



THE CARNOTJET™ SYSTEM

TOTAL FLUID SUBMERSION COOLING
FOR OEM SERVERS

FROM **GREEN REVOLUTION COOLING**

THE CLEAR SOLUTION FOR DATA CENTER COOLING™



DENSE CLUSTERS AND HEAT RECAPTURE



[Left] Dell M1000e blade chassis installed at TACC, [Right] 13U evaluation unit capable of producing 50°C waste water

DENSE CLUSTERS

The CARNOTJET™ system leverages the efficiency of dielectric fluid submersion cooling to produce powerful and reliable cooling for OEM servers. GREEN REVOLUTION COOLING now has multiple installations that feature more than 35 kW of compute capacity per 42U Rack, and GRC systems can scale to more than 100 kW per Rack.

GRC customers are running a variety of high-density servers in production, including dual-CPU, dual-GPU servers and blade servers.

Servers are installed in open-faced Racks filled with circulating GREENDEF™ coolant. The coolant carries nearly 100% of server heat from the Rack to a Pump Module where the heat is transferred to water.

The PUE of a typical CARNOTJET™ system, which is represented by $\text{TOTAL DATA CENTER POWER} \div \text{SERVER POWER}$, is between 1.04 and 1.15, depending on the density of the equipment installed. Relative to air cooling, very little energy is required to cool dense IT equipment, even when installing in a harsh or unconditioned environment.

In addition to the energy savings provided by ultra-efficient cooling, the removal of chassis and power supply fans, which are rendered obsolete in a fluid-cooled environment, further reduces energy use. Depending on the server make and model, server power may be reduced 5-25%.

HEAT RECAPTURE

The CARNOTJET™ system greatly simplifies server heat recapture. Virtually 100% of server heat is captured by GREENDEF™ dielectric fluid in the Rack. The coolant transfers the heat to water in the Pump Module where it is made available for reuse. The CARNOTJET™ system can reliably create waste water at 50°C (122°F), a temperature suitable for reuse in almost every application.

Most recently, researchers at the ROYAL INSTITUTE OF TECHNOLOGY (KTH) in Stockholm, Sweden, evaluated the CARNOTJET™ system for the ability to recapture heat. During the trial, KTH achieved 50°C water output from the system using standard x86 server architecture, including DELL servers and AMD processors.

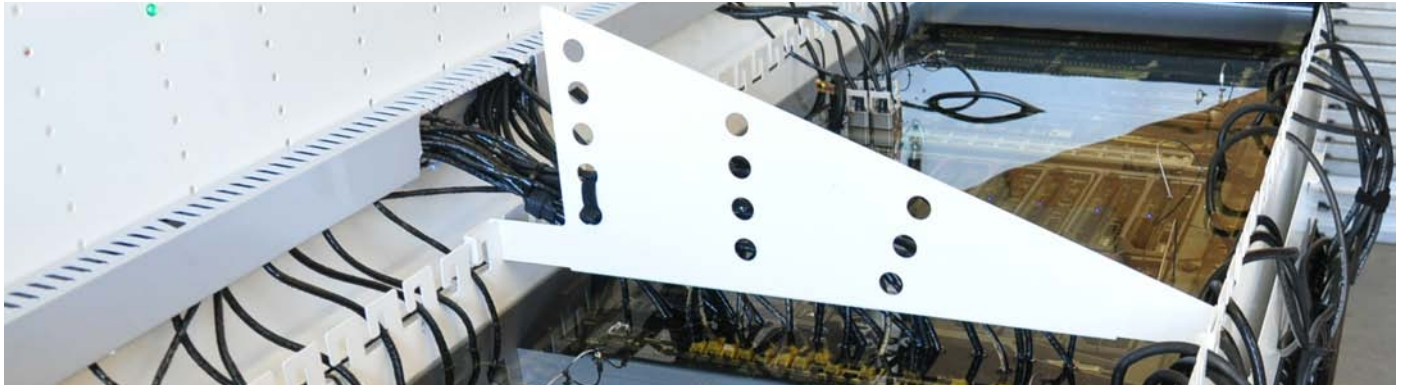
An output of 50°C (122°F) water significantly exceeds the Class W5 liquid cooling standard for reusable waste water set forth in ASHRAE's 2011 *Thermal Guidelines for Liquid Cooled Data Processing Environments*. At 50°C, water may even be pumped to adjacent buildings to be used for heating. Especially during winter months, the ability to produce 50°C water translates to extreme potential energy savings.

The CARNOTJET™ system is the first cooling solution in the industry to recapture nearly 100% of server heat without adding infrastructure costs. For more information on heat recapture and reuse with the CARNOTJET™ system, please visit our website.

For more information on high density server cooling and heat recapture, please visit the [Downloads](#) section of our website.



CASE STUDY: TEXAS ADVANCED COMPUTING CENTER



Open 42U Rack with 1U servers and blade system installed

TEXAS Advanced Computing Center installed a CARNOTJET™ system in April 2010. More than one year of production testing has shown that the system saves 85% of energy use compared to the efficient air-cooled system already in place.

INTRODUCTION

Texas Advanced Computing Center (TACC) is one of the world's leading scientific computing and research centers, in large part because it houses RANGER, the largest open research supercomputer in the world. When TACC switched on Ranger in early 2008, it paved the way for the next generation of scientific research and advancement by bringing online half a petaflop (one thousand-trillion operations per second) of computational capability.

In April 2010, GREEN REVOLUTION COOLING installed a single 42U CARNOTJET™ Rack in TACC's facilities. The installation focused on independently verifying three key items:

- Cooling power efficiency
- Ability to accept full range of form factors
- Potential for over-clocking servers

The installation space features no chilled water, CRACs, or climate control of any kind. Instead of air conditioning, the system rejects heat through an evaporative cooling tower outside that uses very little power.

TIMING OF TEST AND UPTIME

The CarnotJet™ system has run continuously since April 15, 2010 with 100% uptime.

EFFICIENCY

The system has consistently used 6 Watts or less of cooling power for every 100 Watts of IT since April 2010. This has resulted in a ~35% reduction in total power usage (i.e. servers and cooling) as compared to the same hardware cooled by air. Server power consumption decreased significantly. When compared to servers with internal fans, servers submerged in GREENDEF™ coolant regularly reduced energy usage by 10-20%.

TOTAL COST OF OWNERSHIP

- Total savings of ~\$100,000 for a single 22kW server Rack
- 85% less cooling energy compared to air-cooling
- ~35% less total energy than air-cooling
- Lower infrastructure cost

“The system has consistently used 6 Watts or less of cooling power for every 100 Watts of IT since April 2010.”

| SYSTEM ELEMENT | CURRENT SYSTEM | GR COOLING |
|---------------------------|----------------|------------|
| SERVER | 1.0 | .85 |
| POWER DISTRIBUTION LOSSES | .02 | .02 |
| COOLING | .4 | .06 |
| Total | 1.42 | .93 |

Total data center efficiency. Units: $\frac{\text{Power}}{\text{Server Power in an Air-Cooled System}}$

FUTURE PLANNING

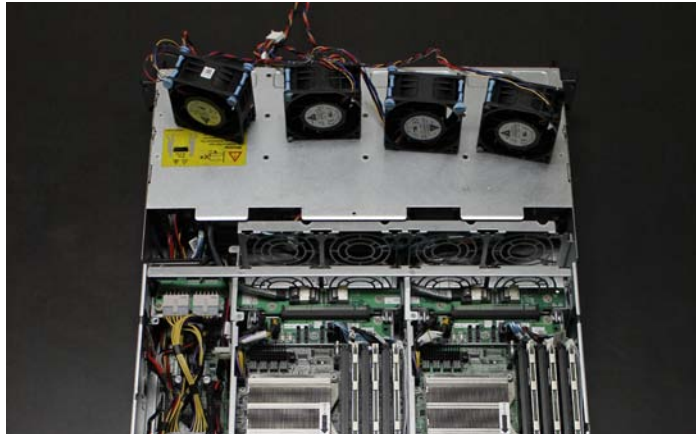
Drawing on the experience of this installation, GRC and TACC are in talks to produce Jalapeno, a two-rack system with 130 kW total capacity (65 kW of compute per Rack) sometime in 2012. To upgrade the existing system, a more robust Pump Module will be installed and connected to multiple Racks to drive circulation of the coolant. By installing extremely dense servers, TACC and GRC will be able to leverage the efficiency of fluid submersion cooling on a larger scale.



SERVER MODIFICATIONS

WHAT DOES IT TAKE TO SUBMERGE AN OEM SERVER IN DIELECTRIC FLUID?

Although OEM servers do not currently come from the factory ready for submersion in dielectric fluid, GRC has developed a three-step process to modify servers for submersion in GREENDEF™ coolant: removal of fans, encapsulation of hard drives, and substitution for thermal grease. The modification process is quick and inexpensive -- depending on the server type, modifications can be completed in less than fifteen minutes.



Server chassis fans removed

1. REMOVAL OF SERVER FANS

Obsolete in a fluid-cooled environment, server fans are removed entirely from the chassis. As a result, server power consumption is reduced 10-25%, significantly reducing overall data center energy expenditures.

Some servers require fan emulators to simulate the presence of a fan. GRC supplies these emulators and can install them in a matter of minutes.

2. HARD DRIVE ENCAPSULATION

Hard drives are encapsulated by GRC using a proprietary potting process. Sealed hard drives are completely air-tight and maintain original form factor. The encapsulation material is very thin and seals against coolant penetration.

Sealed hard drives may be run in air as well as coolant, but the encapsulation process cannot be reversed. Encapsulation is unnecessary for solid state drives.



Sealed hard drive [left] and unsealed hard drive [right]



CPU with Indium foil thermal grease substitute

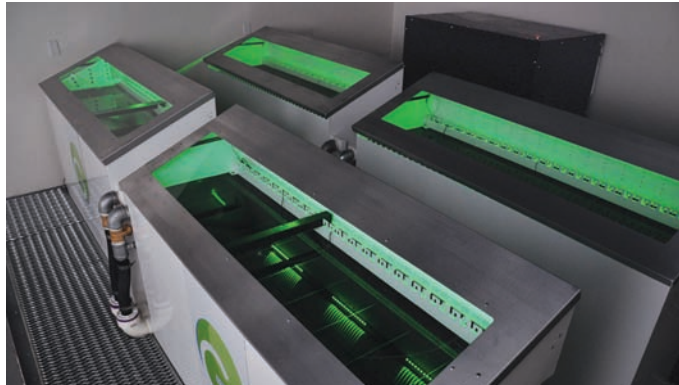
3. THERMAL GREASE REPLACEMENT

Thermal grease assists the heatsink in removing heat from a CPU or a GPU chip. Since this grease is oil-based and will eventually dissolve in GREENDEF™ coolant, it must be replaced with Indium, a soft metal foil with extraordinary heat conductivity.

Indium is safe for submersion and for air cooling alike and it takes less than two minutes to install a piece between a chip and heat sink.



CASE STUDY: MIDAS NETWORKS



[LEFT and RIGHT]: Perspective views of 100 kW four-rack CARNOTJET™ system installation at Midas Networks

MIDAS NETWORKS purchased a four-rack CARNOTJET™ system instead of a traditional air-cooled system and reduced upfront data center build costs by nearly 50% while reducing ongoing power costs by 50% annually to accrue total savings of over \$600,000 for 100kW of server capacity.

MIDAS NETWORKS is a hosting, collocation, and information technology solutions company based in Austin, Texas, that provides an array of hosting services for more than one-hundred businesses in Central Texas and nationwide. As Midas Networks has grown its data center capacity, it has faced the challenges of keeping expenses low while preparing for the future in an increasingly competitive market.

MIDAS NETWORKS was initially focused on finding suppliers of equipment with the following traits:

- Low upfront cost
- Low annual energy expense
- Room for future expansion

In 2010, a high-profile air cooling vendor quoted MIDAS NETWORKS \$120,000 to purchase and install two twenty-ton Computer Room Air Conditioners (CRACs) in order to increase data center compute capacity by 100 kW. MIDAS NETWORKS would have to further spend \$60,000 to optimize the new room for air-flow and heat management (raised floors, etc.) and to install a new generator outside to back up the new systems.

Expanding air-cooling capacity was proving impractical and fiscally burdensome. Understandably, MIDAS NETWORKS went looking for alternative options.

GREEN REVOLUTION COOLING was able to offer MIDAS NETWORKS installation and implementation of a 100kW system for nearly half the price of an air-cooled alternative.

The CARNOTJET™ system does not require CRACs, chillers, climate control, insulation, or large amounts of electricity -- it requires only a level floor and access to an external heat exchanger.

While the upfront infrastructure savings are substantial, the CARNOTJET™ system continues to save energy and money when the servers are powered on. Since enabling the system, MIDAS has reduced cooling power by 95% and total data center power by 50%.

| | Before | CARNOTJET™ |
|----------------------|--------|-------------|
| Servers | 1.00 | 0.85 |
| UPS | 0.08 | 0.07 |
| Cooling | 0.9 | 0.03 |
| Total Power | 1.98 | 0.95 |
| PUE | 1.98 | 1.12 |
| Power Savings | | -52% |

Energy usage with values normalized to server power usage

In addition to dramatic cost savings, MIDAS has gained the ability to cool high-density gear at minimal cost. The CARNOTJET™ system can efficiently cool blades, trays, multiple GPU configurations, and other high density equipment.

Cooling energy used shows a PUE of around 1.1, as expected (even with UPS power loss), and servers are consuming 15% less power than they did when cooled by air.

For MIDAS NETWORKS, low upfront costs, significant ongoing energy savings, and the ability to support high-density equipment combined to make GRC an intelligent choice for data center expansion.

“ We wanted the ability to cool blade servers and other next generation technology, and that was not going to be practical with air-cooling. ”

— Kenneth Tooke, Midas Networks

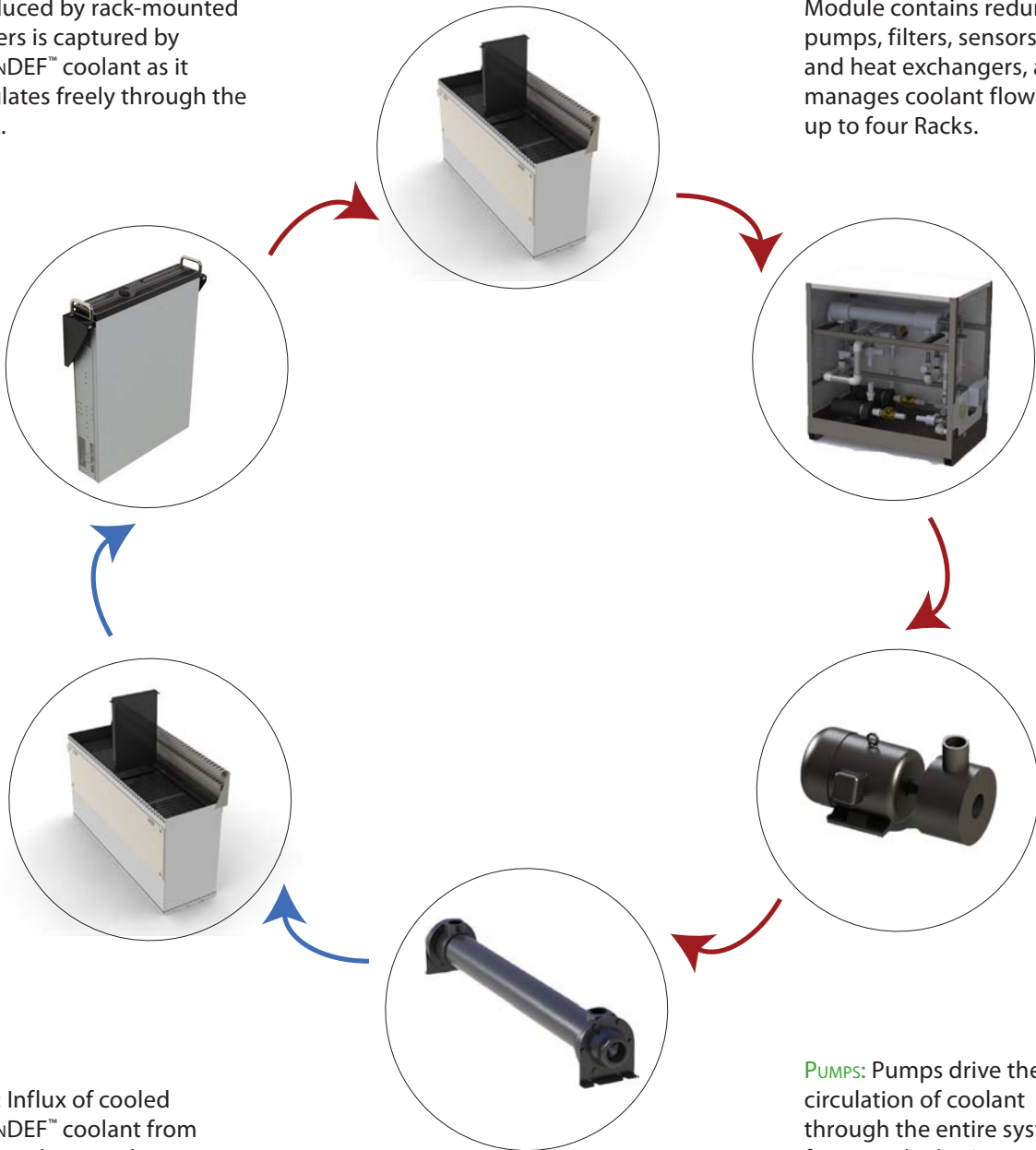


COOLANT FLOW IN THE CARNOTJET™ SYSTEM

SERVER FROM ANY OEM: Heat produced by rack-mounted servers is captured by GREENDEF™ coolant as it circulates freely through the Rack.

CARNOTJET RACK: Heated coolant is removed from the top of the Rack via a suction manifold and sent to the Pump Module.

PUMP MODULE: The Pump Module contains redundant pumps, filters, sensors, and heat exchangers, and manages coolant flow for up to four Racks.



RACK: Influx of cooled GREENDEF™ coolant from heat exchangers keeps Rack temperatures low and cooling consistent.

HEAT EXCHANGER: Part of the Pump Module, heat exchangers transfer heat from coolant to water, which may be reused as hot water or released via evaporative cooling tower.

PUMPS: Pumps drive the circulation of coolant through the entire system from inside the Pump Module. Pumps feature variable speeds with a digital controller.



GREENDEF™ DIELECTRIC FLUID COOLANT

LOW-COST, NONCONDUCTIVE, HIGHLY EFFICIENT FLUID COOLING



[LEFT]: 42U Rack filled with GREENDEF™ dielectric fluid and OEM servers, [RIGHT]: Four CARNOTJET™ system Racks

WHAT IS GREENDEF™ COOLANT? GREENDEF™ coolant is clear, odorless, dielectric, white mineral oil with 1,200x the heat retention capacity of air by volume. It is a specific but non-proprietary blend that offers exceptional performance at low cost. It is electrically nonconductive and 100% compatible with all rack-mounted OEM servers.

HOW IS IT USED? Servers are submerged in Racks filled with GREENDEF™ coolant. Circulation of the dielectric fluid dissipates server heat, which is carried out to a centralized Pump Module where the heat is exchanged to the outside. Coolant returns to Rack at a reduced temperature, lowering the overall temperature of the Rack and delivering consistent and uniform cooling to the servers.

WHY IS IT SO EFFICIENT? GREENDEF™ is efficient because it can be much closer to target server temperature than air. In other words, the coolant can provide the same amount of cooling at higher temperatures, which requires less energy overall. For example, maintaining a coolant temperature of 38°C is much less energy-intensive than cooling air to 25°C, a process that typically requires cooling water to 7°C.



NFPA 704 fire diamond for GREENDEF™

DOES IT LAST? Coolant may be exposed to air with no risk of evaporation. The coolant will last the life of the equipment. During this time, there should be no need to add or replace coolant.

HEALTH EFFECTS? There are no serious health concerns associated with GREENDEF™ coolant.

IS IT A FIRE HAZARD? GREENDEF™ coolant will not readily ignite. The National Fire Prevention Association (NFPA) 704 diamond rates GREENDEF™ as a 0-1-0 substance.

- **HEALTH: 0 - POSES NO HEALTH HAZARD.**
- **FLAMMABILITY: 1 - ON A SCALE OF 0-4. HAS A HIGH FLASH POINT.**
- **REACTIVITY: 0 - STABLE, EVEN UNDER FIRE EXPOSURE CONDITIONS, AND NOT REACTIVE WITH WATER.**

ENVIRONMENTAL CONSIDERATIONS: GREENDEF™ coolant does not pose any significant environmental risks. GRC recommends the installation of secondary containment with every CARNOTJET™ system to catch incidental spills and to prevent slippery floors. Containment is also required when installation site is near a navigable waterway. Coolant can generally be removed from a surface using mild soap and water.

| | |
|---------------------------|----------------------|
| EVAPORATION RATE | Nil |
| PERCENT VOLATILE | Nil |
| AUTO-IGNITION TEMPERATURE | ~650°F (343°C) |
| DENSITY | 7.10-7.13 lbs/gallon |

GREENDEF™ coolant properties



REVOLUTION
COOLING

To read more about our CARNOTJET™ fluid-submersion cooling technology,
please visit us online at www.grcooling.com

GREEN REVOLUTION COOLING

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