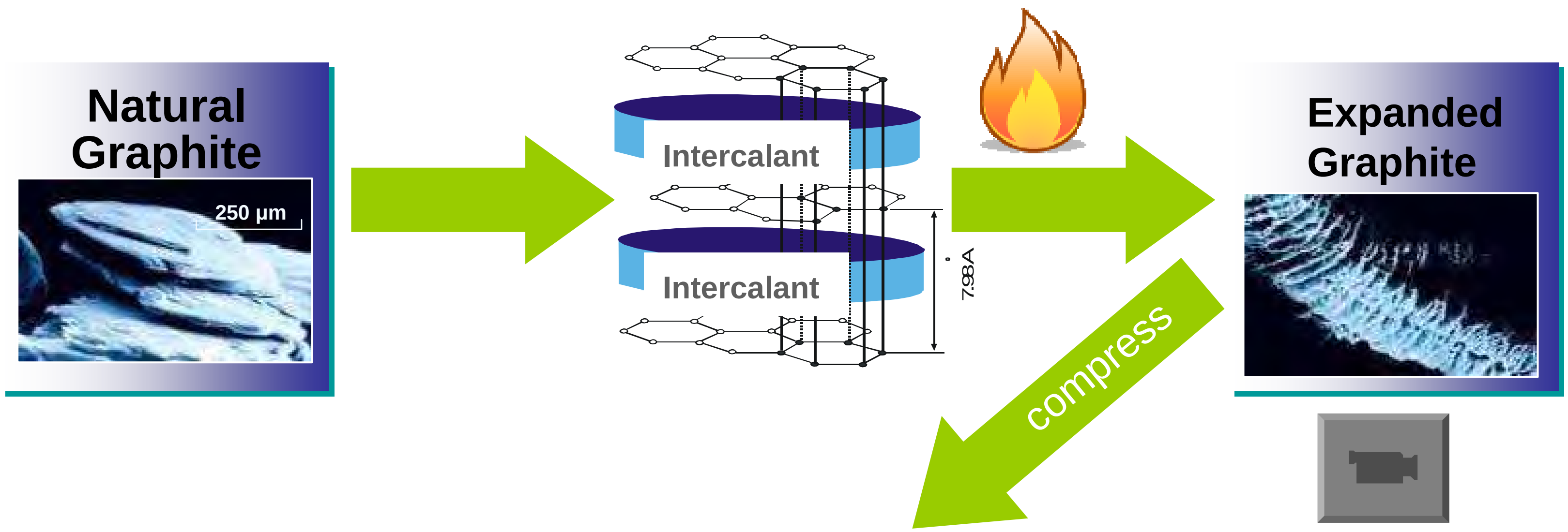

Aluminum profile

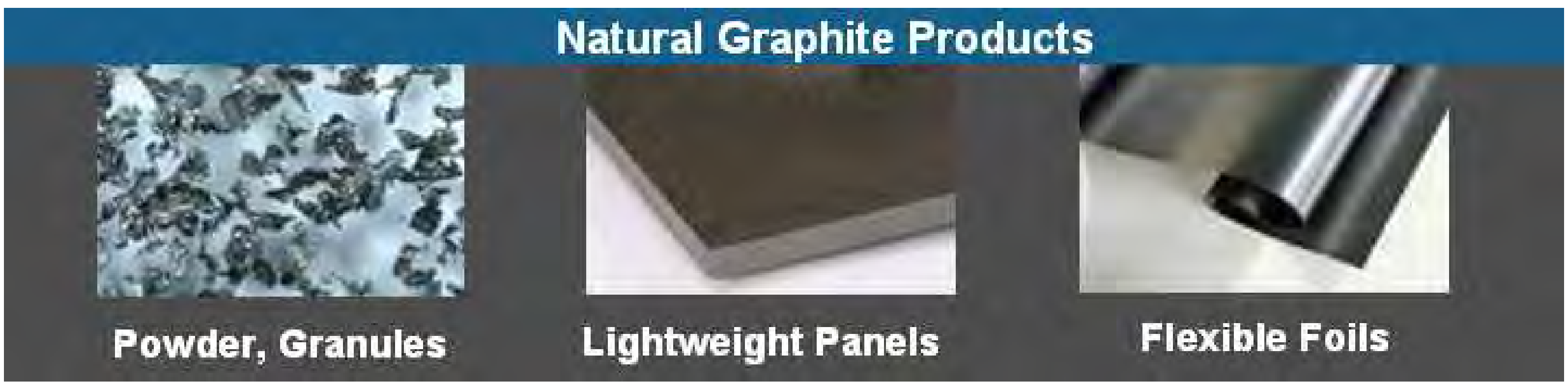
# Graphite's Many Unique Properties




- Superior thermal conductivity
- Superior electrical conductivity
- Chemically & corrosion resistant
- Soft & conformable
- Compressibility & recovery
- Lightweight
- Non flammable
- Thermally stable
- Non-wetting
- Zero CTE

# Expanded Natural Graphite



# Graphite for Automotive

- In the mid 80's Graphite replaced asbestos as the material of choice in critical high temp. engine sealing applications.
- **Thermal stability, conformability, compressibility/recovery & thermal conductivity** enabled many innovative engine improvements
- **Innovation; HP and MPG increased while engine sizes, weight, and emissions were all reduced**

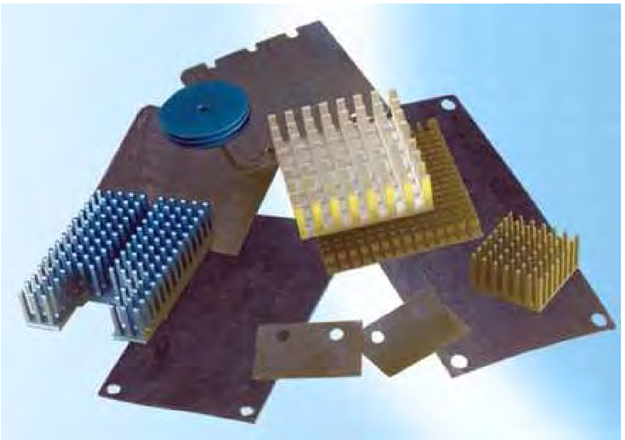
GM Performance Parts
LSX 454-R Siamese Bore engine

4-1/8" Bore Head Gasket

- .043" Thick, Graphite
- 1984–Up Big Twins

# Graphite for Electronics Thermal Management

- The ever increasing heat generated in consumer electronics created opportunities for new thermal management solutions;
  - **Thermal interface materials**
  - **Heat sinks / Heat spreaders**
- Graphite's unique properties led to it's widespread use for ETM solutions
- **Innovation; improved thermal interface and conductance between device and HS, increased surface area greatly improves heat dissipation**




**Thermographic image of a mobile phone**

# Graphite for LED Cooling

- Graphite foil is used in small form factor applications as an effective **TIM & Heat Sink**
- Graphite particles are used as a **conductive additive** in polymers to enable injection molded thermal management solutions
- **Innovation; brighter longer lasting LEDs, fewer parts, simplified mfgr., lower cost!**

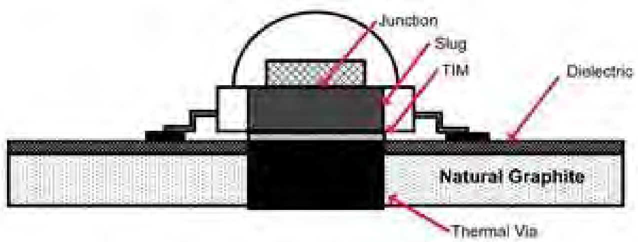
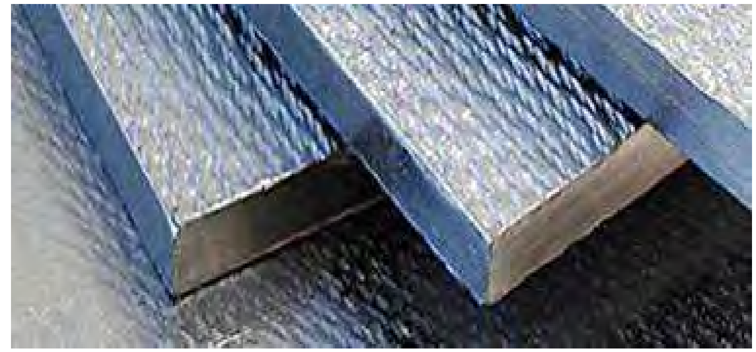


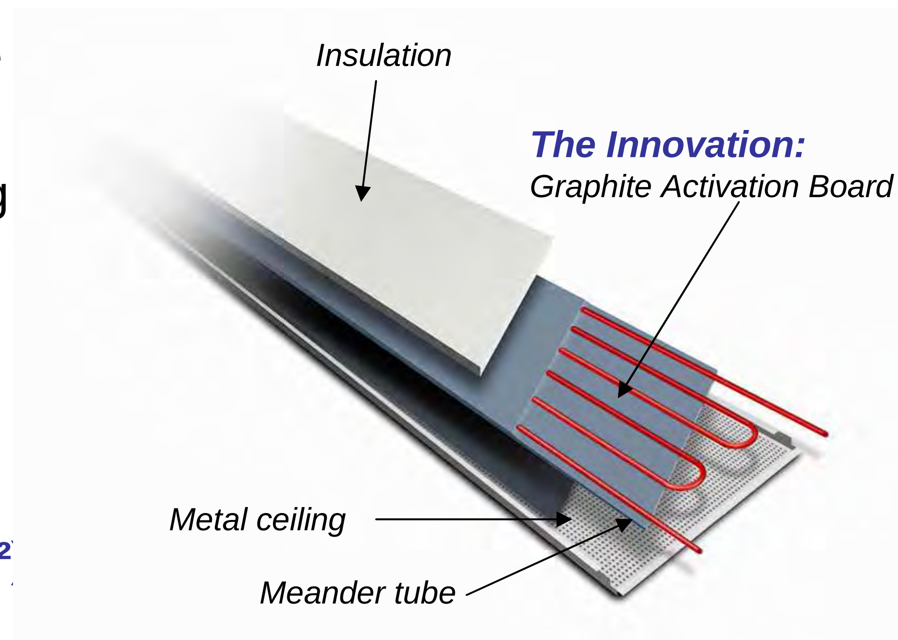

*Figure 3. Cross section of LED with Natural Graphite Heat Spreader*

# Graphite for Radiant HVAC Systems

***Why Graphite?***

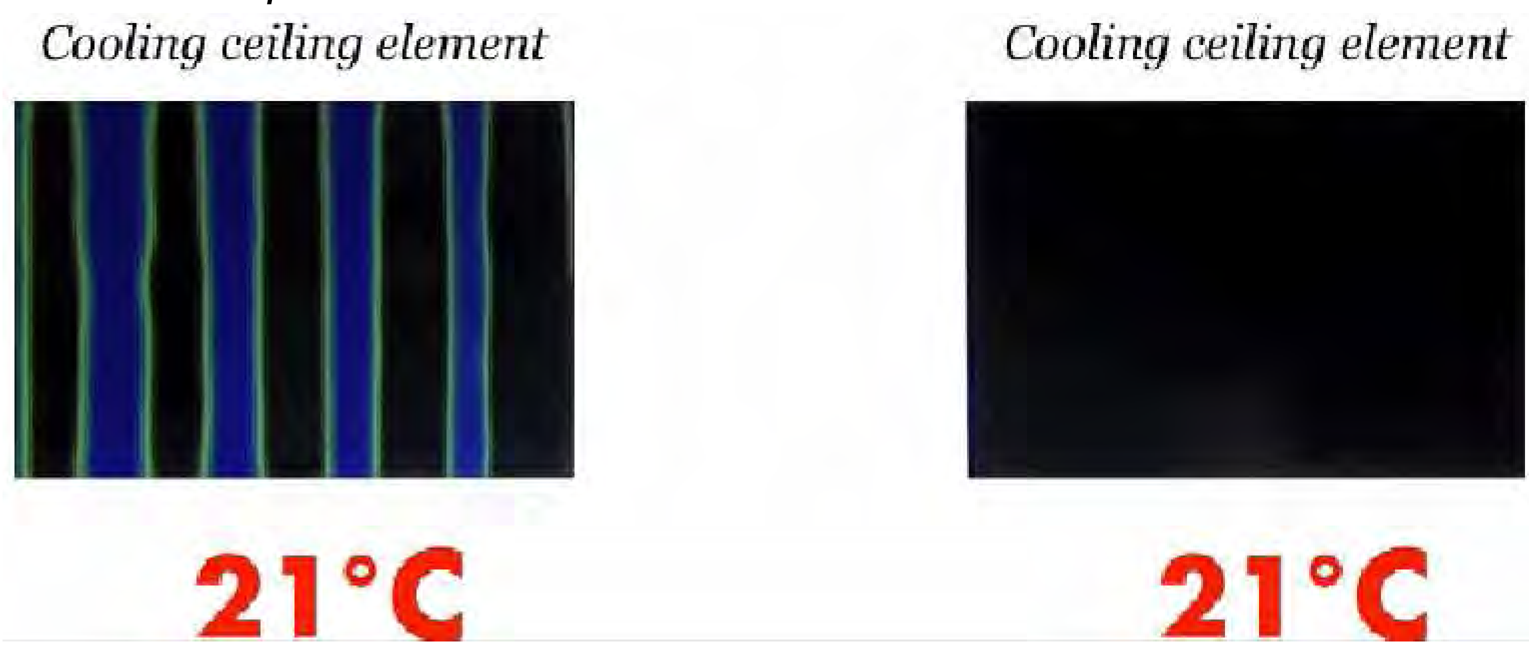
- Soft, compressible and conformable **(tubing easily pressed-in + great thermal interface)**
- Non flammable, non toxic & chemical resistant
- Good thermal conductivity = rapid and uniform temperature distribution **(anisotropic)**
- Light weight = low mass & rapid response time
- Significantly improves cooling and heating efficiency **(high thermal conductivity + great thermal interface + 360º tubing surround + full panel emittance area)**
- Easily recycled
- High performance;
  **- Heating up to 41 BTU/SF/Hr (129 W/m²**
  **- Cooling 35 BTU/SF/Hr (110 W/m²)**





# Side-by-Side Comparison

*Graphite* *Conventional*

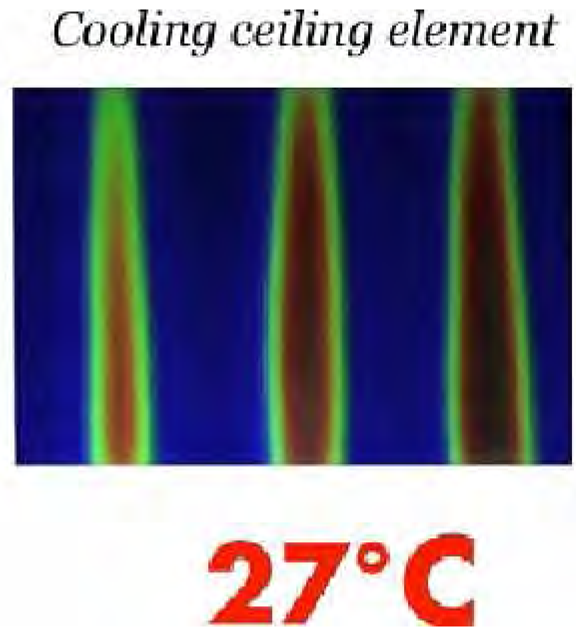



Warm-up phase 11 seconds

# Side-by-Side Comparison

*Graphite*

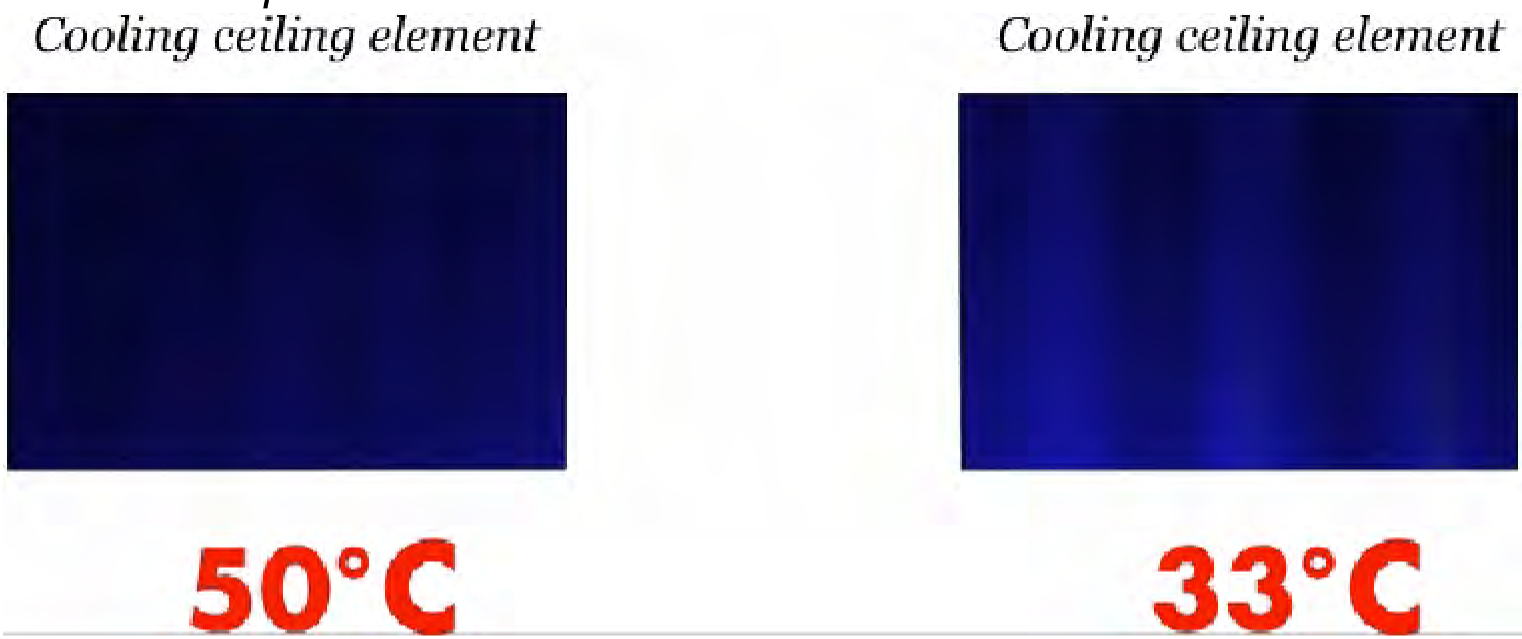

*Conventional*




Warm-up phase 1:15 minutes

# Side-by-Side Comparison

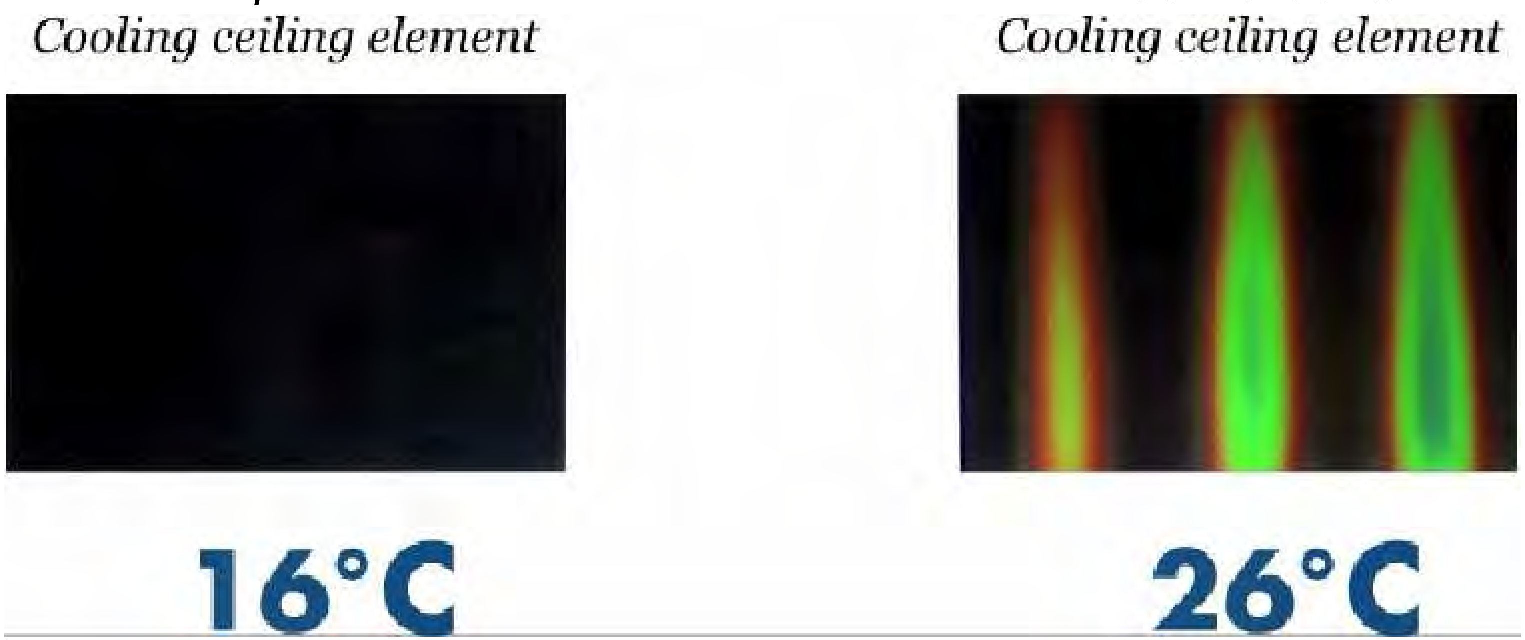
*Graphite* *Conventional*




End of warm-up beginning of cool-down phase 2:00 minutes

# Side-by-Side Comparison

*Graphite* | *Conventional*




End of cool-down phase 4:00 minutes

# Performance according to DIN 14240

**A project planner typically calculates cooling performance as follows:**

Cooling Performance in the room = Specific cooling performance x Active ceiling area

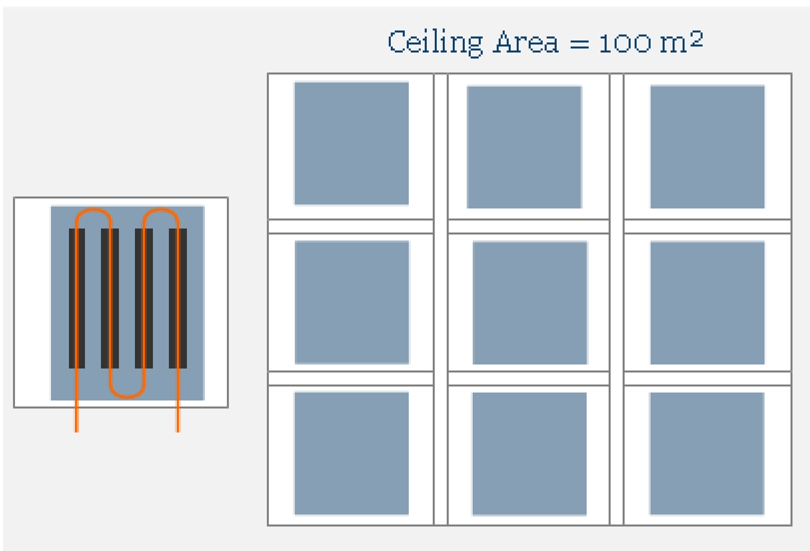
**However, planners and radiant ceiling designers who rely strictly on the specific cooling performance risk a system that has been under designed. The ratio between active area and ceiling area needs to be considered!**

# Performance according to DIN 14240

*Graphite provides 58% higher active ceiling area!*

*How would this change your perspective on activated area of radiant ceiling systems?*

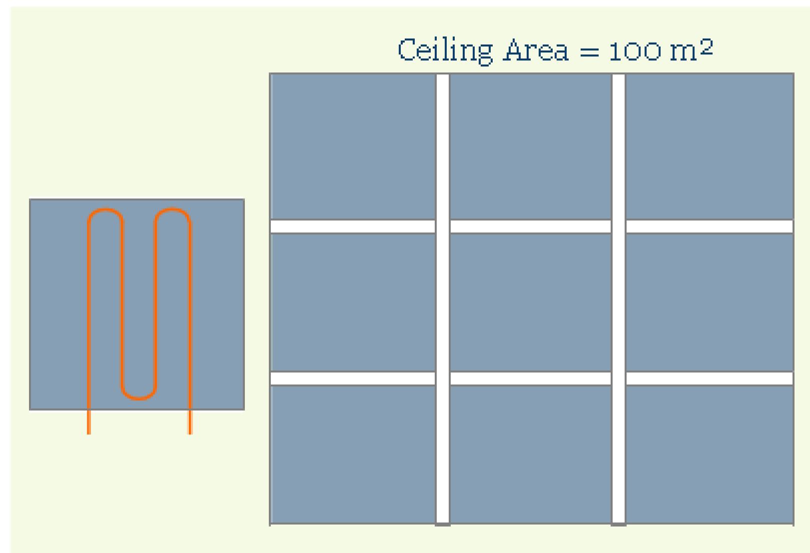
**Standard metal grid radiant ceilings**




Active ceiling area = 62m² (62%)

Inactive ceiling area = 38m² (38%)

**Graphite Panel System**




Active ceiling area = 98m² (98%)

Inactive ceiling area = 2m² ( 2%)

How does this reflect on your system design?

# Performance according to DIN 14240

*Planners and architects face two key challenges during system design*

1

How to maximize the cooling performance in a given room?

→ Which system provides maximum cooling performance for a given ceiling area?

2

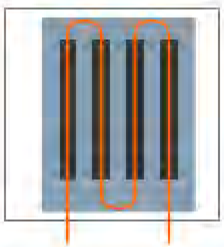
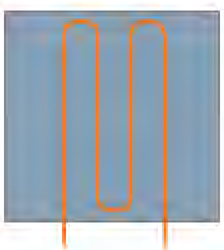
What is the minimum activated area to be installed to realize maximum architectural freedom at a specified performance level?

→ Which system provides the highest share of inactive ceiling area?

How to design a system that fulfills both requirements?

# Performance according to DIN 14240

*Graphite boosts the maximum cooling performance by 21 % for a given ceiling area*

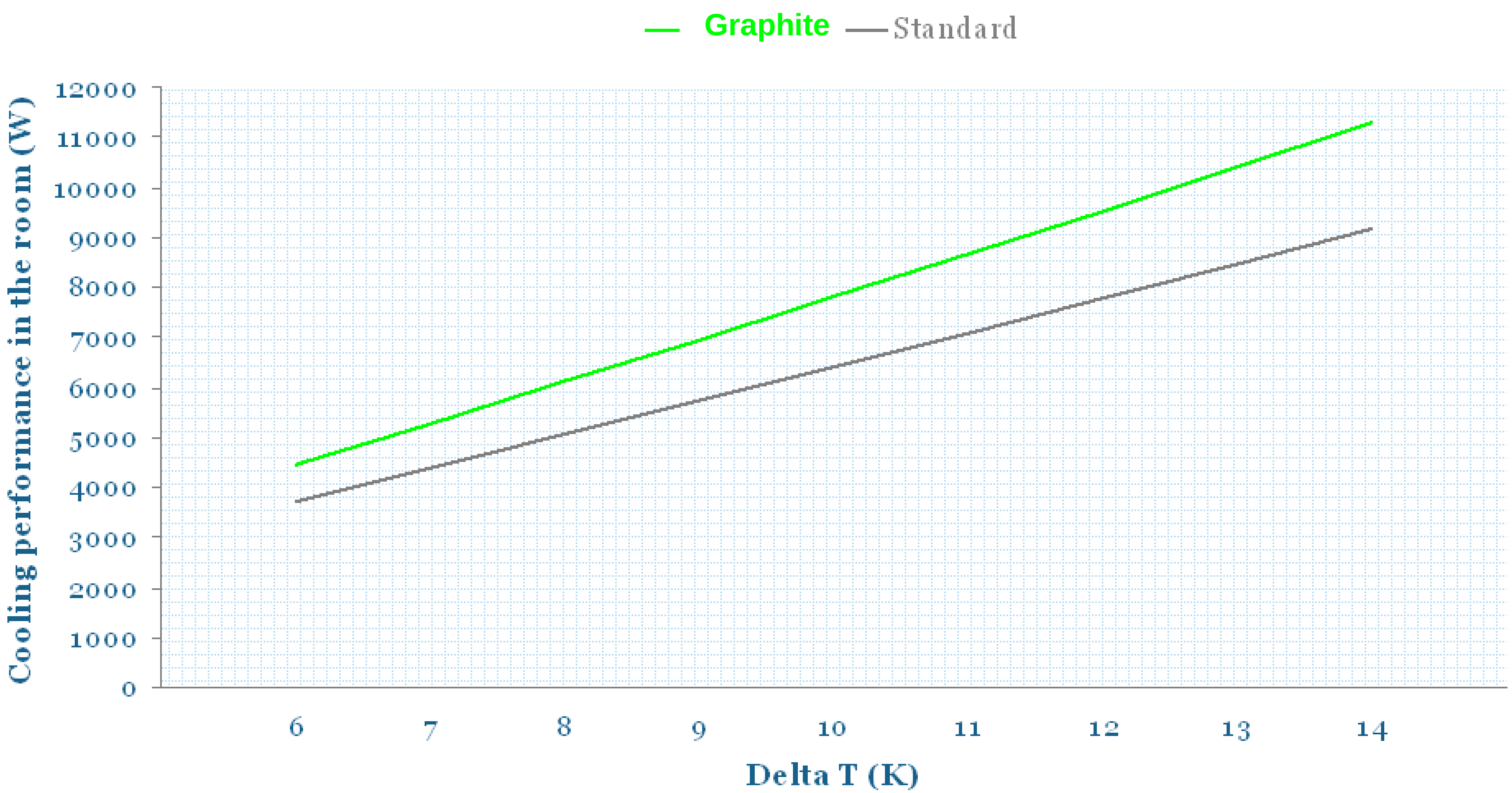
| | Ceiling area | Specific cooling performance | Active ceiling area ratio | **Performance in the room** |
|---|---|---|---|---|
|  | $100\ m^2$ | $81\ W/m^2$* | 62 % | **5022 W** |
|  | $100\ m^2$ | $62\ W/m^2$* | 98 % | **6076 W** |

**Graphite boosts performance by having de facto more activated area!**

Note: *Cooling Performance according to DIN EN 14240 $\Delta t$=8K

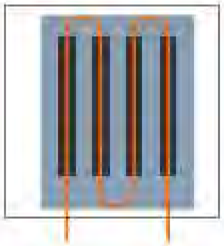
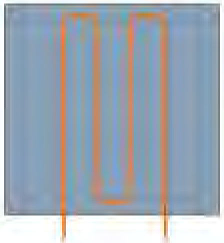
# Performance according to DIN 14240

*Graphite vs. Standard radiant ceiling performance according to DIN EN 14240*



# Performance according to DIN 14240

*More design flexibility with Graphite at a constant performance level!*

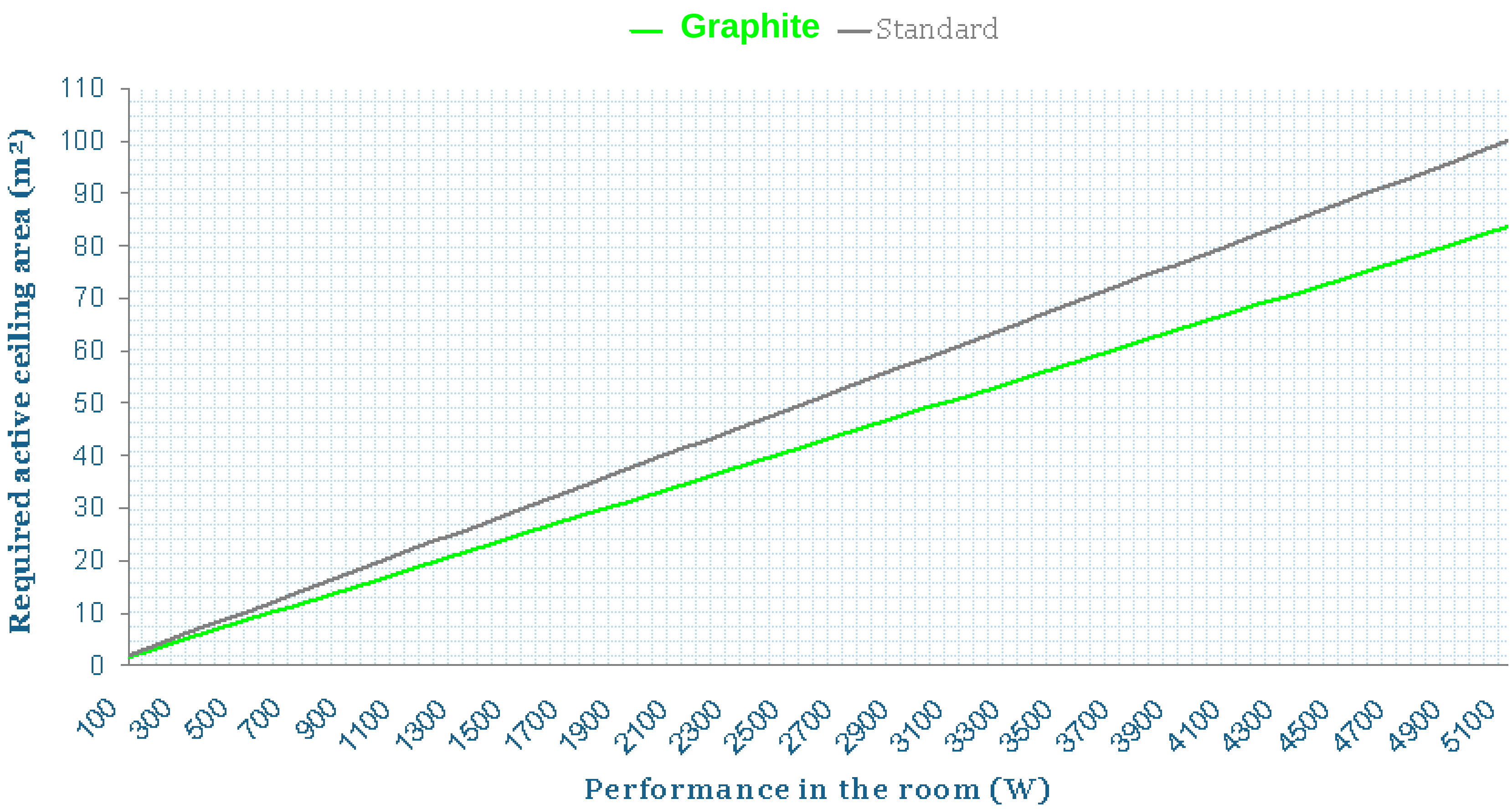
| Ceiling systems | Performance in the room | Specific cooling performance | Active ceiling area ratio | Required active ceiling area |
|---|---|---|---|---|
|  | 5022 W | 81 W/m²* | 62 % | **100 m²** |
|  | 5022 W | 62 W/m²* | 98 % | **83 m²** |

**Graphite enables you to maximize inactive ceiling area at given performance levels!**

Note: *Cooling Performance according to DIN EN 14240 Δt=8K

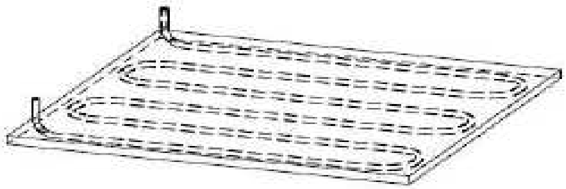
# Performance according to DIN 14240

*More design freedom with Graphite vs. Standard systems at a given performance level*



# Graphite Panel Options

- Activation Boards (for metal cassettes)

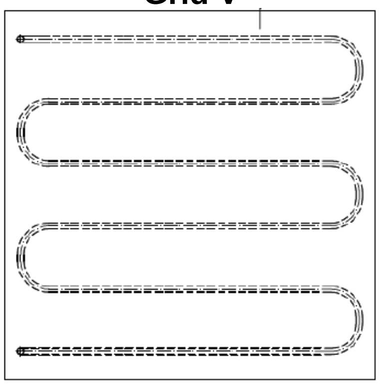
## Technical Data

| Dimensions / Properties | 565x565x15 mm<br><br>(suitable for 600x600, 625x625mm and 2“x2“ metal cassettes) | 1130x565x15 mm<br><br>(suitable for 1200x600 , 1250x625 and 2“x4“ metal cassettes) |
|---|---|---|
| Cooling performance [acc. to DIN EN 14240 at 10K] | Up to 100 W/m² (active area) | Up to 100 W/m² (active area) |
| Heating performance [following DIN EN 14037 at 15K] | Up to 110 W/m² | Up to 110 W/m² |
| Weight (incl. water) | ca. 10Kg/m² | ca. 10Kg/m² |
| Tube connection size | 10mm OD | 10mm OD |

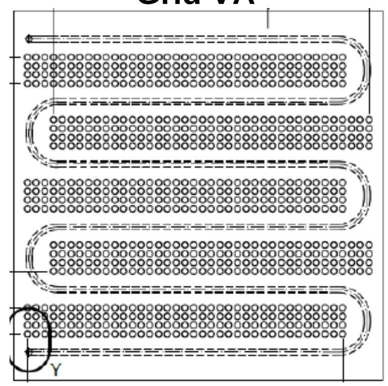
# Graphite Panel Options

- "Finished Panels" (no metal cassette required) non-acoustic and acoustic
- 

"Grid V"



"Grid VA"



*The advantages:*

- *high acoustical absorption*
- *high thermal performance*
- *ready to use*
- *light weight (standard or existing T-grid systems can be used)*
- *even heat distribution*
- *non toxic*

# Graphite Acoustic Panel

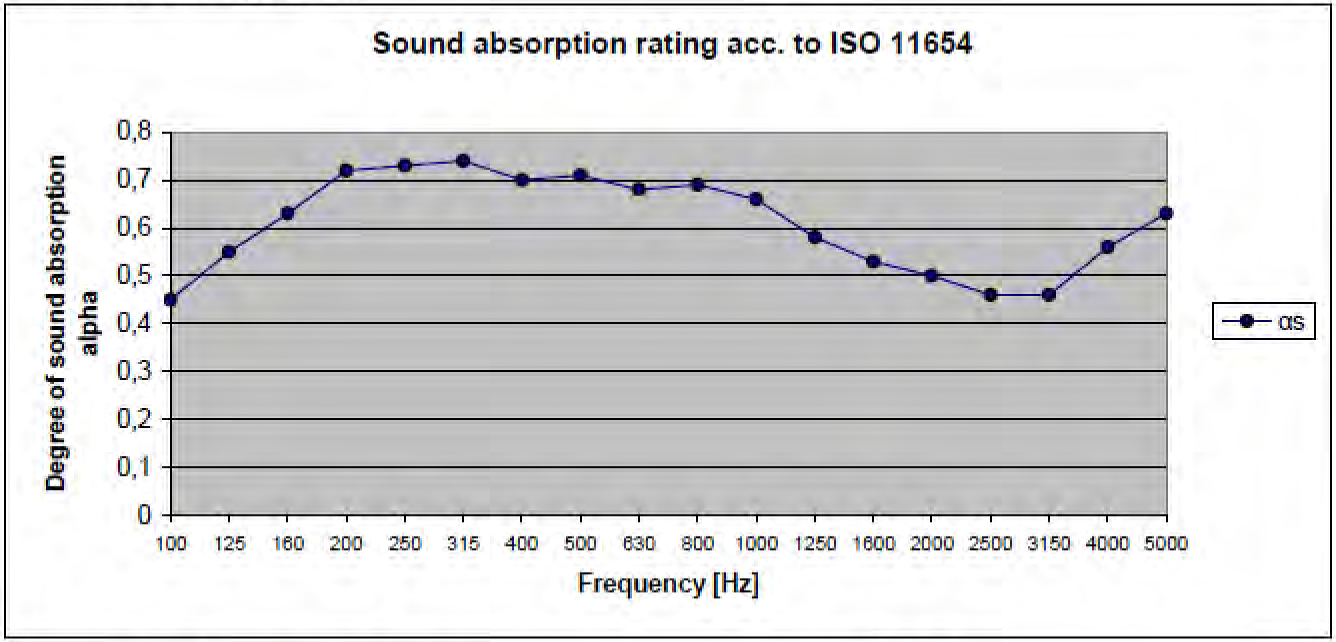
## Technical Data

| Dimensions / Properties | 590x590x15 mm<br>(suitable for 600x600 grid dimensions) | 615x615x15 mm<br>(suitable for 625x625 grid dimensions) | 1190x590x15 mm<br>(suitable for 1200x600 grid dimensions) | 1240x615x15 mm<br>(suitable for 1250x625 grid dimensions) |
|---|---|---|---|---|
| Cooling performance [acc. to DIN EN 14240 at 8K] | 67 $W/m^2$ panel area<br>24 W/panel | 67 $W/m^2$ panel area<br>26 W/panel | 67 $W/m^2$ panel area<br>48W/panel | 67 $W/m^2$ panel area<br>52 W/panel |
| Heating performance [following DIN EN 14037 at 15K] | 93 $W/m^2$ panel area<br>33 W/panel | 93 $W/m^2$ panel area<br>36 W/panel | 94 $W/m^2$ panel area<br>67 W/panel | 94 $W/m^2$ panel area<br>73 W/panel |
| Acoustic absorption | $\alpha_w$ = 0,5 – 0,65<br>Depends on design and execution | $\alpha_w$ = 0,5 – 0,65<br>Depends on design and execution | $\alpha_w$ = 0,5 – 0,65<br>Depends on design and execution | $\alpha_w$ = 0,5 – 0,65<br>Depends on design and execution |
| Fire rating | B-s2-do | B-s2-do | B-s2-do | B-s2-do |
| Weight (incl. water) | ca. 10Kg/$m^2$ | ca. 10Kg/$m^2$ | ca. 10Kg/$m^2$ | ca. 10Kg/$m^2$ |
| Tube connection size | 10mm OD | 10mm OD | 10mm OD | 10mm OD |

# Acoustic Data

Sound absorption acc. to ISO 354
with 30mm insulation on backside (Insula Basic), total construction height 100mm

| Frequenz [Hz] | $\alpha_s$ Terz | $\alpha_p$ Oktave |
|---|---|---|
| 100 | 0,45 | |
| 125 | 0,55 | |
| 160 | 0,63 | 0,55 |
| 200 | 0,72 | |
| 250 | 0,73 | |
| 315 | 0,74 | 0,75 |
| 400 | 0,7 | |
| 500 | 0,71 | |
| 630 | 0,68 | 0,7 |
| 800 | 0,69 | |
| 1000 | 0,66 | |
| 1250 | 0,58 | 0,65 |
| 1600 | 0,53 | |
| 2000 | 0,5 | |
| 2500 | 0,46 | 0,5 |
| 3150 | 0,46 | |
| 4000 | 0,56 | |
| 5000 | 0,63 | 0,55 |




**Sound absorption rating acc.to ISO 11654** **αw = 0,60**

**Sound absorber class C**

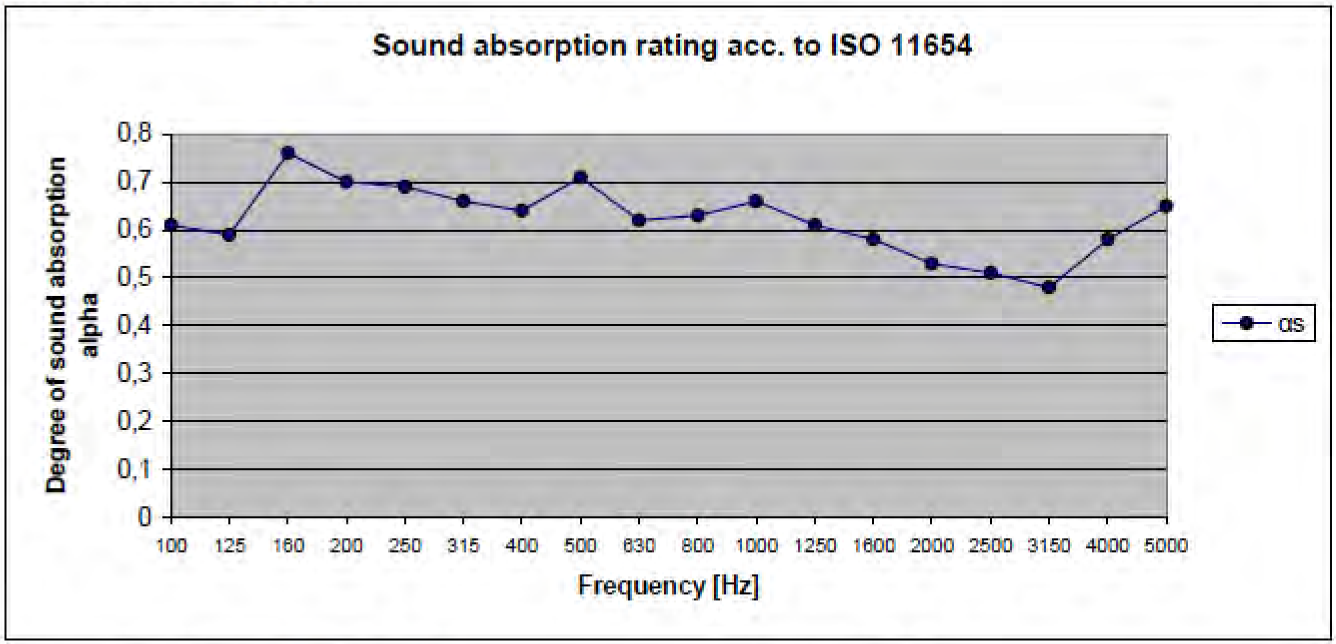
**Sound absorption rating acc.to ASTM C 423a** **NRC = 0,65**

**SAA=0,64**

# Acoustic Data

Sound absorption acc. to ISO 354
with 30mm insulation on backside (Insula Basic), total construction height 200mm

| Frequenz [Hz] | $\alpha_s$ Terz | $\alpha_p$ Oktave |
|---|---|---|
| 100 | 0,61 | |
| 125 | 0,59 | |
| 160 | 0,76 | 0,65 |
| 200 | 0,7 | |
| 250 | 0,69 | |
| 315 | 0,66 | 0,7 |
| 400 | 0,64 | |
| 500 | 0,71 | |
| 630 | 0,62 | 0,65 |
| 800 | 0,63 | |
| 1000 | 0,66 | |
| 1250 | 0,61 | 0,65 |
| 1600 | 0,58 | |
| 2000 | 0,53 | |
| 2500 | 0,51 | 0,55 |
| 3150 | 0,48 | |
| 4000 | 0,58 | |
| 5000 | 0,65 | 0,55 |




**Sound absorption rating acc.to ISO 11654** **αw = 0,65**

**Sound absorber class C**

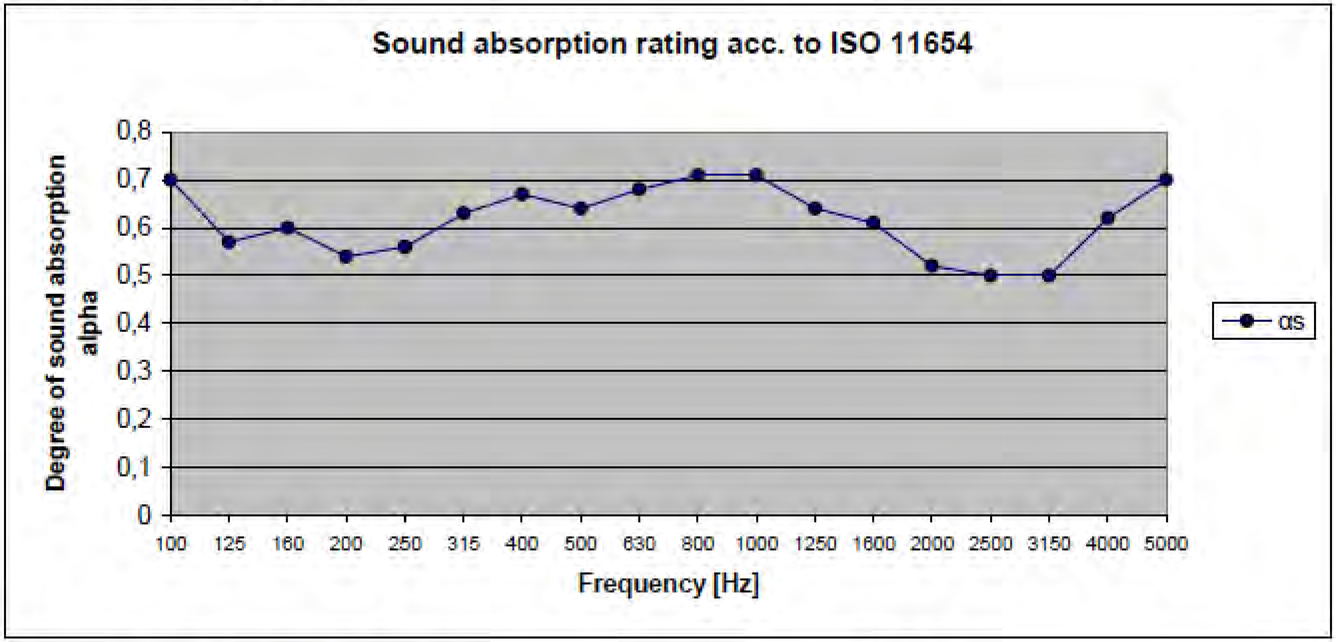
**Sound absortion rating acc.to ASTM C 423a** **NRC = 0,65**

**SAA=0,63**

# Acoustic Data

Sound absorption acc. to ISO 354
with 30mm insulation on backside (Insula Basic), total construction height 400mm

| Frequenz [Hz] | $\alpha_s$ Terz | $\alpha_p$ Oktave |
|---|---|---|
| 100 | 0,7 | |
| 125 | 0,57 | |
| 160 | 0,6 | 0,6 |
| 200 | 0,54 | |
| 250 | 0,56 | |
| 315 | 0,63 | 0,6 |
| 400 | 0,67 | |
| 500 | 0,64 | |
| 630 | 0,68 | 0,65 |
| 800 | 0,71 | |
| 1000 | 0,71 | |
| 1250 | 0,64 | 0,7 |
| 1600 | 0,61 | |
| 2000 | 0,52 | |
| 2500 | 0,5 | 0,55 |
| 3150 | 0,5 | |
| 4000 | 0,62 | |
| 5000 | 0,7 | 0,6 |




**Sound absortion rating acc.to ISO 11654** αw = 0,65

**Sound absorber class C**

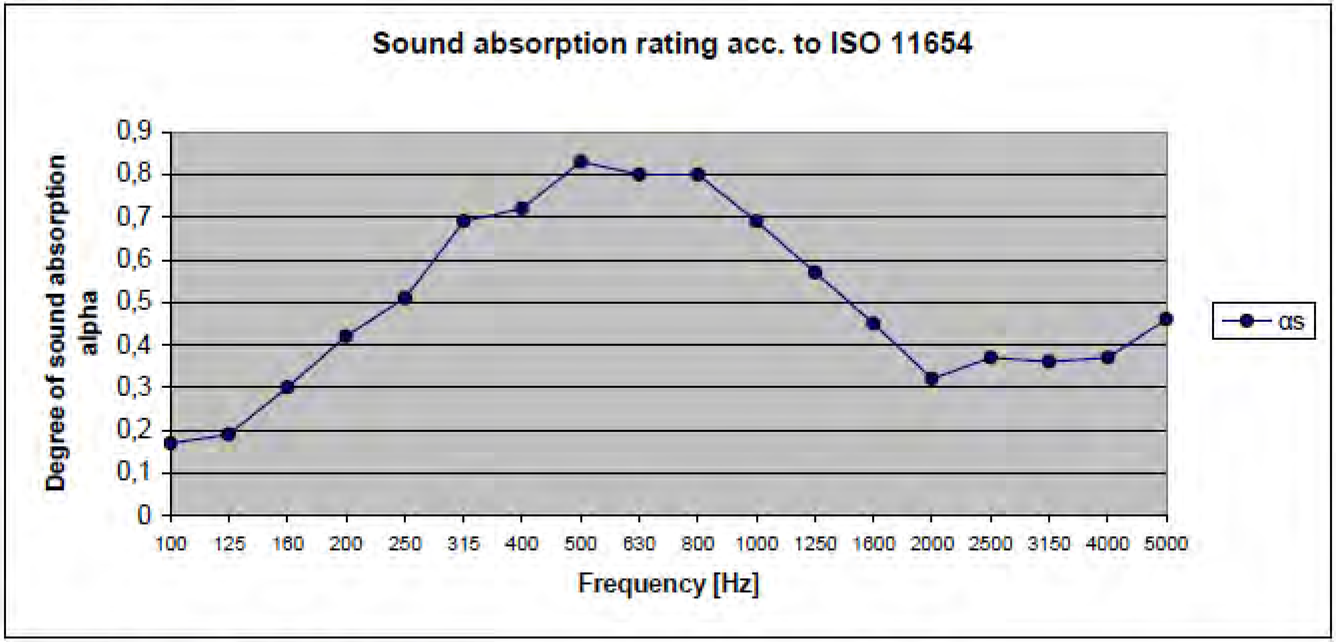
**Sound absortion rating acc.to ASTM C 423a** NRC = 0,60

SAA=0,62

# Acoustic Data

Sound absorption acc. to ISO 354
without insulation on backside, total construction height 100mm

| Frequenz [Hz] | $\alpha_s$ Terz | $\alpha_p$ Oktave |
|---|---|---|
| 100 | 0,17 | |
| 125 | 0,19 | |
| 160 | 0,3 | 0,2 |
| 200 | 0,42 | |
| 250 | 0,51 | |
| 315 | 0,69 | 0,55 |
| 400 | 0,72 | |
| 500 | 0,83 | |
| 630 | 0,8 | 0,8 |
| 800 | 0,8 | |
| 1000 | 0,69 | |
| 1250 | 0,57 | 0,7 |
| 1600 | 0,45 | |
| 2000 | 0,32 | |
| 2500 | 0,37 | 0,4 |
| 3150 | 0,36 | |
| 4000 | 0,37 | |
| 5000 | 0,46 | 0,4 |




**Sound absortion rating acc.to ISO 11654** — **αw = 0,5**

**Sound absorber class C**

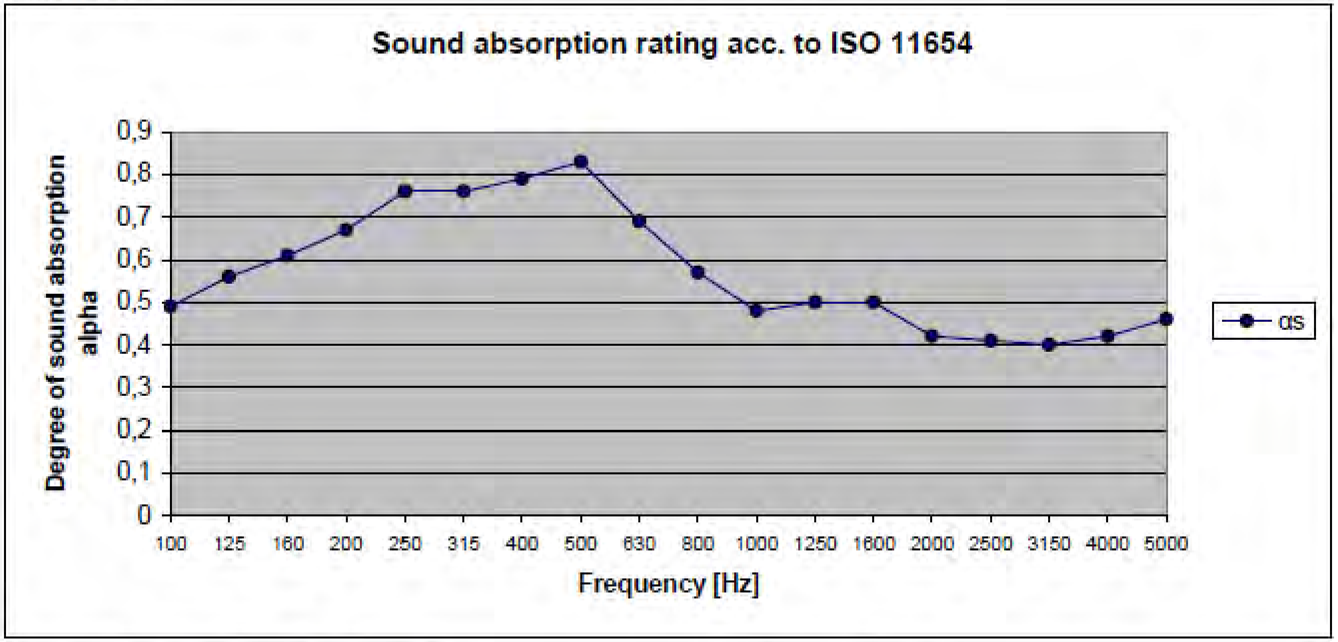
**Sound absortion rating acc.to ASTM C 423a** — **NRC = 0,6**

**SAA = 0,6**

# Acoustic Data

Sound absorption acc. to ISO 354
without insulation on backside, total construction height 200mm

| Frequenz [Hz] | $\alpha_s$ Terz | $\alpha_p$ Oktave |
|---|---|---|
| 100 | 0,49 | |
| 125 | 0,56 | |
| 160 | 0,61 | 0,55 |
| 200 | 0,67 | |
| 250 | 0,76 | |
| 315 | 0,76 | 0,75 |
| 400 | 0,79 | |
| 500 | 0,83 | |
| 630 | 0,69 | 0,75 |
| 800 | 0,57 | |
| 1000 | 0,48 | |
| 1250 | 0,5 | 0,5 |
| 1600 | 0,5 | |
| 2000 | 0,42 | |
| 2500 | 0,41 | 0,45 |
| 3150 | 0,4 | |
| 4000 | 0,42 | |
| 5000 | 0,46 | 0,45 |




**Sound absortion rating acc.to ISO 11654** **αw = 0,5**

**Sound absorber class C**

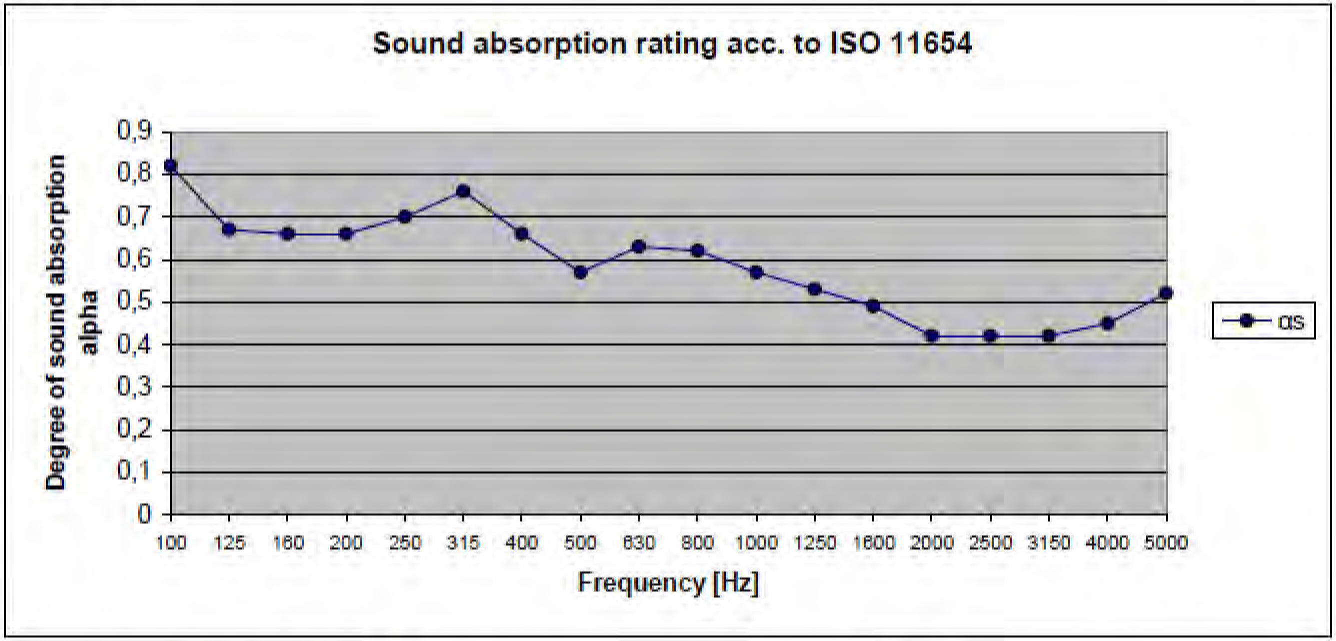
**Sound absortion rating acc.to ASTM C 423a** **NRC = 0,6**

**SAA = 0,62**

# Acoustic Data

Sound absorption acc. to ISO 354
without insulation on backside, total construction height 400mm

| Frequenz [Hz] | $\alpha_s$ Terz | $\alpha_p$ Oktave |
|---|---|---|
| 100 | 0,82 | |
| 125 | 0,67 | |
| 160 | 0,66 | 0,7 |
| 200 | 0,66 | |
| 250 | 0,7 | |
| 315 | 0,76 | 0,7 |
| 400 | 0,66 | |
| 500 | 0,57 | |
| 630 | 0,63 | 0,6 |
| 800 | 0,62 | |
| 1000 | 0,57 | |
| 1250 | 0,53 | 0,55 |
| 1600 | 0,49 | |
| 2000 | 0,42 | |
| 2500 | 0,42 | 0,45 |
| 3150 | 0,42 | |
| 4000 | 0,45 | |
| 5000 | 0,52 | 0,45 |




**Sound absortion rating acc.to ISO 11654** **αw = 0,55**

**Sound absorber class C**

**Sound absortion rating acc.to ASTM C 423a** **NRC = 0,55**

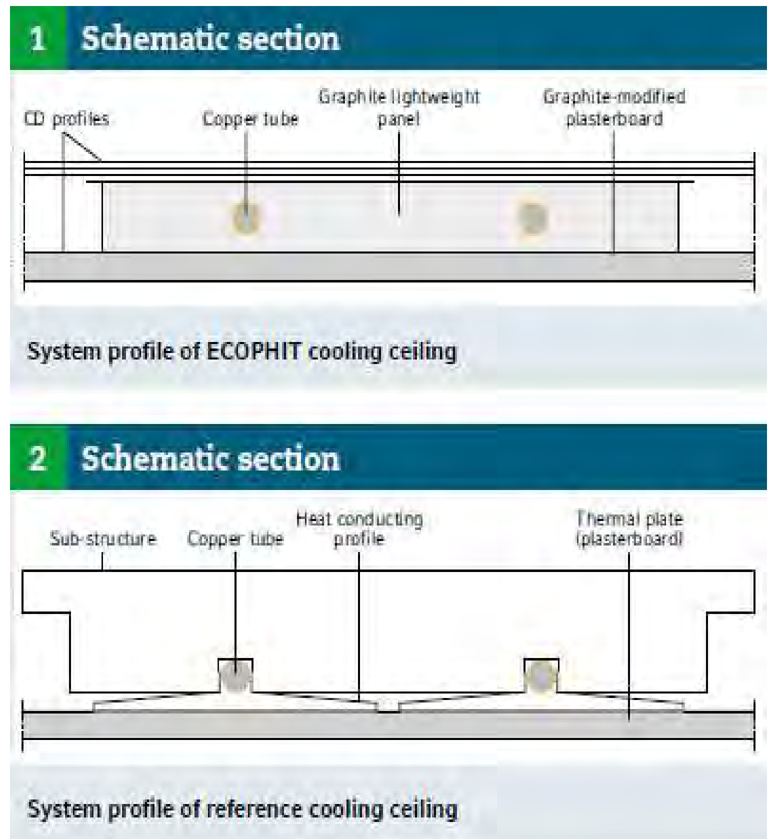
**SAA = 0,59**

# Other Innovations

- Graphite modified gypsum boards
- Seamless radiant ceilings
- Graphite modified gypsum + activation board system
  32 BTU/SF/Hr (100 W/m² Cooling)
  38 BTU/SF/Hr (120 W/m² Heating

# Graphite Modified Seamless System

- "With Graphite the flow **temperature can be increased from16 ℃ to 18.5** ℃ compared to the reference with the same size of cooling ceiling to achieve the same thermal comfort in summer.
- A higher flow temperature **increases the efficiency** of the refrigeration unit by 6 % in the case of a naturally ventilated building and by **7 to 8 % in case of a mechanically ventilated building**.
- Moreover, the **frequency of the use of a dew-point monitor decreases**".



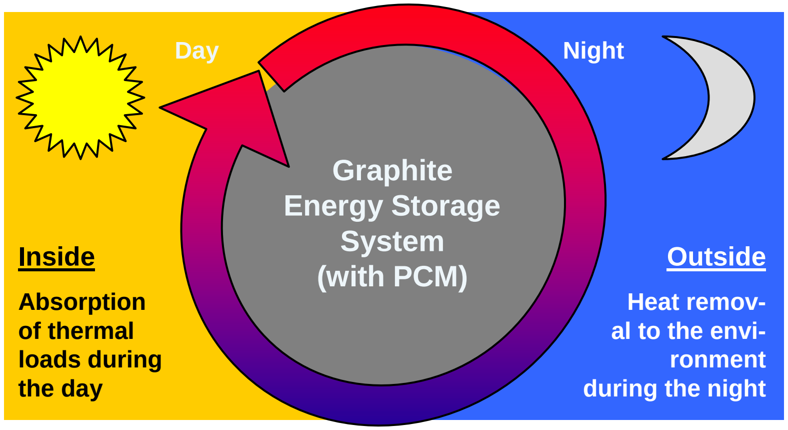

System profile of ECOPHIT cooling ceiling

System profile of reference cooling ceiling

# Other Innovations

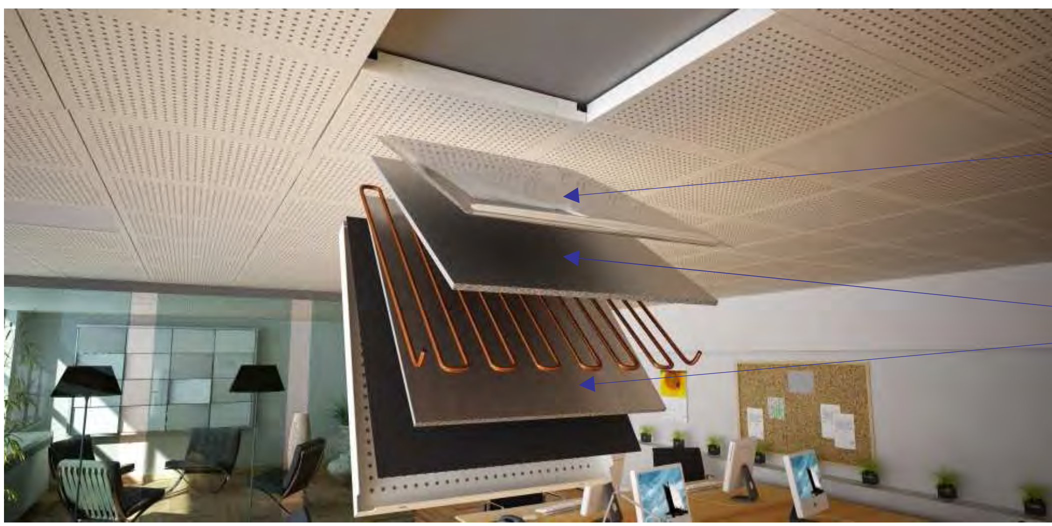
- Typical Phase Change Materials (PCMs) have only relatively low thermal conductivity. **By using PCM/graphite composite materials, thermal conductivity can be enhanced by up to a factor of 100.**

- This combination enhances the thermal conductivity and enables **PCM devices** with high heat capacity and dynamics.
- Used in air conditioning solutions **PCM/graphite** composite materials can be frozen during the cool summer nights at virtually no cost, only to be melted again for cooling purposes during the day. The high heat radiation from the sun is stored in the PCM and returned to the cool atmosphere during the following night.




# Other Innovations

- PCM/Graphite plates could be charged overnight when energy costs are lower, then slowly release energy during the day.
- **Combination high-mass/low-mass system**



# In Summary

- *higher supply temperatures when cooling / lower when heating*
- *decreased frequency of the use of a dew-point monitor*
- *optimum grid connection to renewable energy sources*
- *quick distribution of energy over the entire ceiling surface*
- *savings on system engineering*
- *no draughts*
- *no noise disturbance*
- *no dust swirls*
- *natural and contains no additives*
- *non-flammable*
- *completely recyclable*
- *higher performance from the entire system*
- *comfortable room acoustics new design possibilities*
- *large range of surface designs*
- *more freedom in the integration of technology, e.g. lighting*
- ***Over 1,000,000m² installed!***

SGL Group offices Meitingen, Germany

*Climate control*

*for our times:*

# REFERENCES

*A Bank is saving Energy*

## Deutsche Bank Greentowers, Frankfurt/Germany

*Architects' office MBA Mario Bellini Architects*
*approx. 25,000 m² radiant ceiling*

*Picture source: Thomas Wolf, www.foto-tw.de*

*A Bank is saving Energy*

## Deutsche Bank, Paris/France

*Architects' office Bouchaud Architectes*
*approx. 4,500 m² radiant ceiling*

*Picture source: Bouchaud Architectes*

*A Bank is saving Energy*

## European Central Bank, Frankfurt/Germany

*Architects' office COOP HIMMELB(L)AU*
*approx. 11,000 m² radiant ceiling*

*Picture source: Roland Meinecke, new building of European Central Bank, June 2012*

*A Car moves, a Building remains*

## Maybach Automobile Museum, Neumarkt/Germany

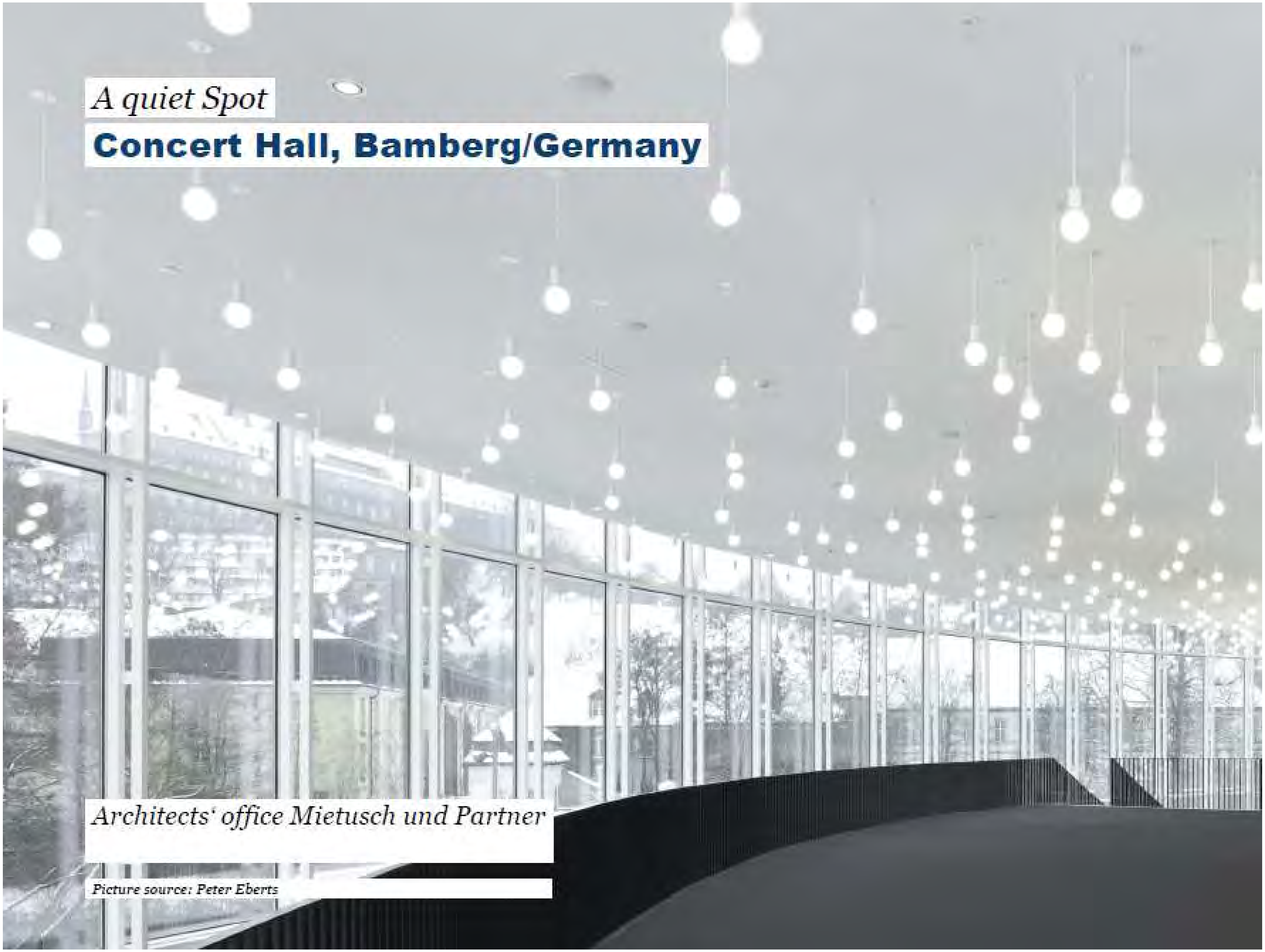
*Architects' office Berschneider + Berschneider*

*Picture source: Berschneider + Berschneider*


A quiet Spot
Concert Hall, Bamberg/Germany
Architects‘ office Mietusch und Partner

*A quiet Spot*

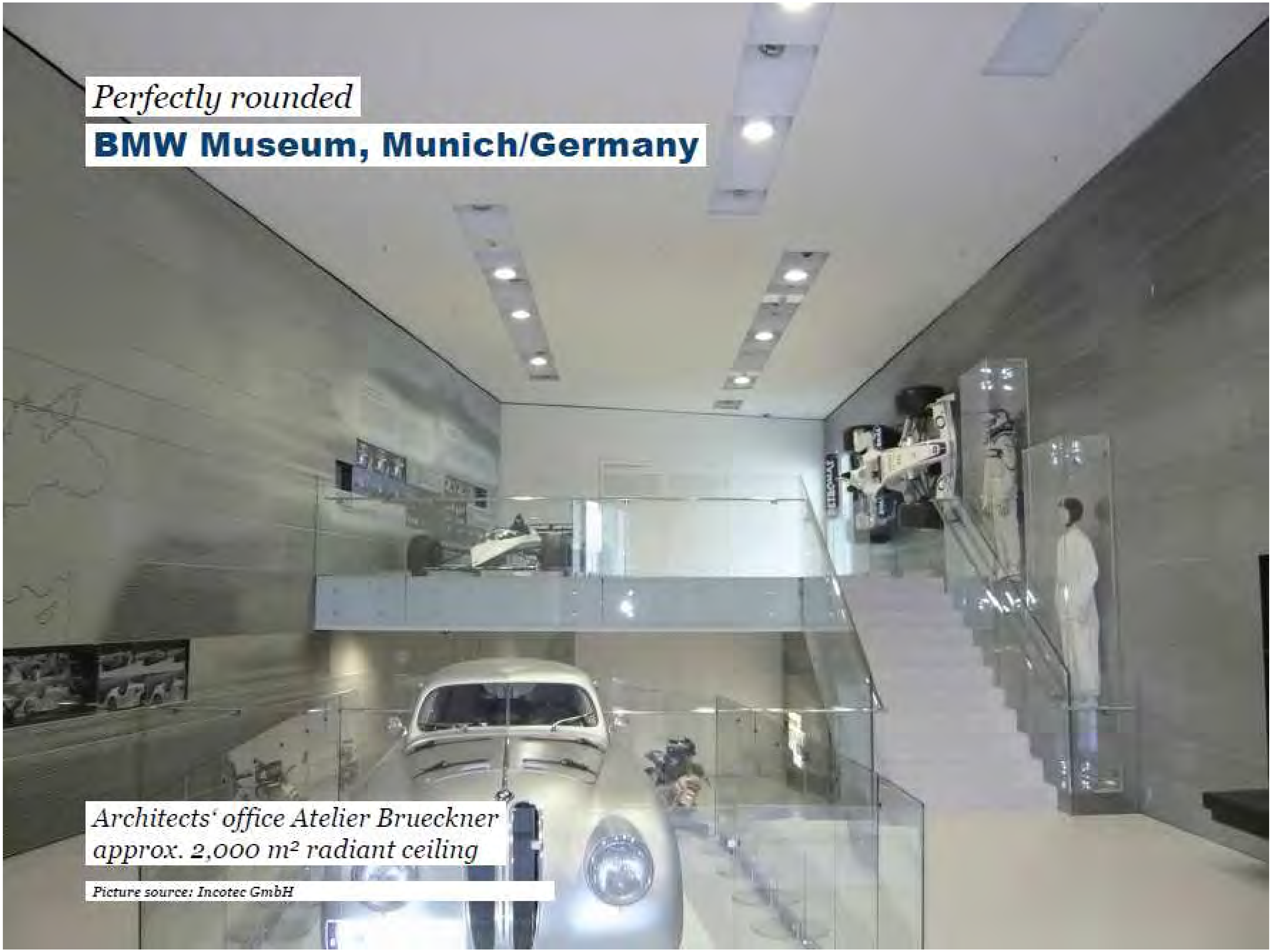
## Concert Hall, Bamberg/Germany



*Architects' office Mietusch und Partner*

*Picture source: Peter Eberts*


*Perfectly rounded*
**BMW Museum, Munich/Germany**
museum
*Architects' office Atelier Brueckner*
*approx. 2,000 m² radiant ceiling*



*Perfectly rounded*
**BMW Museum, Munich/Germany**
*Architects' office Atelier Brueckner*
*approx. 2,000 m² radiant ceiling*
*Picture source: Incotec GmbH*


Rheinvorlandspeicher, Mannheim/Germany
SPEICHER
7
Architects' office Schmucker und Partner
approx. 4,000 m² radiant ceiling


Feel at Home under my Roof
Hotel Speicher 7, Mannheim/Germany
Architects' office Schmucker und Partner
approx. 4,000 m² radiant ceiling

*Bar, Speicher 7, Mannheim*

# SEAMLESS RADIANT CEILING

*Architects' office Schmucker und Partner*
*approx. 4,000 m² radiant ceiling*


Working Climate - a Question of Hot and Cold
Rheinvorlandspeicher, Mannheim/Germany
Architects' office Schmucker und Partner
approx. 4,000 m² radiant ceiling

*Working Climate - a Question of Hot and Cold*

# Infosys Technologies, Bangalore/India

*approx. 7,500 m² radiant ceiling*

*Picture source: Sachin Sharma, Nov. 2008*

*Working Climate - a Question of Hot and Cold*

## Technology Center, Augsburg/Germany

*Architects' office Brechensbauer Weinhart + Partner Architekten*
*approx. 2,000 m² radiant ceiling*

*Picture source: Brechensbauer Weinhart + Partner Architekten*

*Working Climate - a Question of Hot and Cold*

## Office Building „Westpol“, Frankfurt/Germany

*Architects‘ office BeyeScheid Architekten GbR*

*National*

## Energy Efficiency Center, Wuerzburg/Germany

*Bavarian Center for Applied Energy Research (ZAE)*

*585 m² radiant ceiling*

*Picture source: ZAE Bayern*

*National*

## Hospital Engineering Laboratory, Duisburg/Germany

*Fraunhofer-inHaus-Center*

*200 m² radiant ceiling*

*Picture source: Fraunhofer-inHaus-Center*

*International*

## Net Zero Energy Building, Ahemdabad/India

*approx. 400 m² radiant ceiling*

*Picture source: CEPT University*

*International*

## Nanyang Technological University, Singapore

*Energy Research Institute*

*approx. 500 m² radiant ceiling*

*Photo used with permission from JTC Corporation*

*International*

## PAVILION of INNOVATIONS, Shanghai/China

*German Centre Shanghai*


*Source: Pavilion of Innovations*

# Thank You

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