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CASE STUDY: NREL RESEARCH SUPPORT FACILITY IN GOLDEN, COLORADO

Blueprint for America's Energy Future

Cooperative and innovative efforts, including a radiant slab system with 42 miles of PEX tubing, combine to create a first-of-its-kind, award-winning office building that demonstrates ways to build a more sustainable, carbon-neutral workplace environment for all.

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GOLDEN, COLORADO — **Energy-efficient:** a term that long ago became a part of the language used by building owners and contractors to describe residential and commercial structures and HVAC (heating, ventilation and air conditioning) systems that outperform the industry average.

Green building: a newer description for structures that go beyond energy savings to include innovative building technologies and methodologies that combine to reduce their overall environmental footprint.

The next evolutionary step on the path to carbon neutrality is a functioning, super-energy-efficient, 220,000-square-foot office structure that is the largest net-zero energy building in the United States. Opened in 2010, the Research Support Facility (RSF) in Golden, Colorado — a $64 million complex built by the Department of Energy's National Renewable Energy Laboratory (NREL) — showcases what is technologically possible and commercially viable. That's why, in creating the new facility, NREL had a goal as bold as the new RSF itself: to spur innovation and replication throughout the government- and commercial-building sectors.

A new term that seeks to define this new and more sustainable way of designing and constructing commercial spaces is *thermally activated building system,* or TABS. Like the Earth itself, a TABS structure uses its mass to absorb or emit heat through its conditioned surfaces to regulate then interior environment. Two key features typically characterize TABS structures:

1) high-performance enclosures; and

2) a reliance on concrete slabs embedded with hydronic tubing, usually made of crosslinked polyethylene tubing (PEX), for low-temperature radiant heating (emitting energy) and high-temperature radiant cooling (absorbing energy).

Facilitating compliance with ANSI/ASHRAE Standard 55-2010: Thermal Environmental Conditions for Human Occupancy, these radiant slabs also help to cut energy use by more than 50 percent over ASHRAE Standard 90.1(2004): Energy Standard for Buildings Except Low-Rise Residential Buildings.

"In designing and building the new RSF facility, our aim was to move the needle in how America uses energy to heat and cool buildings," says NREL senior engineer Paul Torcellini. "It isn't enough to be energy-efficient when commercially viable technology exists to make buildings energy-neutral."

Among the many groundbreaking innovations that made the RSF possible was a new method for installing radiant heating and cooling systems. Forty-two miles of PEX-a tubing — manufactured by Uponor Inc. and subsequently prefabricated into numerous rolls whose dimensions were customized to match those of the RSF's various heating and cooling zones — enabled mechanical contractor Trautman & Shreve to slash labor time and costs dramatically. These savings, in turn, helped NREL meet its budgetary goals and tight construction schedule. More on this breakthrough innovation in the second half of this article.

High-Performance Building Design

Housing 800 staff members in an open work environment, RSF boosted NREL's campus square footage in Golden by 60 percent, but increased campus energy use by only six percent. Achieving this outcome wasn't accidental; thorough planning with the following mission-critical goals helped to guide the design process:

- Design and build a safe work environment.
- Achieve a LEED Platinum rating.
- Aim for Energy Star "Plus" in terms of energy usage.

The other critical nonnegotiable: a $64 million, fixed-price contract to build the RSF. In a detailed RFP with many hundreds of pages, interested parties were told that the facility is intended "to demonstrate how high-performance buildings can be aesthetically compelling, acquired at a competitive first-cost and lifecycle cost, and through integrated design, how high-performance buildings can reduce performance risks to the owner and constructor."

Adds Torcellini: "A strong owner — clear on what is wanted and how much can be spent to achieve those goals — is critical to changing the building stock. Devoting the upfront time to create a detailed RFP helped streamline construction. When engineers or contractors had questions, the standard reply was, 'Look at the RFP.' It worked well for everyone."

RSF also employed a modified design-and-construction process to identify, reduce and allocate risk to all parties; to encourage performance-cost trade-offs; and to accelerate project delivery. "This process is dramatically different from the traditional design-bid-and-build approach," explains Torcellini, "and is critical to changing the outcome. We can't build better buildings using old models."

NREL employed a two-step, progressive design-build strategy. In step one, the preliminary design phase, the goal was to reduce risk for all parties through firm, fixed-price, design-build contracts — or a decision not to proceed. Energy modeling helps determine performance versus cost trade-offs during this design phase. Construction commences in step two while the final design is completed.

Philip Macey AIA, LEED AP, is design-build project manager at Haselden Construction (Centennial, Colo.), the builder of the NREL Research Support Facility. He helped the project team through critical design decisions based on information in the contractor's cost model and the design team's energy, daylighting, natural-ventilation and thermal-mass models. "Every model helped inform our energy decision," says Torcellini, "but each piece had to fit within the overall project price."

Energy Efficient Ventilation

Principles of thermal mass heating and cooling not only applied to the core TABS radiant system, but also included separate design innovations to improve the pre-heating and pre-cooling of the ventilation system. A unique and innovative ventilation heat exchanger – the labyrinth – was constructed out of the buildings lower level with concrete airflow diverters/partitions. This maze wasn't designed to confuse workers, but it is a trap of sorts — one that captures the heat of the day or the cool of the night, holds onto the thermal energy and then slowly releasing it to help warm or cool the ventilation supply air.

The RSF includes two long wings, connected at the middle by a lobby and a conference area. Each wing rests on a low basement with concrete walls staggered to make the air take S-turns through the space, linger awhile, and then lose its cooling or its heating, depending on the season. “As the air goes through the maze, there's greater contact with the mass — thousands of tons of concrete,” says NREL’s Eric Telesmanich, RSF project manager.

That way, the labyrinth acts as a thermal battery, storing the chill of the night air to reduce the building’s cooling load in summer by pre-cooling the ventilation air. During the winter, the labyrinth stores heat drawn from two sources: 1) computers in the facility’s new data center; and 2) outside air warmed by the sun beating down on a transpired air collector.

Transpired air collector systems essentially consist of a dark-colored, perforated sheet metal façade installed on the building’s south-facing wall. A fan draws ventilation air into the building through the perforated absorber plate and across the plenum (the air space between the absorber and the south wall). Solar energy absorbed by the dark absorber and transferred to the air flowing through it can preheat the intake air by as much as 40°F. Reduced heating costs will pay for the systems in three to 12 years.

Engineering consultant David Okada of Stantec in San Francisco wrote a unique computer program to understand the performance of the labyrinth system, while Stantec colleague Joe Tai engineered the radiant system. “Our goal was to maximize the passive performance of this facility,” says Okada. “Then we focused on making the engineered systems as efficient as possible. Thermal and energy modeling provided the information the Design Build Team needed to keep the design true to the project’s aggressive goals.”

In recognition of Stantec’s engineering consulting work on the RSF, the company was awarded the prestigious Engineering Excellence Grand Award from the American Council of Engineering Companies (ACEC) in April 2011.

Different Way to Install Radiant

The twin performance criteria of energy efficiency and cost control complicated the job of Denver-based mechanical contractor Trautman & Shreve, which installed the radiant heating and cooling in the slabs. Project manager Tony Barela needed an ultra-efficiency tool all his own to meet an exceptionally tight construction schedule.

"The job schedule was critical on this project," explains Barela. "Working with Haselden Construction, we knew that the five days allocated to us were not enough time to build all the radiant heating and cooling zones up on the decks at RSF. It was critical we find another way, because conventional radiant installation was out of the question."

Find another way he did in May 2009. Working with local Uponor sales agents Tom Meek and Tobi Gibson from TM Sales in Arvada, Colo., Barela and superintendent Don Martinez devised a pre-fab plan for the radiant zones. After mapping out all the zones, Trautman & Shreve purchased PEX tubing in standard 1,000- and 500-foot rolls. Then, using three-foot plastic rails (with loops in 6" to 10" spacings to hold the pipe together in an even width), they prefabricated their own radiant mats.

(Note: These mats were a precursor of the Uponor Radiant Rollout™ Mat, a product then under development and eventually introduced in the summer of 2010. As with the Trautman & Shreve version, the mat is a custom-designed, prefabricated, pre-pressurized network of PEX-a tubing connected with ProPEX engineered plastic fittings. These mats can install approximately 85 percent faster than conventional radiant tubing methods.)

A crew of five people spent three months in the yard at Trautman & Shreve pre-fabbing each zone: laying out the tubing, tying it to the rails, and rolling up each mat for storage until the decks at RSF became ready. "Zones on this project ranged anywhere from 48 to 250 feet long and up to 24 feet wide," explains Barela, "so we customized each mat in whatever dimensions were needed." For example, on the widest zone, four, six-foot mats were connected to complete that zone.

Once the RSF decks were ready, Trautman & Shreve used a crane to lift the large bundles of tubing. A crew unrolled the tubing, tied it down and quickly made the necessary connections. The entire tubing-installation task ended up taking only *two* days, enabling Trautman & Shreve to beat the deadline by three days. "Overall, we saved 28 days in the construction schedule," says Barela, estimating that the true day-savings was much more like 60 versus the time required in a conventional radiant installation.

A Way Forward

NREL's Paul Torcellini believes that the PEX-based, radiant heating and cooling slabs are one of the keys to the energy performance at RSF and, he hopes, in TABS-style buildings yet to come.

"Logic will prevail," says Torcellini. "Water is a much better conductor of energy than air, and employing hydronic systems as a pathway for energy will be one of the strongest tools in rewriting our energy profile."

Installation tools like the Radiant Rollout Mat devised by Trautman & Shreve and subsequently commercialized by Uponor dramatically speed the installation of radiant systems. In doing so, such innovations help lower the up-front system costs for building owners, making sustainability even more economically viable and contributing to a very different and brighter energy future for commercial buildings.

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Uponor, Inc. is a leading supplier of plumbing, fire safety, and radiant heating and cooling systems for the residential and commercial building markets in the United States. Uponor, Inc. employs 380 people at its North American headquarters in Apple Valley, Minn. For more information, visit www.uponor-usa.com or call (800) 321-4739.

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Hi-res versions of a photograph to accompany this release are available for immediate download in .tif format by using this link:

http://uponor.oreilly-depalma.com/casestudies/nrel-rsf.shtml

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SIDEBAR 1

Renewable Energy and Energy Efficiency Features

RSF showcases numerous high-performance design features, passive energy strategies, and renewable energy technologies:

- **Building orientation:** The relatively narrow floor plate (60' wide) enables daylighting and natural ventilation for all occupants. Building orientation and geometry minimizes east and west glazing. North and south glazing is optimally sized and shaded to provide daylighting while minimizing unwanted heat losses and gains.
- **Labyrinth thermal storage:** A labyrinth of massive concrete structures is in the RSF crawl space. The labyrinth stores thermal energy and provides additional capacity for passive heating of the building.
- **Transpired solar collectors:** Outside ventilation air is passively preheated via a transpired solar collector (a technology developed by NREL) on the building's south-facing wall before delivery to the labyrinth and occupied space.
- **Daylighting:** 100 percent of the workstations are day lit. Daylight enters the upper portions of the south-facing windows and is reflected to the ceiling and deep into the space with light-reflecting devices.
- **Triple glazed, operable windows with individual sunshades:** Aggressive window shading is designed to address different orientations and positions of glazed openings. Occupants can open some windows to bring in fresh air and cool the building naturally.

- **Precast concrete insulated panels:** A thermally massive exterior wall assembly using an insulated precast concrete panel system provides significant thermal mass to moderate the building's internal temperature.

- **Radiant heating and cooling:** Approximately 42 miles of Uponor tubing is used in the radiant piping that runs through all floors of the building, using water as the cooling and heating medium in the majority of workspaces — instead of forced air.

- **Underfloor ventilation:** A demand-controlled dedicated outside air system provides fresh air from a raised floor when building windows are closed on the hottest and coolest days. Ventilation is distributed through an under-floor air distribution system. Evaporative cooling and energy recovery systems further reduce outdoor air heating and cooling loads.

- **Energy-efficient data center and workstations**: A fully contained hot and cold aisle data center configuration allows for effective air-side economizer cooling with evaporative boost when needed, while capturing waste heat for use in the building. Plug loads are minimized with extensive use of laptops and high-efficiency office equipment.

- **On-site solar energy system:** Approximately 1.6 megawatts of on-site photovoltaics (PV) will be installed and dedicated to the RSF. Rooftop PV power will be added through a Power Purchase Agreement, and PV power from adjacent parking areas will be purchased with 2009 American Recovery and Reinvestment Act funding.

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SIDEBAR 2

Building Facts:
Research Supply Facility

Size: Approximately 222,000 sq. ft.

Occupants: Approximately 800

Energy Use: 35 kBtu/sq. ft./year*

Energy Performance: 50 percent better than ASHRAE 90.1 2004 standard

LEED Rating: Platinum** (including the maximum points for energy)

Cost: $57.4 million (construction cost); $64 million, including furnishings

***Includes high-performance data center**   ****Targeted**

SIDEBAR 3

Stantec: Helping to Engineer the Nation's Largest Net-Zero Energy Commercial Building

Resourceful engineering design produced the nation's largest commercial building to achieve net-zero annual energy. The 800 occupants of the new, $64 million, 220,000-square-foot Research Support Facility (RSF) on the campus of the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) in Golden, Colo., consume energy generated only by the renewable power sources on and near the building.

Recognized with a national Engineering Excellence Grand Award from the American Council of Engineering Companies (ACEC), the RSF features the following elements:

- a 1.6-megawatt solar panel array;
- an underground, thermal labyrinth storage system that captures and reintroduces recovered heat;
- a radiant heating and cooling system utilizing water to adjust the temperature of the interior.

Intended as a replicable example for the future of large-scale, net-zero structures, the RSF is expected to achieve the U.S. Green Building Council's LEED® (Leadership in Energy and Environmental Design) highest rating of Platinum.

The aggressive energy efficiency requirements at RSF drove critical elements of the architecture, engineering and construction solutions. According to project performance manager David Okada, an engineer with Stantec in San Francisco, this outcome was best achieved "through an early and sustained collaboration between the design team and construction contractor, and a strong commitment to sustainable design by the owner and client."

Among the distinctive high-performance building concepts that Stantec brought to the project were:

- an array of both passive and active heating and cooling systems that are integrated in ceilings, walls and mechanical systems;
- the aforementioned, concrete thermal labyrinth;

- building-integrated solar energy strategies, and
- a high-performance building envelope.

Additionally, Stantec provided counsel on the building's form and orientation for natural light and ventilation, which created optimal day-lighting and temperature control in the building.

The culmination of all these sustainability-driven strategies allows the building to consume 50 percent less energy than similar buildings erected to the current commercial code.

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