3M Science. Applied to Life.™

Authorized HPC Partner
EXTOLL latency matters.

Highly Effective Cooling of High-Performance Computers and Servers

With 3M™ Novec™ Engineered Fluid

Optimized Energy Efficiency, Performance and Reliability

Quantum Leap for the Cooling of Power Electronics with the New Cooling- and Network-Technology from EXTOLL

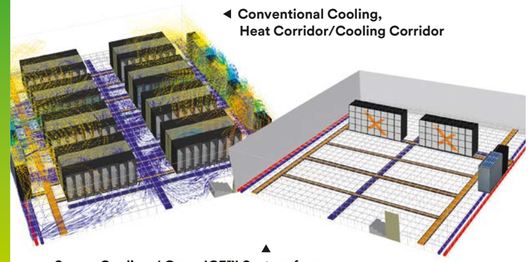
The operation of today's high-performance electronics generates enormous amounts of dissipated heat. For the efficiency of such systems, thermal management has come to be a decisive criterion.

By employing the principle of 2-phase immersion cooling for power electronics, such as high-performance computers or server modules, with 3M™ Novec™ Engineered Fluid, enormous potentials for energy and cost savings are opened up in data and computer centers as well as in other high-performance computing applications.

The electrical energy needed to cool the electronics can be reduced by up to 97% with this innovative solution! In addition, the use of 2-phase immersion cooling technology makes it possible to achieve a much higher packing density of the power electronics boards, and also results in a significant improvement of the reliability of the devices.

Illustrative consideration of a Data Center

- Room size: 1,314 m^3
- Total cooling capacity required: 848 kW



◀ **Conventional Cooling, Heat Corridor/Cooling Corridor**

▲ **Server Cooling / GreenICE™ System from EXTOLL with 3M™ Novec™ Engineered Fluid**

- No heat dissipation into the room, PUE (Power Usage Effectiveness) down to 1.01
- Enormous hardware packing density, space savings, and savings on conventional air conditioning equipment

GREEN ICE

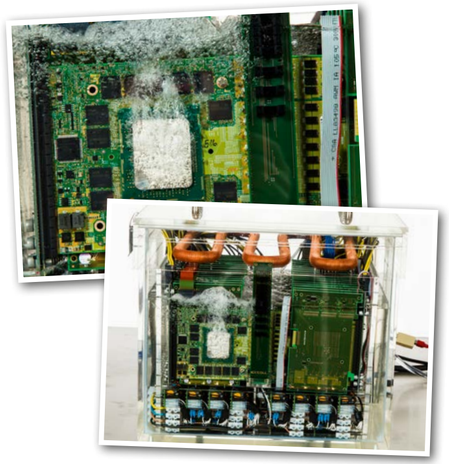
GreenICE System from EXTOLL

Developed for the Highest Demands

Energy-efficient Immersion Cooling for Power Electronics

The GreenICE™ High-Performance Cooling System

The GreenICE System by EXTOLL is based on the principle of 2-phase immersion cooling. The electronic assemblies, such as server modules, are arranged standing up in a chassis filled with 3M™ Novec™ 649 Engineered Fluid. On the surfaces of the power electronics components that heat up during operation, the Novec 649 Engineered Fluid already vaporizes at very moderate temperatures. Due to the phase change from liquid to vapor, the cooling effect is maximized.



This concept prevents the components that are heating up from coming into contact with the ambient air. This results in an enormous energy saving potential for the air conditioning of computer rooms. No heat is emitted into the computer-center or work-area rooms. Blowers, air-conditioning and ventilation equipment can be almost entirely eliminated.

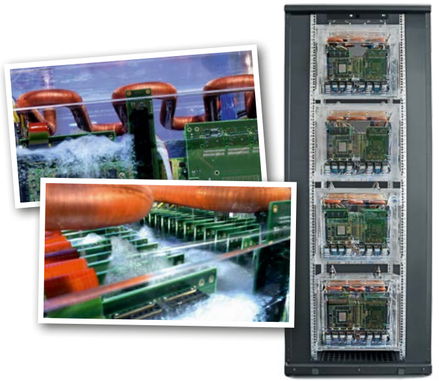
The people working in smaller work areas (such as labs) in which high performance computers are also located, are thus spared the nuisance of being subjected to heat emitted into the room, and the noise of ventilation and air conditioning systems.

Design and Functional Principle of the GreenICE Server System

The design and functioning of the GreenICE System differs radically from the previous technologies employed in existing data centers and standard server racks that have grown historically. Yet the new technology still offers the benefit that it can be integrated into the existing 19" architecture.

The server modules are inserted standing up next to each other without individual housings. This results in the highest possible packing density. The functional principle on which this cooling method is based requires only a minimal separation of roughly 1 millimeter between the critical components.

In the upper area of the chassis, there is a heat exchanger that works with water, via which the heat is transferred out of the chassis and server rack. The vaporized Novec 649 Engineered Fluid condenses in this area already at 49°C, and drips back into the chassis immersion bath.



Highest Performance within Smallest Volume

The installed height of a chassis occupies 10 height units of a 19" rack. At an effective cooling volume of only 43 dm^3, the system can provide a cooling performance of 12 kW. It thus achieves a computing performance of 32 x 1.2 TFLOPS = 38.4 TFLOPS!

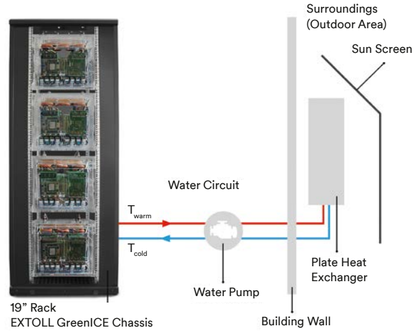
Up to four chassis can be integrated into a single 19" rack unit. A single cabinet is thus able to extract 48 kW of heat. This corresponds roughly to the performance of four state-of-the-art (2015) air-cooled server racks, and thus to a hardware compaction of about 1:4!

Server-rack Internal and External Thermal Management

Three Heat Exchange Processes:

- CPU/fluid: ΔT_{if} – dependent on CPU cover and vaporization technology
- Novec/water ΔT_{fw} – dependent on heat exchanger, layout, water temperature, etc.
- Water/environs ΔTwa – dependent on plate heat exchanger, volume, etc.

Computer Room



1 3M™ Novec™ 649 Engineered Fluid (49°C Boiling Point)

2 Intel® Xeon Phi™ / Extoll NIC Processor < 18 mm Distance (interspatial)

3 Generated Heat / Novec Fluid vaporizes on the chip

4 Condensed Novec Fluid flows back into the bath

Up to an outdoor temperature of 35°C, the cooling system does not require additional fans. Cooling to the required inlet temperature can be achieved via a simple plate heat exchanger. There is thus no need for additional energy in order to bring the cooling water back down to the level of the inlet temperature. The pump operating in the low pressure area of the cooling circuit requires no more than 150 W of power per rack.

Low PUE value? Then take a closer look...

The PUE value (Power Usage Effectiveness), as a key factor for assessing the energy efficiency of a data center, is calculated as the energy required to operate the IT equipment including its cooling divided by the energy required to operate it without cooling. The ideal PUE value would therefore be 1.0, i.e., no energy is required for cooling. However, typically the energy consumption of the fan inside the server is not taken into account, because it is built into the server. You should keep this fact in mind when you use the PUE value as an evaluation criterion.

Particularly the fans inside the server consume quite a lot of electrical energy, and thus have a large impact on overall energy efficiency. The true PUE value can therefore be up to 10% higher! With Novec-cooled server systems, no fans are needed at all for the servers!

Excellent Environmental Compatibility and Safety

Novec 649 Engineered Fluid is not a hazardous material, and enables the development of a server technology suitable for long-term use. It features a very low GWP value (global warming potential) of only 1, and is thus not subject to the European F-Gas Regulation. Moreover, it exhibits zero Ozone Depletion Potential.

Novec 649 Engineered Fluid is inert, i.e., it does not chemically react with most of the materials used in the electronics industry. It is also colorless and odorless, vaporizes quickly without leaving a residue, and is non-flammable.

If you have any questions, please contact:

On **Novec 649 Engineered Fluid:**
www.3m.de/novec

On **Hardware and IT infrastructure:**
www.extoll.de

3M Deutschland GmbH
Electronics & Energy Produkte
Carl-Schurz-Straße 1
41453 Neuss
Tel.: +49 (0)2131 / 14-5999
www.3M.de/novec
www.3M.de/elektronik

Extoll GmbH
B6, 26
68159 Mannheim
Tel.: +49 (0)621 / 181-2716
www.extoll.de

Dr.Nr. AA88OD3406S 01/10.2015 Index 1

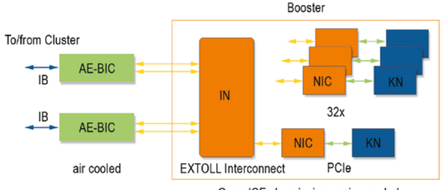
Please recycle. Printed in Germany.
© 3M 2015. All rights reserved.

Background on Data Management of the GreenICE

The GreenICE chassis is modularly designed and contains 32 nodes. Each node consists of an Intel® Xeon Phi™ Coprocessor (KNC) and an EXTOLL NIC. The NIC is implemented with an EXTOLL ASIC Tourmalet PCIe board. The high-performance nodes used in the chassis have a power consumption of 250 W each.

Hardware Architecture of the GreenICE Chassis

The topology of the network is configured as a 3D torus with 32 nodes, represented by a logical arrangement of 4x4x2.



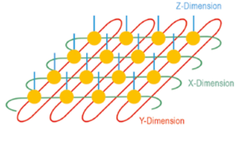
GreenICE chassis, immersion cooled

16 interfaces of the Z-axis can be used to connect the chassis to the next 3D torus level, or directly to a scalar processing system inside a cluster-booster configuration.

The scalar nodes must be equipped with a Tourmalet ASIC NIC in order to set up the communication connections.

Each KNC is connected via a PCI-Express Gen 2x16 interface with the corresponding EXTOLL NIC. The NIC is configured as a "Root Port," and can therefore take over management of the KNC for initialization and booting without the need for a server connected as host to the PCIe for this purpose.

To transmit the PCI-Express bus signals, a backplane with high packing density is used. One backplane can accommodate 8 nodes. The board interspersing distance is only 18 mm. Four of these backplanes are installed per chassis.

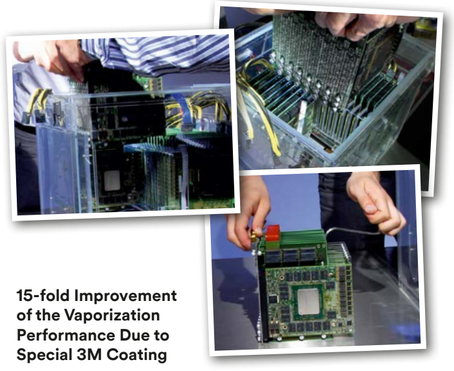


The entire Booster system thus encompasses a total of 32 nodes. The peak computing performance of the system is 38.4 Tflop/s. One layer (X-Y level) of the EXTOLL infrastructure is shown in the graphic.

Great Flexibility Also When Servicing Is Needed

Special couplings to the rack enable the individual chassis to be hot-swapped during operation. If a component should fail during operation, the board can be replaced quickly and easily. The entire construction of the chassis has been designed such that servicing takes only about 15 minutes, and also does not require special tools. Servicing can be done easily on site.

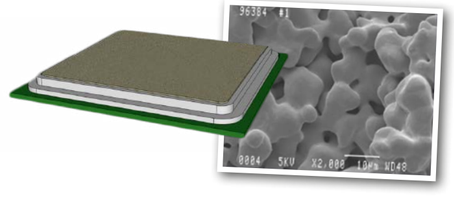
When the boards are removed from the Novec Fluid, they dry immediately and they are also completely clean (no residue). The chassis is hermetically sealed, so that no fluid is lost. It therefore never has to be replaced or refilled over the entire life cycle of the system. It can even continue to be used following a server upgrade, because its properties do not change during operation.



15-fold Improvement of the Vaporization Performance Due to Special 3M Coating

The 3M Coating Material makes it possible to achieve very "fine" boiling, and thus a uniform vaporization of the Novec Fluid on hot component surfaces.

This helps to significantly increase the functional reliability of the components under extreme loads.



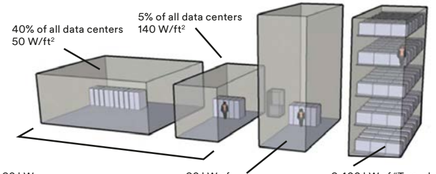
Benefits of the GreenICE Server System at a Glance

- Enormous energy cost savings for air conditioning and cooling (up to 97% compared to conventional air/water cooling)
- Maximal increase of packing density of high-performance servers, savings on floor space, approx. 48 kW per server rack corresponds roughly to the performance of 4 state-of-the-art air cooled server racks!
- Optimization of interconnection routes (shorter distances)
- Conventional air conditioning and control equipment no longer needed > savings of floor space up to factor 1:7 and investment costs
- Better handling of peak demands that previously led to component damage and failure > enormous increase in availability
- Internal server fans are no longer needed > these are usually the components with the highest failure rate, high noise output and immense energy consumption that is not calculated into the PUE value!
- Increased fire protection > Novec is non-flammable > increased operating safety
- Short maintenance times of only about 15 minutes to replace a board; "hot-swap" capable removal of a chassis
- Increased reliability because the components are operated at a much lower temperature. > Boiling point of the cooling media is only 49°C!
- Novec 649 Engineered Fluid is not subject to the F-Gas Regulation > high security of investment
- Novec 649 Engineered Fluid is a non-hazardous material, and does not leave a residue in the event of leakage
- Server upgrades can be easily implemented simply be replacing the nodes in the chassis > significant reduction of upgrading costs

Why Direct Cooling with Novec?

- Increased computing performance
- Better utilization of capacities
- Increased reliability and availability
- Savings in operating costs
- Low environmental impact

Significant Energy and Space Savings



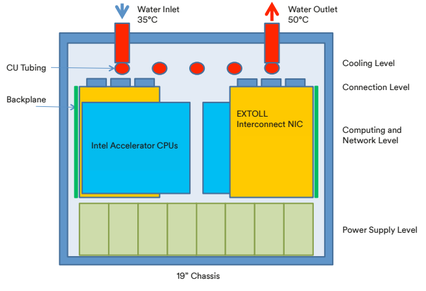
The EXTOLL GreenICE High-Performance Cooling System

▶ Energy Efficient Cooling of Accelerated Computer Hardware

Significant Benefits for Server Upgrades

In order to keep up with increasing demands for more computing power, servers are, as a rule, replaced every two to three years. In systems where the power electronics are cooled via cold-plates, this incurs enormous costs, because the entire plumbing for cooling and the design of the cold-plates must be adapted to the new server board. This usually entails having to replace all of the existing hardware. But with the GreenICE solution from EXTOLL, this is now a thing of the past. This hardware allows the next generation server boards to be quite easily integrated into the existing enclosure. The existing cooling system can remain in place in its entirety. Moreover, the existing Novec 649 Engineered Fluid can also be reused. The result is significantly lowered investment costs when planning to modernize!

General Layout of the GreenICE Chassis



19" Chassis

High Operational Safety

The design of the system precludes that cooling water, in the event of leakage, can enter any areas where it would be critical for the electronics. With the cold-plate solution, this is not the case, because the water circuit is located directly in the area of the active electronics.