WHITEPAPER

IMMERSED COMPUTING®

Asperitas

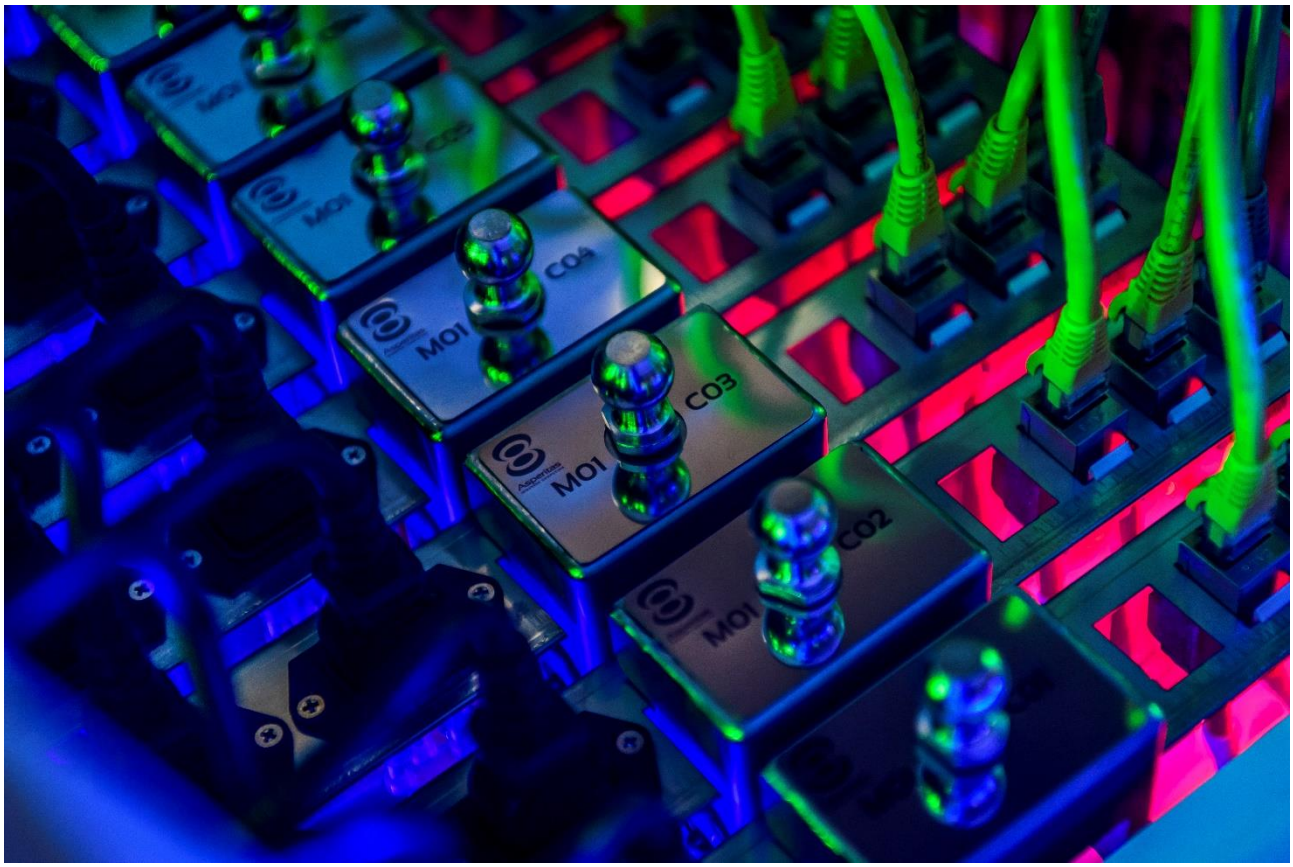
IMMERSED COMPUTING

ROLF BRINK, CEO

www.asperitas.com

IMMERSED COMPUTING®
BY ASPERITAS

A concept driven by sustainability, efficiency and flexibility. Using the most efficient model for operating IT, Total Liquid Cooling, and going far beyond just technology. Immersed Computing® includes an optimised way of work, highly effective deployment, flexible choice of IT and drastic simplification of datacentre design. Offering great advantages on all levels of the datacentre value chain. Realising maximum results in Cloud, HPC and Edge.



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1. BACKGROUND

The datacentre industry is at the peak of its growth. New datacentres are continuously being built and the challenges for datacentres are growing as fast as the industry itself. This growth is accompanied by a high demand for high density datacentres and platforms. The main cause of the increasing demand is the Internet of Things (IoT), big data and a global move to cloud based computing.

THE INDUSTRY IS CONSUMING ABOUT 5% OF THE GLOBAL ENERGY SUPPLY and it is still growing. This has caused the focus to shift from high amounts of floor space with distributed IT environments, to high density and energy efficient centralised cloud environments.

AIR BASED COOLING BECOMES AN EVER GROWING CHALLENGE with the increasing demand for these high density cloud environments. Extreme wind speeds within server racks (5-10 Beaufort) are required to cool high density environments and air becomes ever more problematic in these environments with vibration issues, high IT overhead for fan energy, zinc whiskers across IT components and power thirsty cooling installations.

THE FOCUS HAS BEEN ON COOLING, the biggest overhead. The Power Usage Effectiveness (PUE) has been adopted as a major KPI for datacentres. The formula is simple: total energy footprint of the facility divided by the energy consumed by IT. The downside of this approach is that IT inefficiency is being rewarded, thus leaving the focus on high energy savings on cooling installations and less on possible energy reduction by increasing the energy efficiency of the IT itself.

IN THE PAST YEARS, LIQUID COOLING HAS BEEN (RE)INTRODUCED, although mostly in High Performance Computing (HPC) environments like supercomputing. The requirements in this part of the industry are such that more effective cooling allows for higher performance. Therefore, liquid was quickly adopted and today it is inconceivable that a supercomputer will be built without some form of liquid cooling.

CLOUD PLATFORMS NOW HAVE ENERGY AND DENSITY CHALLENGES, although the density challenges have a different focus compared to HPC environments. Cloud platforms are designed for continuity and flexibility, not necessarily the highest performance. This is where liquid cooling ran into its limitations. The available technologies were usually limited in some way: too complex, expensive, hard to operate, messy, incompatible with existing data floors or too inflexible due to proprietary IT.

TO MAKE LIQUID A VIABLE SOLUTION FOR THE CLOUD INDUSTRY, a different approach is required. An approach which addresses sustainability, continuity, flexibility, Total Cost of Ownership (TCO), tidiness, cleanliness and compatibility with existing environments.

THIS APPROACH IS CALLED IMMERSED COMPUTING®

2. IMMERSED COMPUTING® EXPLAINED

Immersed Computing® is a concept consisting of technological and operational aspects. It is focused on optimising all aspects around the IT, the core of every datacentre, resulting in a digital infrastructure. This optimisation goes beyond IT and addresses the entire infrastructure to facilitate IT in the most optimal way.

2.1 TOTAL LIQUID COOLING

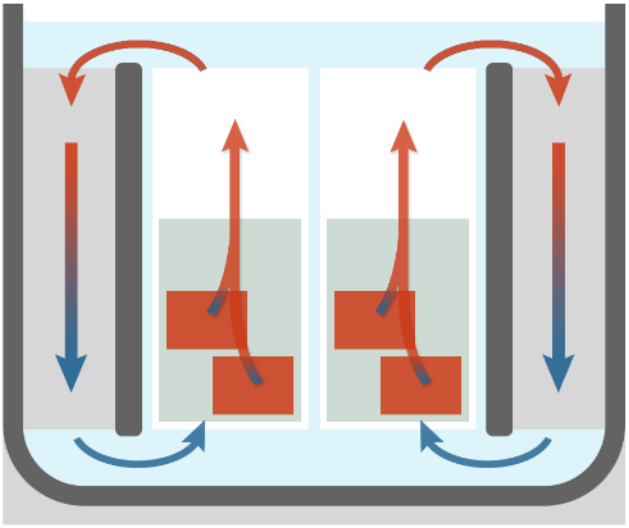
TOTAL LIQUID COOLING of IT, also called Immersion Cooling, is at the foundation of Immersed Computing®. It means the complete immersion of electronic components in a dielectric liquid. By doing so, all the heat generated by the IT is captured in the liquid. Suitable dielectric liquids can absorb approximately 1500 times more heat energy than air with the same volumes and temperatures.

TOTAL LIQUID COOLING IS NOT NEW. It has been an accepted method of conditioning electronics for more than half a century. In the late sixties, the first patents for oil immersion systems were already granted. These were abandoned after some time due to the lack of focus on energy efficiency. Air based systems were already abundant and 19" racks already were accepted standards. The use of Total Liquid Cooling has only remained common practice in niches where other factors became problematic like deep sea research (pressure vessels) or high voltage installations.

SUITABLE DIELECTRIC LIQUIDS today are oil and chemically engineered liquids. With the core values of Immersed Computing® in mind, Asperitas has chosen medicinal quality oil as a primary cooling medium. This is due to the wide availability throughout the world of medicinal oil, the low cost and the lack of safety concerns involved. Medicinal oils are manufactured by all oil companies and brands can be mixed and interchanged freely. Chemically engineered liquids, although still suitable for Immersed Computing®, come at price which is usually 20 to 40 times higher. This makes it less interesting for an open bath approach. The medicinal quality oil used by Asperitas is the same product as Vaseline, although with a different viscosity.

THE CIRCULATION AND REJECTION OF HEAT from the primary liquid is an important aspect of total liquid cooling. Traditional oil approaches use infrastructures with pumps and piping for circulating oil from a basin, through a facility, to a cooling tower and back into the immersion basin. This same circulation pushes the oil through the IT chassis and over the micro-electronics, thus removing their generated heat.

THE CIRCULATION OF THE LIQUID is where Immersed Computing® is unique and ground-breaking. Asperitas eliminates any infrastructure for the primary medium, oil. Instead, the oil is circulated by natural means and does not leave the immersion system. The oil circulates by the heat generated by the IT and water cooled "Convection Drives"™. This means that the primary circulation is completely driven by the thermal expansion of the oil and gravity. The only requirement for heat rejection is any common water infrastructure.



THE LACK OF DEGRADATION of the oil in Immersed Computing® is caused by the lack of moving parts and the fact that everything in touch with the oil has been tested before insertion. No air is ever mixed into the oil in the system and the lid is closed by default, since a closed lid improves the effectiveness of the natural circulation. This prevents oxygen from reacting with the oil. The oil never reaches temperatures which cause it to "crack".

A DOUBLE HULL AND COLD SHELL protect the environment of the system from any leakage or additional heat. The double hull is insulated and provides an optimal safeguard against leakage. The hull also prevents heat from escaping from the liquid. The only place for the heat to go is into the water circuit. This means that the result of Immersed Computing® is water with the same amount of heat energy as the IT consumption. Simply put, 22 kW IT equals 22 kW heat captured in water with minimised losses.

ANY TYPE OF SERVER can be inserted into the system, although it does not maintain the traditional server shapes as we know them in air-cooled racks. After all, traditional servers are not designed to allow oil to flow through the chassis by itself. Immersed Computing® servers consist of IT components like mainboards with components attached, power supplies and storage. Specialised Asperitas Universal Cassettes or AUC's are used for Asperitas systems. All information on the AUC's is publicly available for hardware designers and manufacturers.

2.2 ENCLOSED AND SELF CONTAINED

THE FOCUS IS ON COMPUTE, as IT is at the basis of every datacentre. All other aspects of a server, rack, cooling or even power system only facilitate the IT. The natural convection approach and the containment of the liquid in the system allows for a shift in focus from Cooling to Compute. The self contained approach allows for a further level of integration. Everything required to facilitate IT is integrated in the system. Besides cooling, IT requires power and data connectivity. Immersed Computing® integrates this in the solution and makes it manageable.

- **INTEGRATED POWER DISTRIBUTION** is used for powering all IT in the system. The power distribution system can be redundant and fully managed and must be applied in such a way that cable management is simplified and nothing needs to be routed outside the immersion system.
- **INTEGRATED UNIVERSAL SWITCHING** allows for the distribution of Ethernet connectivity throughout the system. Universal Switching Cassettes allow for any brand of switch to be immersed, and the network connections are distributed to each server with minimised and intuitive cable management.
- **THE INTEGRATED CABLE MANAGEMENT** approach allows for standardised and optimised serviceable cabling and logical cable management without bundles or over lengths. Only backbone cabling comes out of the system.

2.3 FLEXIBILITY

FLEXIBILITY IS KEY for Immersed Computing®. Platforms must be easily expandable and should grow with the environment. To address the current challenges in the industry, systems must be easy to deploy and the platforms should not be limited to proprietary IT.

IMMERSED COMPUTING® IS PLUG AND PLAY. Due to the self-contained approach, a single system requires only (redundant) power, access to a water loop and data connectivity to operate. This limited requirement enables high flexibility when determining appropriate deployment sites and scenarios.

MODULARITY is achieved with self-contained immersion systems with a known footprint (600x1200 mm). A single water loop can be shared across multiple modules and modules can be placed back-to-back and side-to-side. Since there is no air required for the system to operate, large rows of interconnected systems can be placed in relatively small spaces.

THE SCALABILITY OF IMMERSED COMPUTING® allows for very fast deployment of datacentre locations because there is hardly any infrastructure required. Power systems are minimised with less overhead, cooling infrastructure is minimised and IT is optimised for high utilisation.

THE OPEN IT APPROACH allows for any type of IT to be used with Immersed Computing®. As long as the components fit within the AUC's or cassettes, it can be used. Limiting factors are related to the use of liquid. Thermal paste will dissolve in any liquid, so this is be replaced with a non-dissolvable material (i.e. Indium Foil). SSD's can readily be deployed, but traditional spinning hard drives cannot. Unless they are certified for immersion by the manufacturer or designed to be airtight (Helium drives) with chemical resistant sealant.

2.4 WAY OF WORK

The most critical factor with Immersed Computing® is the mind-set and way of work. Implementing Immersed Computing® means working with oil. Asperitas has focused the majority of the engineering on creating a solution where working with oil is easy and clean.

UNDERSTANDING OIL itself is an important first step. By adopting oil, certain aspects of a datacentre operation and way of work will need to change. Most obviously, oil is a liquid. This means that it behaves different than air. The interaction with the substance is therefore also different. Anything which is immersed in oil will remain moistened with the liquid during servicing or after replacements. Anything taken from the liquid, when properly worked with, may leak when removed and may cause slipping situations. Although oil seems similar to water, it behaves a lot different.

PREVENTING LEAKAGE is the first step in the design of the system and the way of work. The system itself is already focused at no-spill. This leaves the way of work. People servicing IT must be prepared to deal with oil, to adjust the work process, to have proper supplies and take the time required for oil to drip. Asperitas develops all the tools required to deal with regular and irregular maintenance.

CLEANING THE SMALLEST SPILLS must be a routine. Leakage will not evaporate, but will remain on a surface unless properly cleaned. A small drop of oil is not a big deal, but over time an oil film on a surface can collect dust or dirt which creates stains. Each drop should therefore be wiped immediately.

SUPPLIES AND CONSUMABLES which are specialised for oil are required for maintenance and clean operations. Water can easily be cleared with a towel or sponge and residue will simply evaporate, but oil will not be absorbed by the same materials, nor will it evaporate easily. Therefore, specialised supplies need to be available wherever people are working on immersed systems. Asperitas includes all oil materials required for normal maintenance and any type of spill with its solutions.

MAINTENANCE ON ELECTRONIC COMPONENTS requires removal of the IT from the oil. Since all the IT is placed in a vertical position and needs to leak for a little while, it becomes impractical to manually lift a server from the basin. This is addressed with a specialised, automatic hoisting mechanism: The Asperitas Service Trolley is specialised for hoisting cassettes, servicing and transporting IT, cleaning up spills and servicing oil.

TRAINING OF SERVICE STAFF on the properties and operation of oil and the use of essential supplies is of utmost importance. It is quite simple and lessons are easily handed over, but the basic knowledge should be there.

3. BENEFITS

Immersed Computing® provides benefits for many layers within the datacentre industry, from the physical geographical location to the end user of a platform. Each type of environment is different so it helps to create more insight in the layers underneath a dense platform.

3.1 ENERGY EFFICIENCY

Total Liquid Cooling allows for the greatest energy efficiency of IT environments today. This is caused by two main factors and several side effects.

THE LACK OF MOVING PARTS REDUCES 10-45% OF IT ENERGY. Any air cooled IT equipment requires air circulation. In servers this consumes between 10% and 45% of the total energy footprint. 1U servers with average CPU power with good utilisation (i.e. 80W per CPU) often end up with the highest fan overhead. Larger servers (2-5U) have larger fans which consume less energy, but these servers take up a lot more space in a rack which makes the rack less effective. This fan overhead and space limitation is completely eliminated with Total Liquid Cooling.

1U server energy reduction
A single 1U fan consumes about 12 watts at full power. A fan assembly usually consists of 2 fans. 1U servers often require at least four of these assemblies across the width of the chassis and additional fans for the power supplies. This adds up to about 120 watts. With low powered servers, this is up to 45% of the energy footprint.

THE HIGH HEAT CAPACITY OF LIQUID allows IT to operate within higher temperatures compared to air. This means that running IT in higher environmental temperatures, still allows the IT components to operate well below the maximum component temperatures. The Asperitas Immersion systems can be cooled with water of 40°C. So there are no chiller units required and energy overhead is reduced to a minimum.

ENERGY REUSE is greatly optimised as all IT energy is captured in the form of heat inside water. After all, the enclosed system is water cooled and there is no other way for the heat to go besides the water which runs through the convection drives. Warm water can easily be transported or even stored for energy reuse scenarios.

3.2 DATACENTRE BUILD

The cheapest datacentre is the one you don't need to build.

REDUCED FLOORSPACE is one of the obvious benefits of Immersed Computing®. Compared to an average air cooled cloud datacentre, Immersed Computing® can facilitate 5-10 times as much density.

Air cooled rack
An air cooled rack can commonly support about 5kW of IT power, and takes the space of 2 floor tiles. In order to get sufficient air through the rack, 1 or 2 floor tiles are needed in front and in the rear of the rack, also for service space. The total footprint of the rack now becomes 600x2400/3600 mm. 5kW of air cooled IT divided over 1U servers is comparable to 3 kW of immersed IT.
This results in a power density of **1,5-2kW per m²**

Immersed Computing®
Immersed Computing® can support 22 kW of pure IT power with a footprint of 600x1200 mm. No airflow is required but we'll assume a service area of 600x1200 mm with each module.
This results in a power density of **more than 15 kW/m²**

NO RAISED FLOORS AND ISLE SEPARATION SCHEMES are required. Since there is no air involved with Immersed Computing®, there are no air flows to separate. Although raised floors are fully supported, they are in no way a requirement for Immersed Computing®.

THE PHYSICAL LOCATION of the datacentre becomes less challenging with Immersed Computing®. Since there is hardly any environmental impact like noise, datacentres can be built in rural areas. This opens up possibilities to get closer to the edge of the network to allow further growth of Internet of Things and delivery of content to end users with minimised impact on the core network.

3.3 DATACENTRE FACILITIES

Overhead facilities can be downsized or existing capacity can allow for more IT.

THE MINIMISED COOLING REQUIREMENTS for Immersed Computing® result in smaller and heavily simplified cooling installations. However, if these are already present, there is more capacity for more IT power. In reusable heat scenarios, warm water can simply be used and cooled by other means which can eliminate coolers all together.

MINIMISED POWER REQUIREMENTS have a significant impact on the emergency no-break power systems. These are expensive and depending on the type of datacentre, these need to be sized to allow all IT to function during power outages, as well as the cooling installations to facilitate the IT. The power systems can be downsized or, when already present, facilitate more IT.

3.4 DATACENTRE OPERATIONS

Immersed Computing® offers significant benefits towards business continuity and maintenance costs.

BUSINESS CONTINUITY IS IMPROVED as total immersion of IT protects the IT itself much better than traditional air environments, because:

- No oxygen gets in touch with the actual components which prevents oxidation. The oil creates a protective barrier since oxidation requires oxygen and water. The oil keeps both away from the IT. This completely eliminates the physical degradation of the IT components over time.
- Moisture does not mix well with oil. Since there are no moving parts and all oil movement is caused by natural means, any water accumulation from condensation or small spills will just sit in the bottom of the environment. This moisture will usually evaporate out of the system. Residual moisture can also easily be taken out by an oil polishing system which is part of the service trolley.
- Thermal Shock is greatly reduced due to the high heat capacity of liquid. Where air cooled systems have enormous temperature fluctuations within the chassis when utilisation fluctuates, the immersed environment only has minor fluctuations. This greatly reduces stress by thermal expansion on micro-electronics.

Reduced component failures are the result of these effects. These in turn reduce component costs and workload for service staff.

NORMAL MAINTENANCE COSTS ARE GREATLY REDUCED. Since total immersion eliminates the root cause of most electronic component failures, the most important situation to address is regular maintenance, upgrades and renewals. Reduced and simplified overhead installations for power and cooling also result in reduced potential for failure and maintenance.

3.5 IT HARDWARE

IT HARDWARE SHOULD BE OPTIMISED for Total Liquid Cooling to ensure the maximum beneficial effect. This means that servers will be able to perform much better than traditional air cooled servers. The loading of a single immersed server can be sized to replace 3 or more low power air cooled servers. This results in an enormous consolidation where less IT is required to provide with the same amount of digital capacity.

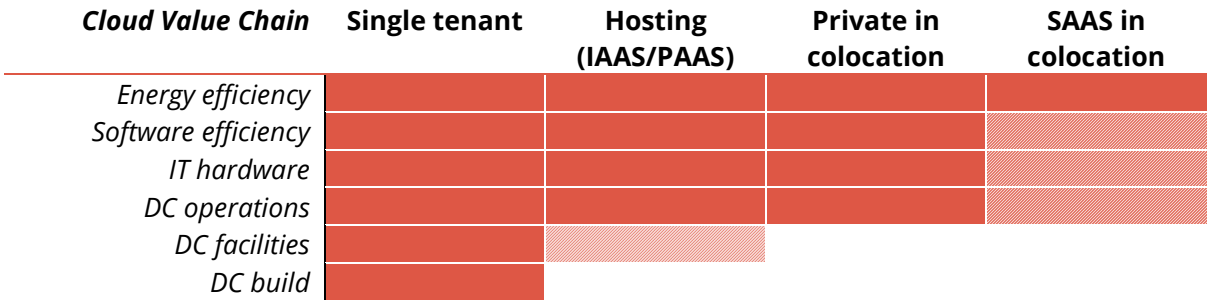
3.6 SOFTWARE COST

LESS OS AND CPU LICENCES ARE REQUIRED due to the use of optimised IT hardware. Because of the smaller number of physical servers, there are less operating system licenses required. The same can be said about applications which adopt a per CPU licensing structure. Often database servers and virtualisation systems benefit from less CPUs from a licensing perspective. Since licensing cost often outweigh the hardware cost, this may in some cases be the highest financial saving in the entire value chain.

3.7 ENVIRONMENTS WITH GREATEST BENEFITS

ALL DATACENTRE OPERATORS BENEFIT from investing in Immersed Computing®. Immersed Computing® not only positively impacts sustainability, but also many CAPEX and OPEX areas, dramatically reducing TCO. However, the more links a company controls in the value chain, the more financially attractive the business case for adopting Immersed Computing®. Especially for a greenfield situation.

CLOUD INFRASTRUCTURE PROVIDERS will achieve the best results, especially single tenant and IAAS/PAAS hosting providers.



In other IT environments, Immersed Computing® also solves issues or adds value. For instance:

- **HIGH PERFORMANCE COMPUTING**
  Immersed Computing® solves density requirements and allows for liquid cooling on a much larger scale than currently usual.
- **PRIVATE DATACENTRES**
  Private / hybrid cloud operators who own the entire value chain experience the same benefits as cloud operators.
- **CLOUD OPTIMISED COLO DATACENTRES**
  Colocation datacentres which focus on facilitating Cloud providers. These can facilitate the growth of cloud systems by offering Immersed Computing® as a dedicated housing environment.
- **EDGE COMPUTING**
  The limited infrastructure requirements of Immersed Computing® open up possibilities for new solutions within rural areas.
- **MOBILE SOLUTIONS**
  The Plug-and-play solutions and minimal infrastructure requirements make applications possible in remote geographical areas where availability of energy supply and cooling is problematic.

4. ASPERITAS SOLUTIONS

Asperitas has developed the solutions to address all aspects of Immersed Computing®. This development is based on a central product, the AIC24, which is the basic immersion system, supplemented with the tooling required for operating the system. The most important elements of the tooling are the service trolley and the maintenance supplies for working with Immersed IT. Finally, Asperitas provides training which addresses the new elements around operating and maintaining Immersed Computing® as effectively as possible.

AIC24
The AIC is a fully self-contained, plug and play, modular unit with a footprint of 600x1200 mm. The AIC24 can contain up to 48 servers (twin configuration). Any type of server mainboard can be supported up to a maximum size of E-ATX for a 1U chassis.

SERVICE TROLLEY
The ESD protected service trolley has been developed and optimised for Immersed Computing® with the AIC24 modules. It addresses all maintenance: hoisting cassettes, servicing and transporting IT, cleaning up spills and polishing oil.

TOOLING
All the tooling required for the maintenance with oil covered IT is developed by Asperitas, including ESD leak trays, spill kits, oil supplies and more.

TRAINING
The following trainings are available at the Asperitas Technology Center:

- Operating AIC24 and the service trolley
- Designing IT for Immersed Computing®
- Risk management with Immersed Computing®

5. BEST PRACTICES

Best practices in datacentre planning, processes and IT and platform design, help get the maximum results out of Immersed Computing®.*

5.1 DATACENTRE PLANNING

CONSIDERING MAXIMUM HEAT REUSE when chosing the geographical location. Reusing the energy used in a datacentre becomes viable with Immersed Computing® because the heat is already captured in water, an easily transportable medium. This heat can be used in a completely different industry to replace energy used to heat something. A datacentre built in the proximity of such an industry can achieve the maximum reuse of energy.

USING THE BEST TECHNOLOGY for the best purpose is made easy with Immersed Computing®. Its flexibility enables a hybrid approach to any cloud environment where the best of all worlds can be applied. The simplicity and scalability of Immersed Computing® allows it to be applied in harmony with any other (existing) environment.

OPTIMISING TEMPERATURES for water loops is made possible by aligning different technologies appropriately. By setting up different technologies in series an air cooled datacentre can build up the temperature in the water loop: water cooled HVAC systems require the lowest temperatures, then a specific liquid IT environment like rear door cooling, followed by an Immersed Computing® environment after which a Direct Liquid Cooled environment adds the last energy to the loop. This gives high temperature differences on a cooling machine which makes the cooling process more efficient, because a higher percentage of energy can be rejected without compression cooling.

DESIGNATED LIQUID MAINTENANCE AREAS ensure clean and safe (large scale) maintenance of liquid cooled IT. A maintenance room for liquid is easily set up. Such a room is similar to common IT maintenance areas (ESD protected), but with a few fundamental differences like sufficient tooling for liquid management: Leak trays, consumables (oil cloths and gloves), ESD lab coats and a drain.

5.2 LIQUID PROCESSES

THERE ARE SPECIFIC SAFETY PROTOCOLS for liquid systems, like a spill management process and oil specified fire safety systems (not water based, as water only spreads oil). Fire in an oil cooled datacentre is however quite unlikely, as the entire mass needs to be heated to well over 300°C (depending on oil type) before it can ever catch fire.

DOCUMENTED PROCEDURES AND INVENTORY of dielectric liquid are part of the safety protocols. Each type of liquid comes with a Material Safety Data Sheet (MSDS) and a Technical Data Sheet (TDS). The MSDS contains all necessary safety related information like classification and recommended safety procedures including fire management. The TDS contains all technical data like ingredients viscosity, density, pour- and flashpoint. These documents should be available to anyone with access to a facility where liquid is used and easily and quickly reachable for emergency services.

* In addition to the European Code of Conduct for Data Centres - Best practice guidelines

5.3 IT AND PLATFORM DESIGN

OPTIMISING IT SPECIFICATIONS ensures the full benefits of Immersed Computing®. Where an air cooled rack is optimally utilised with high numbers of relatively low powered servers, Immersed Computing® allows for the same server density in quantity, but with much higher powered specifications. A single Asperitas module can facilitate about 22 kW of IT power (comparable to 35 kW of air cooled IT spread over 7 racks). Each server cassette can facilitate about 900W of pure IT power. This can be achieved with higher powered CPU's (TPD 160+), which greatly reduces the total amount of servers needed.

IT UTILISATION OF 70% (depending on CPU architecture) is within reach with Immersed Computing®. It provides the highest effectiveness for any cloud based platform. It creates a good continuous load on IT while delivering a high return on investment. The continuous load also provides a relatively constant amount of heat and the components run at optimal energy efficiency.

THE FULL LIFECYCLE of the entire environment has been considered. Asperitas' solutions can be easily recycled and used oil gets a new purpose after it is removed. The IT is fully cleaned and refurbished or recycled. All materials used inside the systems can be scrapped and recycled. Suitable components should be refurbished before recycling, unless they contain protected information.

6. ASPERITAS COMPANY

ASPERITAS IS A CLEAN-TECH COMPANY focused on greening the datacentre industry by introducing Immersed Computing®.

SINCE 2014 Asperitas has worked on validating and developing Immersed Computing® as a unique approach to the datacentre industry. Building on existing liquid immersion cooling technologies by adding integration of power and network components, improving cooling physics with a strong focus on design and engineering for usability, Asperitas has come up with a complete and integrated solution which can be effectively utilised in most, if not all situations.

THE ASPERITAS DEVELOPMENT PARTNERS include University of Leeds, Aircraft Development and Systems Engineering (ADSE), Super Micro, Total, Schleifenbauer and Brink Industrial. Asperitas is furthermore recognised and supported by the Netherlands Enterprise Agency as a promising new Cleantech company.

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