Liquid Cooling Requirements White Paper

液冷需求白皮书

FOREWARD
前言

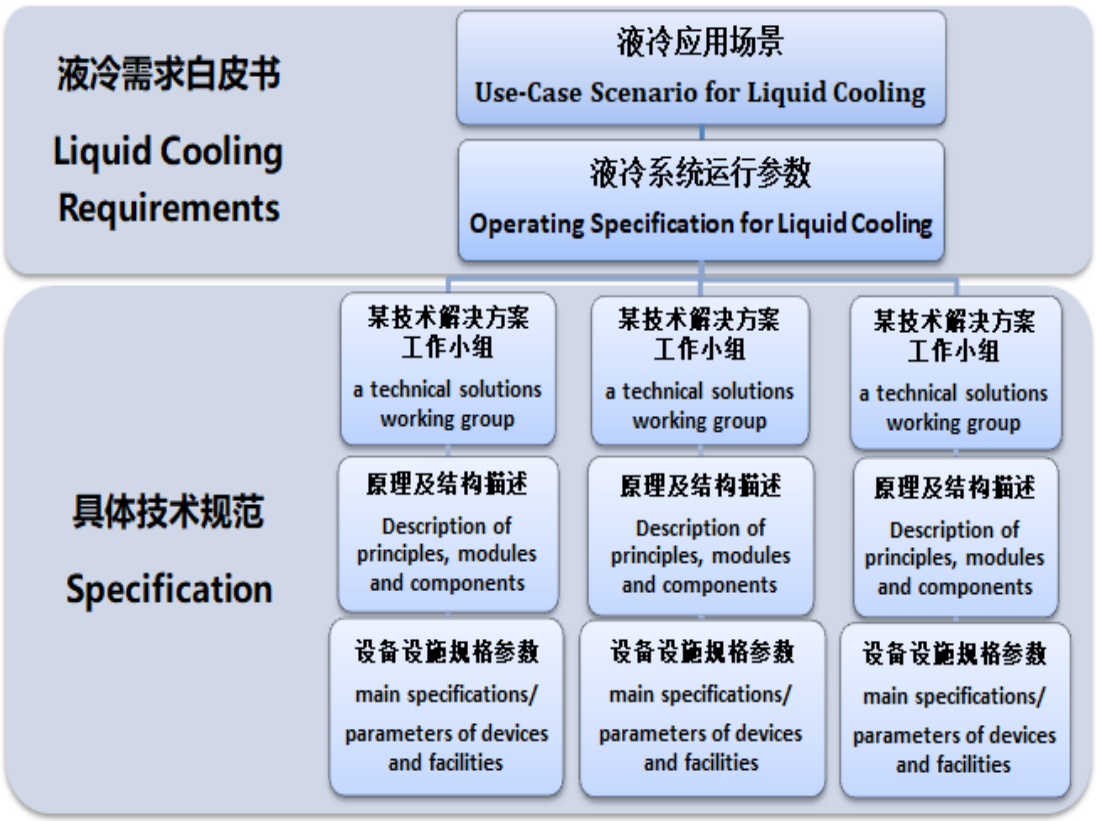
In China and the United States, data centers are growing in number, size, and intensity, and consume a lot of energy. China and the United States are both committed to improve energy efficiency, but have also developed inconsistent standards, specifications, and testing protocols. In order to promote the influential Internet and IT companies in China and the United States to exchange and coordinate data center standards and specifications, to give manufacturers clear market signals, thereby promoting technology compatibility and cost reduction, achieving high efficiency and low emission of data centers. Initiated by Lawrence Berkeley National Laboratory(LBNL), LBNL and China Institute of Electronics(CIE) jointly launched the U.S.- China Green Data Center Bilateral Working Group together with Google, Facebook, Microsoft, Intel，Baidu, Tencent, Alibaba, and JD Cloud. The working group is supported by the U.S. Department of Energy and the Chinese Ministry of Industry and Information Technology.

在中国和美国，数据中心的数量、规模、强度均不断增长，消耗大量的能源。中国和美国均致力于提高能源利用效率，但同时也形成了不一致的标准、规格和测试协议。为推动中美两国有影响力的互

联网和 IT 企业共同交流、协调数据中心的标准、规范，给制造商明确的市场信号，从而促进技术的兼容和成本的下降，实现数据中心的高效率和低排放。经美国劳伦斯伯克利国家实验室倡议，劳伦斯伯克利国家实验室(LBNL)会同中国电子学会（CIE）联合百度（Baidu）、阿里巴巴（Alibaba）、腾讯（Tencent）、京东云（JD Cloud）、Facebook、谷歌（Google）、微软（Microsoft）、Intel 等共同发起成立中美绿色数据中心联合工作组。该项工作得到了美国能源部和中国工业和信息化部的支持。

Liquid cooling is the current focus of the bilateral working group. Given the development of each liquid cooling technology scheme, it is not yet possible to prove that the solution is optimal. The technical solutions preferred by the members of the working groups are different. The methods of the working group have been continuously evolved. The final determined method is: to approach from the user's perspective and in accordance with the business development plan, to explore the need for liquid cooling. Lastly, the formation and joint release of the "Liquid Cooling Requirements White Paper." In the later stage, according to the technical solutions of their respective interests, the Internet companies interested in the program will jointly work with the technical solution provider to form a working group to discuss the specific technical standards around the “Liquid Cooling Requirements White Paper”. The specific work framework is as follows.

液体冷却是联合工作组目前的工作重点。鉴于各个液冷技术方案均处于发展阶段，尚无法证明那种方案是最优解。且各工作组成员倾向的技术方案有所不同。工作组的工作方法经过不断演化，最终确定的是：前期从用户的角度出发，根据业务发展规划，探讨对液体冷却的需求，形成并联合发布“液冷需求白皮书”。后期根据各自所感兴趣的技术解决方案，由对该方案感兴趣的互联网企业联合该技术解决方案提供厂商组成工作小组，围绕“液冷需求白皮书”探讨具体的技术标准。具体工作框图如下。



The content in the white paper was reviewed, revised and confirmed by the bilateral working group members and now it will be released publicly.

经过全体联合工作组成员的讨论、修改、确认，联合发布本液冷需求白皮书。

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Part I. Use-Case Scenario for Liquid Cooling
第一部分：液冷应用场景

It is expected that over time the ever increasing data volume will demand processing chips with higher power density; faster data transmission, and easiness-to-use requirements would drive the adoption of machines with increasingly higher energy density. Naturally it will be more challenging for heat management in data centers.

我们认为未来的发展趋势是，对数据处理能力需求的快速增长将带来芯片功率密度的不断增加，数据传输速度的提高及使用的便利性要求将带来设备集成度的不断提高。由此会带来更高的散热需求。

As the heat load increases, conventional air cooling methods are under increasing pressure. Data centers need more powerful fans with larger diameter, larger space to allow heat dissipation, more effort to maintain acceptable operating environment, etc. All these will result in

high air noise, thermal impact to the environment, and will be translated into increased CAPEX and OPEX.

为此风冷形式需要配备更高转速及更大直径的风扇、更大体积的散热通道，以及对运行环境要求的日渐提高。由此带来巨大的风噪声、对环境的热影响，以及建设成本和运行成本的上升。

On the contrary, liquid cooling technology is able to handle higher heat load with minimal noise and lower operating cost. It also gives more leeway to embrace the coming technology advancements for IT equipment, and allows for heat recovery and reuse so as to achieve higher energy efficiency and lower environmental impact. But in some cases liquid cooling comes with higher CAPX investment, which might not be an attractive solution for lower power density scenarios.

液冷形式可以提供更高的散热能力，极低的运行噪音，较低的运行成本。同时可以给 IT 设备的技术进步提供更大的发展空间，并可以进行热量回收及综合利用以提高能源利用效率及减少对环境的影响。但某些情况下建设成本相对较高，对于低功率密度的应用场景不具有足够的吸引力。

In light of the above considerations, we believe that once heat load per standard unit in the 19 inch rack reaches around 500W, liquid cooling would become popular. Liquid cooling would become a widely accepted cooling method with considerable market share. And once heat

load per standard unit equipment reaches around 1000W, liquid cooling will become the primary cooling method or even the sole method.

基于以上考虑，我们认为，当 19 英寸机柜内平均每标准 UNIT 功率达到 500W 左右时，将会出现液冷和风冷并存的局面。也就是说，液冷会成为一种能够被广泛接受并占有相当份额的散热形式。当机柜内平均每标准UNIT功率达到1000W左右时，液冷将成为主流的散热形式，甚至是唯一的散热形式。

(**Note 1:** Specific consensus is yet to be reached on the evolutionary path for the relation between a liquid cooling application and average per standard UNIT power in single IT equipment, and/or the evolutionary path for the relation with single chip power density. As liquid cooling is to be used in such cases, relative content in this Whitepaper can be used as reference.)

（**补充说明 1：**对于液冷应用与单个 IT 设备的平均每标准 UNIT 功率之间关系演进路径，以及与单芯片功率密度之间关系演进路径，我们尚未达成明确的共识。如同样采取液冷方式，可以参考本白皮书内相关内容。）

(**Note 2:** Standard UNIT is a unit of thickness for servers. It is put forward by EIA and has been widely adopted by the industry. It can be abbreviated in short as U, where 1U=4.445cm.)

（**补充说明 2：**标准 UNIT 即美国电子工业协会（EIA）所提出并为业界所通用的服务器的厚度单位，缩写为 U，1U=4.445cm。）

Therefore we believe it is necessary for the data center designers and cooling solution providers to give enough attention to this trend, and to involve more organizations to the development of liquid cooling technologies.

在这种情况下，我们认为，有必要引起数据中心设计方及散热方案提供方对此种趋势的足够重视，并吸引更多机构参与到液冷技术的开发中来。同时，需要努力推动液冷散热方案的通用化从而降低采购及应用成本。基于以上考虑，我们联合发布本液冷需求白皮书，作为后续发展液冷散热技术的指引。

As liquid cooling technologies continue to grow, the first step for a data center operator is to define a liquid cooling application scenario in the data center, and then identify concerns and operating specification requirements for the cooling system. The cooling solution providers can develop designs based on those specific requirements.

为了更好地提供指引，同时考虑到液冷散热技术仍然在不断发展，作为数据中心的用户，我们将首先设定一个液冷散热型数据中心的应用场景，然后以数据中心用户角度向液冷散热型数据中心的设计总包方提出基于该场景下的对于液冷系统的关注点和相关的运行参数要求。散热技术提供方也可以围绕该要求进行相应的开发。

We picture the use case scenario to be a general-purpose data center，engaged in multiple regular services such as cloud computing, video processing, search engine, etc., whose heat load on a per standard

unit equipment in a 19 inch rack is no less than 500W, or might be as high as 1000W or more, under continues and stable operation. The following contents in this whitepaper are operating specifications of a cooling system under this defined use case.

我们设定的应用场景是：通用类型的、可进行云计算、视频处理、搜索等多种常规业务的数据中心，19 英寸机柜内平均每标准 UNIT 连续稳定运行功率应不低于 500W，并希望能够达到 1000W 以上。本白皮书后续的内容即为该应用场景下液冷系统需要满足的运行参数要求。

Part II. Operating Specification for Liquid Cooling System

第二部分：液冷系统运行参数

A. General Specifications

一、 通用要求

1. Overall Requirements

1、散热总需求

No. 序号	Item 指标	Description/Reference Value 参数值
1.1	Cooling Capacity 散热能力	1. The minimum rack level cooling capacity is 500W per standard unit in 19 inch rack under stable operation; the supported cooling capacity can be 1000W or above. 2. For certain data center IT equipment with special cooling needs, the cooling capacity required by equipment vendors should be satisfied. 3. For certain IT equipment chip with higher power densities whose vendor recommends liquid cooling, the cooling capacity required by the vendors should be satisfied. 1、可提供19英寸机柜内平均每标准UNIT功率不低于 500W 的连续稳定散热能力，甚至说达到1000W 以上。 2、对于某些数据中心内应用到的、具有特定散热

No. 序号	Item 指标	Description/Reference Value 参数值
		需求的 IT 设备，需提供满足该设备供应商散热要求的散热能力。 3、对于某些 IT 设备应用到的、具有较高功率密度，且芯片供应商建议采取液冷方式的芯片，需提供满足芯片供应商散热要求的散热能力。
1.2	Operating Environment for IT Equipment IT设备运行环境条件	1. No intervention is required on ambient temperature or humidity, unless the data center is located at a place with special climatic conditions, and/or intervention is necessary to ensure personal safety or to meet special required operating conditions for the cooling system. 2. Dust removal and/or static proof is required. 1、除因数据中心所在地气候条件特殊，为保障运行维护人员人身安全或液冷系统运行所必需条件，人为对 IT 设备运行环境的温度、湿度进行必要调整外，IT 设备运行环境的温度、湿度可无需进行人为调整。 2、需进行除尘及防静电处理。

2. Specifications for Infrastructure

2、基础设施要求

No. 序号	Item 指标	Description/Reference Value 参数值
2.1	Rack Width 机架宽度	Minimum 600mm. In case wider rack is needed, the rack width should be increased by 100mm. 最小 600mm，如果有必要增加机架宽度，需要按照 100mm 的间隔增加。
2.2	Piping 液体管路	1. The liquid piping design in a data center should be consistent and based on one specification. 2. Due considerations should be made on system security and serviceability, with sufficient valves and pumps in place. 3. Due considerations should be made on coolant refill and replacement. 1、同一数据中心内液体管路的设计需遵循同一设计规范。 2、应充分考虑系统运行安全性及可维护性，设置足够的阀门与泵。 3、应充分考虑冷却液补充和更换的需求。
2.3	Civil Engineering 土建基础	Due considerations should be made on: 1. The weight of the cooling system. 2. Possible vibration during operation of the liquid cooling system. 3. Coolant leakage, and its potential damages to building structures and potential personal injuries.

No. 序号	Item 指标	Description/Reference Value 参数值
		1、应充分考虑液冷系统的重量。 2、应充分考虑液冷系统运行时可能产生的震动。 3、应充分考虑冷却液泄漏可能造成的对建筑结构的损害以及对数据中心运行维护人员的人身伤害。
2.4	Coolant 冷却液	1. The coolant used should be non-hazardous to humans, environmentally friendly, fire-safe; and its properties such as toxicity/corrosiveness/oxidizability/volatility/Greenhouse effect/flammability should be compliant with pertinent health and safety laws and regulations of the country where the cooling system is operated. 2. The coolant used should have stable chemical and physical properties throughout service life. Or changes in chemical and physical properties have no effect on cooling applications. 3. Due consideration is made on convenience of operation and CAPEX +OPEX. 4. It can be recycled and disposed safely. 1、毒性、腐蚀性、氧化性、挥发性、温室效应、可燃性等必须满足数据中心所在国法律法规对人身安全、环境安全、消防安全等方面的对应要求，并希望能够达到国际公认的所对应的最严苛的标准。 2、在寿命期内保持化学及物理性质稳定，或者化学与物理性质的变化对其冷却应用不产生影

No. 序号	Item 指标	Description/Reference Value 参数值
		响。 3、应充分考虑运行及维护的便利性要求，充分考虑采购及使用成本。 4、可安全回收并进行无害化处理。
2.5	Other Materials 其他材料集	Requirements are the same as the coolant. In addition, other materials should meet the followings: 1. Due consideration is made on easy disassembly. 2. Recycled materials and recyclable materials are encouraged. 与对冷却液要求相同。除此之外： 1、应充分考虑拆解的便利性。 2、鼓励应用再生材料及可回收材料。
2.6	Controls and Telemetry 控制和遥测设施	1. At multiple subsystem level, monitoring of operating status is supported; Centralized display and control interface（dashboard）is supported. 2. It supports remote control of valves and pumps at critical nodes; meanwhile, manual start/stop function remains enabled. 3. Distributed displays and control interfaces, voice communications system on each subsystem should be adequately provided, according to operation and maintenance needs.

No. 序号	Item 指标	Description/Reference Value 参数值
		4. Due considerations are to be made on the safety, reliability and fool-proof design for the control and telemetry system. 5. Due considerations are to be made on automated control functions. 1、需具备对各级液冷分系统的运行情况进行监控及报警能力并具有集中显示及控制界面。 2、需要具备对各关键节点的阀门与泵的远程控制能力，同时保留其手动启停功能。 3、应结合运行维护需求针对各分系统设置足够的分布式显示及控制界面以及语音通信系统。 4、应对控制和遥测系统自身的运行安全性、可靠性以及人员误操作的可能性予以充分考虑。 5、应充分考虑自动控制功能。
2.7	Disaster Recovery 灾备设施	1. Analysis reporting on liquid cooling system failures is required; Contingency plan is required. 2. Critical component redundancy or backup equipment is required; 3. Sufficient spare parts is required, particularly consumable ones 1、需提供液冷系统故障模式分析报告及应急方案。 2、关键部件应有性能冗余或设备备份。 3、易损件应提供充足的备件。

3. Specification for Operation & Maintenance

3、运行与维护要求

No. 序号	Item 指标	Description/Reference Value 参数值
3.1	System Level Service Life 液冷全系统使用寿命	≥10 years（ For the independent liquid cooling unit coming with of the IT equipment, the service life can be consistent with the service life of the IT equipment .） 不小于 10 年（对于属于 IT 设备自身附属设施的液冷单元，其使用寿命可与 IT 设备使用寿命一致）
3.2	Reliability 可靠性	1. Cooling system as a whole should never crash under any circumstance. 2. Single point of failure in the liquid cooling system and/or component failure, including coolant leakage, should not impair normal operation of the data center as a whole. 1、 任何情况下都不能出现液冷系统全系统功能崩溃状况。 2、 液冷系统内软件系统的单点故障或硬件系统的部件故障，包括冷却液泄漏均不能影响数据中心整体正常运行。
3.3	Serviceability 可维护性	1. On-site repair or replacement with simple tools is supported; there is enough room for operators; during service period，the rest of the cooling system should be able to continue functioning, and personal safety is ensured.

No. 序号	Item 指标	Description/Reference Value 参数值
		2. There should be pre-verified standard procedures in place for regular maintenance and service; due consideration is given on possible human error during maintenance and repair. 3. The normal operation of the data center as a whole should not be affected by maintenance and repair on the liquid cooling system. 4. Due consideration is made on easy refill and replace of coolant. The cooling system stays functioning during coolant refill. 1、应可利用简单工具进行现场维修或更换，具有充分的操作空间，且维修或更换时对其他正常运行部件无损害，对维修人员人身安全无伤害。 2、应具有经过验证的例行维护检修标准程序，且充分考虑维护检修人员误操作的可能性。 3、液冷系统维护维修时不得影响数据中心整体正常运行。 4、应充分考虑液冷系统补充或更换冷却液的便利性，且补充或更换时不得影响数据中心整体正常运行。

4. Others

4、其他

No. 序号	Item 指标	Description/Reference Value 参数值
4.1	Certifications and regulatory compliance 认证和法规遵从性	At the very least the system should meet safety and other regulations of the country where it is operated. 最低要求满足数据中心所在国安全监察要求
4.2	Heat Recovery and Reuse (Optional) 热量回收及再利用（可选项）	Due consideration is recommended on recovering and reusing the heat from operating IT equipment. 建议对IT设备运行所散发热量进行回收及再利用予以充分考虑。

B. General Principles for Use of Equipment

二、 设备使用指引

1. It is expected that the liquid piping connectors are compliant with international standards or industrial standards.

2. It is expected that products adopted are modularized and support plug-and-play.

1、希望液体管路连接接口器件采用国际标准接口或行业通用接口。

2、希望采用模块化的可即插即用的产品。

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