ESSB INDUSTRY STANDARD

ESSB 1:xxxx

ICS: 23.020.10

Specifications for Ariel buffer tank

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Enlighted Solutions Sdn Bhd (ESSB)

ESSB has over two decades of experience in the design and supply of high-performance buffer tanks and thermal management solutions for industrial and commercial applications. Throughout this period, ESSB has established a strong reputation for technical reliability, engineering excellence, and consistent product quality.

In response to the rapid growth of digital infrastructure, ESSB has in recent years expanded its focus to serve the data centre sector. The increasing demand for reliable, energy-efficient cooling systems has highlighted the critical role of effective thermal management in ensuring operational continuity, performance optimisation, and protection of mission-critical assets.

ESSB's buffer tank solutions are custom-designed to support stable temperature regulation, enhance system durability, and improve overall energy efficiency. These solutions are developed to meet the stringent operational requirements of modern data centres, including applications involving liquid cooling, hydronic systems, thermal storage, and heat recovery.

Supported by a team of skilled engineers and a strong commitment to innovation and quality, ESSB provides comprehensive end-to-end services encompassing consultation, system design, installation, and maintenance. This integrated approach ensures that solutions are tailored to the specific needs of each application while aligning with sustainability and efficiency objectives.

ESSB has diversified from building construction into delivering sales, trading, and energy solutions that improve air-conditioning efficiency.

ESSB STANDARD

ESSB Standard is developed according to the SIRIM standardisation procedures with the participation of various stakeholders from ministry/agency, operator, industry players and higher-learning institutions. The standards are developed through consensus by committees, which consist of experts in the subject matter.

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Foreword

This ESSB Standard was developed by the Project Committee on Ariel Buffer Tank established by ESSB and SIRIM Berhad.

This standard was developed with the following objectives:

a) to specify requirements for Ariel buffer tank for manufacturing and optional performance testing service;

b) to be used as a guidance by users and manufacturers; and

c) to be used as a basis for product certification.

This standard will be subjected to review to reflect current needs and conditions. Users and other interested parties may submit comments on the contents of this standard for consideration in future versions.

Compliance with this standard does not by itself grant immunity from legal obligations.

Specifications for Ariel buffer tank

1. Scope

This standard specifies the design, installation, performance criteria, and associated testing and validation procedures for the Ariel buffer tank intended for use in critical cooling applications, including but not limited to data centres.

Where applicable, this standard also describes the functional interaction between the buffer tank and associated systems used to support its operation and performance evaluation.

2. Normative references

The following documents, in whole or in part, are normatively referenced in this standard and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ASME BPVC.VIII.1, *ASME Boiler and Pressure Vessel Code, Section VIII: Rules for Construction of Pressure Vessels, Division 1*

ASTM A516, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service*

BS EN 10224, *Non-alloy steel tubes and fittings for the conveyance of water and other aqueous liquids. Technical delivery conditions*

BS EN 10311, *Joints for the connection of steel tubes and fittings for the conveyance of water and other aqueous liquids*

JIS G3452, *Carbon steel pipes for ordinary piping*

MS 1919, *Ductile iron pipes, fittings, accessories and their joints for water pipelines - Requirements and test method*

MS 2286-2, *Plastics piping systems for hot and cold water installations - Polypropylene (PP) - Part 2: Pipes*

MS 2286-3, *Plastics piping systems for hot and cold water installations - Polypropylene (PP) - Part 3 : Fittings*

Registration of Engineers Act 1967

Occupational Safety and Health (Plant Requiring Certificate of Fitness) Regulations 2024

3. Terms and definitions

For the purposes of this standard, the following terms and definitions apply.

3.1 Authorised Inspecting Body (AIB)

Any entity listed in the First Schedule of *Occupational Safety and Health (Plant Requiring Certificate of Fitness) Regulations 2024*.

3.2 capacity

Gross volume of water (in litres or gallons) in the tank when filled completely.

3.3 manufacturer

Party that manufactures, fabricates or produces materials or products.

3.4 professional engineer

Person registered under subsection 10 (2) of *Registration of Engineers Act 1967*.

3.5 tank

A reservoir used for water storage.

3.6 FOM (Figure of Merit)

A parameter or performance indicator used to evaluate the effectiveness or efficiency of the buffer tank in its application.

3.7 Computational Fluid Dynamics (CFD)

A branch of fluid mechanics that uses numerical analysis and high-powered computers to solve and analyse problems involving fluid flow. It allows building and testing buffer tanks in a virtual environment with incredible detail.

4. General requirements

4.1 The product shall comply with all applicable acts, regulations, and statutory requirements, including but not limited to testing, certification, labelling, and importation requirements, as enforced in Malaysia and, where applicable, in the country of export.

4.2 For the Ariel buffer tank designed as a vessel containing water under pressure, with a design pressure not exceeding 300 PSIG (20.68 bar) and a design temperature not exceeding 99 °C, the tank shall be subjected to non-application as per specified in the Second Schedule of the *Occupational Safety and Health (Plant Requiring Certificate of Fitness) Regulations 2024.*

4.3 The requirement for any Department of Occupational Safety and Health Malaysia (DOSH) approval, registration, certification, or notification, if applicable, may be determined by the end user, owner, or installer based on the actual application, installation configuration, operating conditions, and interpretation by the relevant authority.

5. Capacity

Capacity of the water storage shall be at least 2 m^3.

In the event that any larger capacity tank size is required (> 2 m^3), the selection of the tank size shall be subject to agreement between the purchaser and the tank manufacturer.

NOTE.   1 m^3 = 1 000 L = 220 gallons

6. Materials

6.1   General

All materials shall be new and shall comply with all of the requirements in this standard.

Steel materials shall have mill certificates.

6.2   Foundation

The suitability of the foundation material used to support the tank when filled to full capacity and the reinforced concrete shall be determined and approved by a professional engineer.

6.3   Buffer tank body

Material for buffer tank body shall be made of carbon steel S275JR as per BS EN 10025, SA516MGR70 as per ASTM A516 or stainless steel AISI304.

6.4   Pipes and fittings for fluid conductors

6.4.1   Materials for pipes and fittings (including inlet, outlet and overflow pipes and fittings) for fluid conductors shall conform to Table 1.

6.4.2 Other types of pipes may be specified, provided they conform to recognised national standards or equivalent standards. Unless otherwise specified, joints may be either screwed or flanged.

Table 1. Pipe and fitting materials for fluid conductors

Material	Standard
Ductile iron	MS 1919
Polypropylene (PP)	MS 2286-2, MS 2286-3
Carbon steel	BS EN 10224, BS EN 1031, JIS G3452
Stainless steel	AISI304

6.5 Coatings

Welded joints shall be prepared in accordance with ASME standard on weld clean-up procedures. In addition, representative samples of machine and manual welds shall be provided in the "as-welded" condition, conforming to the supplier's standard practices.

All welds shall be free from slag, spatter, rust, loose scale, oil, and other contaminants prior to coating application. Welded joints shall be painted only after completion of welding activities, successful pressure testing, and formal acceptance.

Prior to coating application, all surfaces shall be cleaned to a minimum of SA 2.5 finish in accordance with ISO 8501-1, ensuring removal of mill scale, rust, and other foreign matter.

Coating shall be applied only when ambient temperature, relative humidity, and surface cleanliness are within the limits specified by the coating manufacturer. Application shall be suspended during adverse conditions that may compromise coating integrity.

For external surfaces (Under Insulation), the material shall be Red Oxide Primer with a minimum dry film thickness (DFT) of 50 μm, or an equivalent approved product.

For internal surfaces, the material shall be Epoxy Primer with a minimum DFT of 75 μm, or Cathodic Protection Epoxy Enamel with a minimum DFT of 125 μm, or equivalent.

6.6 Insulation

The insulation system shall be designed and installed to meet the specified thermal performance criteria, ensuring not more than 0.5 °C heat gain under ambient conditions of 45 °C.

The insulation design for tanks shall incorporate the following materials, polyurethane foam, nitrile rubber, or other closed-cell foam types. The minimum density shall be 40 kg/m³ – 45 kg/m³. The thermal conductivity shall not exceed 0.035 W/m °C at 20 °C, in accordance with ISO 8302 or equivalent standards.

7. Design

7.1 General design

7.1.1 The buffer tank shall be designed to have sufficient strength to withstand expected loads. The buffer tank shall be designed based on ASME Section VIII and shall meet the requirements as Table 2 below.

Table 2. Buffer tank design requirements

Parameter	Requirement
Design pressure	6.0 bar – 16.0 bar
Hydrostatic test pressure	1.3 times design pressure
Welding joint efficiency	≥ 85 %

7.1.2 Hydrostatic test

Upon completion of fabrication, the water tank shall be filled with water and pressurised to the required hydrostatic test pressure in accordance with ASME Boiler and Pressure Vessel Code (BPVC), Section VIII, Division 1. The test pressure shall be maintained at ambient temperature for a minimum duration of 30 min. During this period, there shall be no pressure drop and no visible signs of leakage.

The hydrostatic test shall be witnessed by an AIB.

7.1.3 Wind load

The wind load shall be determined by a professional engineer taking into consideration meteorological conditions of the location where the tank will be installed, and in accordance with the recognised national or international standards.

7.2 Foundation

The foundation constructed of suitable non-corrodible material or treated with corrosion resistant material supporting the entire tank (including the base) shall be designed and approved by a professional engineer.

7.3 Diffusers (internal flow distributors)

The diffuser shall be designed and constructed in accordance with the ASHRAE Handbook, Latest Edition, Chapter 51 – Thermal storage.

7.3.1 Performance criteria

The Froude number shall not exceed 1.0, ensuring stable flow conditions and minimising turbulence. The total hydraulic head loss from the tank inlet flange to the tank outlet flange shall not exceed 3.5 psi at the maximum design flow rate. The FOM shall be minimum 80 %.

7.3.2 Structural integrity and pressure transients

The diffuser structure shall be designed to accommodate severe pressure transients, including water hammer effects resulting from rapid valve closure or isolation. Accordingly, the diffuser shall be of a self-supported type, capable of maintaining structural stability under such dynamic conditions.

7.3.3 Air release considerations

The diffuser system shall incorporate design features that allow for the release of trapped air from the diffuser piping. This shall be achieved without compromising diffuser performance or flow uniformity.

7.3.4 Computational Fluid Dynamics (CFD) Validation

The performance of the diffuser design shall be simulated using complex physics modelling includes natural convection governed by Boussinesq's approximation for temperature-dependent density at valid temperature range or full compressible flow. The number of elements starts with at least 5 million and above (this would depend on the turbulence level, the strength of the gradient flow, the complexity of the construction and etc). The performance simulation uses coupling between fluid flow and fluid heat transfer simultaneously. Speeding up computation is required with unlimited parallel cores and GPU accelerator.

CFD shall be performed using a commercially licensed, internationally recognised CFD platform capable of transient, buoyancy-driven thermal modelling.

Simulation shall include 3D transient modelling, full design flowrate, design ΔT, charging/discharging cycles, and chiller trip scenario.

Vendor shall provide mesh independence study, turbulence model description, boundary conditions, velocity contours, temperature contours, thermocline analysis, and predicted ride-through duration.

The diffuser design shall be deemed acceptable when all of the following criteria are met:

a) outlet temperature deviation is ≤ 1.5 °C;

b) diffuser outlet velocity is ≤ 0.6 m/s;

c) thermocline thickness is ≤ 25 % of the tank height; and

d) thermal hold time meets or exceeds the specified duration.

8. Dimensions

The diameter, shell height and capacity shall be declared and shall be in accordance with the manufacturer's specification.

9. Erection

9.1 General

The tank shall be erected according to instructions provided with the tank. Instructions shall include, but not limited to, the following:

a) details on bolting;

b) coating repair procedures; and

c) assembly procedures.

9.2 Bolting

All bolts, nuts and washers shall be located and installed in accordance with the erection instructions.

9.3 Coatings

Coatings should be in accordance with manufacturer's specification, if applicable. The coatings should be visually inspected and any damage to the factory-applied coatings should be repaired in accordance with the erection instructions.

10. On-site installation

The on-site installation of the tank shall comply with the manufacturer's procedures.

11. Tank accessories

11.1 Opening for pipe connections

11.1.1 Appropriately positioned openings shall be provided to accommodate connections for inlet, outlet, overflow, and drainage piping in accordance with the system design requirements.

11.1.2 One (1) 600 mm diameter access manhole shall be provided on the tank shell with minimum one (1) 600 mm diameter for inspection and maintenance access. All access openings shall be equipped with flanged and gasketed blank-off plates, complete with Davit arm assemblies to facilitate safe and efficient handling.

11.1.3 Piping connections

The piping connections shall be provided as follows:

a) One (1) chilled water supply inlet/outlet connection, with a diameter of 250 mm, 300 mm, or 350 mm, or as per design specifications.

b) Four (4) nozzles located at the upper head of the tank for quick fill, contractor's installation for pressure gauge, pressure sensors and safety valve.

c) One (1) drain outlet positioned at the lowest point of the tank.

d) One (1) vent nozzle located at the apex of the tank to allow for air release.

e) The number of nozzles for temperature sensors as per ASHRAE requirements.

11.1.4 All piping connections shall be provided with ANSI Class 150 welded flanges, ensuring compatibility with standard piping systems and maintaining pressure integrity.

11.2 Ladders

11.2.1 Outside tank ladder

An exterior ladder shall be provided from the bottom of the shell, or other specified level, to the top of the shell or roof at the specified orientation. Provide exterior galvanized steel/paint coated mild steel with safe compliant vertical ladder and cage, temperature sensor insertion well nozzle welded to shell on the tank shell height as per ASHRAE recommendation.

11.3 Galvanic corrosion

Dissimilar metals (e.g. stainless steel, aluminium, etc.) installed inside the tank shall be electrically isolated from carbon steel tank components to which they are attached.

12. Marking

Every tank conforming to this standard shall be permanently and legibly marked with the following:

a)   name of the manufacturer;

b)   the number of this standard;

c)   the tank size or capacity;

d)   project number or serial number; and

e)   the date of manufacture.

13. Chiller Plant Optimisation System (CPOS)

13.1   General

The Ariel buffer tank may be integrated within a chilled water system ecosystem incorporating a Chiller Plant Optimisation System (CPOS). Within this ecosystem, the CPOS functions as a supervisory control and data management system that coordinates buffer tank operation with associated system components.

This clause specifies the functional role and minimum capabilities of a CPOS when used in conjunction with an Ariel buffer tank. This clause does not prescribe specific hardware, software platforms, control architectures, or proprietary solutions.

13.2   Role of CPOS in the buffer tank ecosystem

When integrated with an Ariel buffer tank, the CPOS shall support the following functions:

a)   coordination of buffer tank operating modes, including charging, circulation, and discharging;

b)   supervision of hydraulic and thermal conditions affecting buffer tank performance;

c)   monitoring, recording, and management of operational data relevant to buffer tank performance; and

d)   controlled transition between operating states to minimise thermal or hydraulic disturbances.

The CPOS shall be considered as an associated system and not part of the buffer tank product.

13.3 Operating modes involving the buffer tank

The CPOS shall support defined operating modes applicable to the buffer tank ecosystem. As a minimum, the following modes shall be supported, where applicable:

a) charging mode, to establish required thermal conditions within the buffer tank;

b) circulation mode, to stabilise temperature and hydraulic conditions within the buffer tank loop; and

c) discharging mode, to facilitate controlled release of stored thermal energy.

Operating parameters associated with each mode shall be determined by system design requirements and declared operating or test conditions.

13.4 Monitoring and data handling

The CPOS shall be capable of monitoring parameters relevant to buffer tank operation, which may include:

a) water temperature;

b) system pressure;

c) flow rate; and

d) time-based operational status.

Recorded data shall be suitable for trending, analysis, and reporting for operational review and performance evaluation.

Annex A provides descriptions of CPOS in data centres.

14. Inspection and testing

14.1 Authorised Inspecting Body (AIB) inspection

AIB inspection shall at a minimum consist of a visual inspection of the fabricating practices and operations to determine compliance with this standard.

14.1.1 Mill certificates

Copies of certified mill certificates shall be provided upon inspection.

14.2 Performance test

14.2.2 Discharging performance test

The discharging performance test is an optional verification test intended to evaluate the thermal discharge behaviour of the chilled water buffer tank under controlled flow and temperature conditions. The test may be conducted to demonstrate conformity with the design intent, declared performance specifications, and to validate Computational Fluid Dynamics (CFD) simulation results, where applicable.

The test shall be carried out using a test rig comprising a chilled water source, the buffer tank under test, a circulation pump, a flowmeter, inlet and outlet temperature sensors, and a data acquisition system. Measuring instruments shall be calibrated prior to testing.

The test shall be performed at a constant and predefined flow rate. Inlet and outlet water temperatures shall be continuously monitored and recorded throughout the discharging cycle. The test procedure shall be as follows:

a) The water contained in the buffer tank shall be pre-chilled to the specified initial temperature and maintained for a minimum duration of 15 minutes to achieve thermal stabilisation.

b) Hot water at a predetermined inlet temperature shall be introduced into the buffer tank and circulated for a duration of 5 minutes to initiate the discharging cycle.

c) The inlet water temperature, outlet water temperature, and flow rate shall be measured and recorded at 5-second intervals for the duration of the test.

d) Data logging shall be continuous. An alert shall be generated and recorded when the outlet water temperature exceeds the initial stabilised tank temperature by more than 1.3 °C.

Test data and observations shall be documented. A sample of the test report template is provided in Annex A for guidance.

Annex A
(informative)

Example of Chiller Plant Optimisation System (CPOS) in data centres

A.1 General

The Chiller Plant Optimisation System (CPOS) is a Programmable Logic Controller (PLC) with embedded software to control the entire chilled water system. This includes all chillers, chilled water pumps, condenser water pumps and cooling towers fans. Embedded software is in-built for variable primary flow control configuration, automation and optimisation. Contractors are to propose a suitable CPOS that meets the requirements set out in this section of the specifications. The CPOS is to have the following minimum features.

a) Capability for connection of a minimum of X chiller systems including associated pumps and cooling towers, of equal or unequal capacities. The CPOS shall be capable of supporting a minimum of two (2) chillers at initial implementation (day 1) and up to a final design configuration of X parallel chillers with common primary pumps operating under a variable primary flow arrangement (via two-way valves), including a differential pressure valve and bypass line. Where required, multiple CPOS programs may be implemented in stages to provide control for additional chillers.

b) The microprocessor-based CPOS automate a complete chilled water plant system as described in this annex. All application software that perform the required control functions shall be pre-tested and pre-configured prior to delivery.

c) The CPOS shall include inherent input and output capabilities, in addition to a high-level interface (HLI) via Modbus TCP/IP or RTU. The input and output capabilities shall, as a minimum, support standard HVAC sensor inputs (5k, 10k, 4 – 20 mA, and discrete signals), as well as analogue and digital outputs for controlling ancillary equipment necessary to meet the sequence of operation.

d) Equipped with fully redundant controller which is in a master-slave configuration and easily hot-swappable without requiring system or controls restart. In the event of CPOS failure, all equipment and systems shall continue to run based on the last known instruction. No shutdown of equipment on failure of CPOS shall be accepted. A further redundancy is for the CPOS to be bypassed via a 2-way switch to manually operate system in the event of a controller failure or malfunction. Similarly, all components shall assume their last known positions when this feature is activated.

e) Remotely accessible via IP for troubleshooting. Access shall be via firewall protection with full encryption. The CPOS should be easily configured and customised with no maintenance requirements. Software updates shall not pose any risk to the systems operations.

f) The controller shall include the capability to provide a local graphic interface for all operating values, alarms, etc., via a panel mounted Local Interface Device. The controller shall also be capable of interfacing with a portable PC for configuration or address setting, as well as for performing uploads and downloads, through a local interface connector.

A.2 Operating strategy and control program requirements

A.2.1 The operating strategy is to have the chiller plant completely managed by CPOS and is fully separated from the building management system. CPOS shall act as the primary control, and for monitoring and alarm reporting; the building management system shall be connected to CPOS via RS485 and shall act as the secondary monitoring to capture information signals and alarms from the CPOS.

The objectives of the CPOS in order of priority are:

a) to increase plant resiliency by ensuring that all duty and standby equipment is managed to allow for automated start and stop depending on operating parameters and equipment failure/availability. In addition, equipment runtime is to be managed to allow for equal wear and tear.

b) to increase plant efficiency through optimisation of equipment power consumption dependent on load to achieve best possible kW/RT figure without compromising resiliency.

A.2.2 The CPOS shall be equipped with the following general control features.

a) Program Enable/Disable:

The CPOS shall have the ability to be enabled manually by the operator through a point available on the graphic screen, or automatically via a network command, a Modbus/BACnet schedule or a schedule network input combined with OA temperature. The plant shall automatically disable itself only if a significant erroneous entry is made in the configuration risking plant operation or if there are no chillers available to control. An alarm shall be generated whenever the programme disables itself.

b) Lead/Lag Determination and Rotation:

The chiller start sequence shall be operator-selectable from the first chiller through the last chiller. The staging routine has the ability to control based upon the following parameters:

i) chilled water temperature only;

ii) chilled water temperature and/or load (tonnage);

iii) chilled water temperature and/or % capacity; and

iv) chilled water temperature and/or % KW.

The CPOS shall allow the operator to select any of the following rotation sequences:

i)   never rotate;

ii) weekly;

iii) monthly;

iv) manual rotation; and

v)   rotation by runtime.

A.2.3   At the system level, the CPOS shall include the ability to coordinate the operation of all plant room equipment. This includes the following features.

a) Operator override:

   i)   If the CPOS is operating under a time schedule, the operator shall have the ability to override the unoccupied mode by entering an override schedule through any of the interface devices.

   ii) If the time override option is initiated during an occupied period, the time schedule shall remain occupied for the duration of the time entered.

   iii) If the operator initiates an override during the unoccupied period, the time schedule shall be indexed to occupied for the duration of the value entered.

b) Chiller override: The CPOS shall include the ability for the operator to remove individual chiller(s) from the sequence and lock the chiller(s) 'on' or 'off' via the user interface.

c) Chiller faulting: A chiller shall be considered faulted if a fault status is reported to the CPOS by the chiller PIC. Chillers having a communication failure (after the operator adjustable start time value has expired) shall be left in their last commanded state. Chillers faulted for any other reason shall be commanded off. All faulted chillers shall be automatically replaced, if applicable, to maintain on-line capacity.

d) Start/stop delay timers: The CPOS shall include operator adjustable time delay values to prevent chillers from cycling due to short duration conditions and to allow plant pulldown conditions.

e) Stopping chillers: When the programme status is enabled but the CPOS has determined that cooling is no longer required, the CPOS shall command all chillers, including the lead chiller to stop in reverse of the starting order. The CPOS shall monitor each chiller status and generate an alarm if a chiller has failed to stop.

A.2.4   Capacity controls

The chillers shall be equipped with microprocessor-based sequence and capacity controllers arranged in parallel configuration with each chiller capable of being served by any chilled water pump through the ring configuration shown in the drawings.

The plant systems may be operated individually or in parallel with each other, in which case, the two or more chillers shall stabilise and operate at equal cooling capacity.

Each chiller shall be fitted with individual leaving water thermostat to maintain the leaving chilled water temperature within the accuracy of +- 0.5 °C of the specified leaving chilled water temperature. Proportional plus integral type thermostat control shall be provided.

One chiller shall be selected as the lead unit and the remaining chillers shall be called in succession. The automatic loading and unloading of the chiller shall be capable of selecting any one of the chillers as the lead machine.

Note that there will be a 15-minute time delay between the starting of one chiller and the next to allow the system to settle down before the need for the next chiller is established.

The control system for sequencing a parallel-configured chilled water plant shall include the following components and features:

a) Temperature sensors shall be provided at the chilled water supply header and return header, one (1) unit each.

b) A chilled water return flow transducer shall be provided, one (1) unit.

c) A chiller sequencing and capacity controller shall be provided.

A.2.5 Equipment control

The following equipment are to be fully connected and controlled by the CPOS:

a) All chillers, Pump VSD's and Cooling Tower VSD's.

b) All motorised valves in chiller plant.

c) All motorised bypass valves.

d) All power and flow transducers.

e) All temperature transmitters.

f) Bypass valve to thermal storage tanks.

A network of DDC Controllers can be used to act as the interface between CPOS and Field Equipment and configured in a way where failure of any particular equipment does not result in the non-availability of the particular system (E.g. Chiller 1, Cooling Tower 1, CHW Pump 1 and CDW Pump 1).

A.2.6 Field controller requirements

The building management system field controllers used for the chiller plant shall meet the following requirements:

a) Each system (e.g. Chiller 1, Cooling Tower 1, Chilled Water Pump 1 and Condenser Water Pump 1) plant control and monitoring shall be via a network of direct digital controllers.

b) Each of the DDC controller for each system is connected to the CPOS PLC Master and Slave System which acts as the 'brains' for the entire chilled water system.

c) Controllers shall be programmed to operate independently of the network functionality. In the event a DDC Controller has failed, it can be bypassed and the equipment can be operated manually.

d) Where specified Peer to Peer (P2P) or Master Slave controllers shall be provided to allow full backup of programming for critical applications such as chiller staging sequencing. Master Slave controllers shall automatically changeover on fault condition of the master controller.

e) All controllers shall be located within dedicated DDC panels as indicated in the drawings.

f) Provide controllers with sufficient analogue and digital inputs and outputs to achieve the specified functional intent. Provide controllers with 20 % spare points of each type. Size control panels to accommodate a 30 % increase in the overall number of points.

g) Each controller shall have battery back-up to support the real time clock and all volatile memory for a minimum of 72 hours.

h) Upon restoration of normal power, controllers shall automatically resume full operation without manual intervention.

i) Provide static, transient and short circuit protection on all inputs and outputs.

j) The failure of any one controller or the head-end shall not disrupt communication on the network.

k) The system shall have a response time of less than five (5) seconds for all changes of state or mode changes.

l) Gateways and interfaces shall be provided as necessary to allow BACnet or Modbus communications received from dedicated control and SCADA systems to be converted and distributed onto the BMS.

The contractor shall supply and install all necessary automatic controls for the efficient, safe and economic operation of the complete air conditioning and ventilation systems including all plants, system components and accessories, whether or not these items are specifically mentioned in these standard or as shown in the drawings. During routine maintenance or repair, all systems and components shall be 'fail-safe'. All automatic dampers and valves shall be of spring return type and so arranged to return to their normal operating positions on the resumption of power after failure or shutdown. The bypass valves shall modulate to ensure the minimum percentage flow through any operating chiller is maintained above 70 % of the design flow.

Further to increasing resiliency, the CPOS shall provide market leading efficiencies and should have the following minimum features:

i)   variable primary flow chilled water optimisation;

ii)   optimised chiller staging and sequencing;

iii)   chilled water temperature reset;

iv)   condenser water temperature reset;

v)   plant measurement and verification;

vi)   plant diagnostics and reporting; and

vii)   continuous commissioning and tuning.

The CPOS should be selected and configured to achieve maximum efficiency in Kw/RT. Any associated equipment such as power meters and temperature sensors that are not shown on the schematics but are required for optimal plant performance shall be provided by the mechanical contractor in conjunction with selection of a CPOS.

Annex B
(informative)

Sample of Chilled Water Buffer Tank Test Report

Project Summary

Description	Details
Project Name	
Client / Consultant	
Manufacturer / Factory	
Orientation / Capacity	
Dimension, mm (W x D x H)	
Empty Weight, kg	
Serial No.	
Test Location	
Test Date	

Results and Analysis

Parameter	Tested Result	Remarks (Pass/Fail)
Average Flowrate (l/s)		
Charging Duration (sec)		
Discharging Duration (sec)		
Max ΔT (°C)		
Average ΔT (°C)		
Pressure drop (kPa)		
Tank Volume (m³)		

Company	Name	Designation	Signature	Date

CONTENT

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1. Checklist

Checklist Item	Description	Requirement / Tolerance	Reference / Standard	Status (√ / Ⅹ / N/A)
1. Ambient Influence	Record ambient room temp during test. Best practice for test repeatability	<±2 °C Variation	ASHRAE Fundamentals Ch. 23	
2. Flow Rate Stability	Use calibrated sensors for temperature measurement	±5 % of rated flow	AHRI 550/590	
3. Sensor Location	Ensure temp sensors at inlet, outlet, and mid-tank for proper stratification monitoring	Every 0.6m to 0.8m	ASHRAE Guideline 36	
4. Holding Time Duration	Confirm the duration of temperature maintenance	±5 % of specified time (e.g., if 5 mins, ±0.25 min)		
5. Temperature & Flow Monitoring	Use calibrated sensors, PT100 and Flowmeter ±1 %	±0.3 °C temperature accuracy, ±1 % for flow rate accuracy		
6. Data Recording	Continuous data logging of temperature and time at least 5 seconds interval	Log data with timestamps		
7. Documentation & Reporting	Maintain records of all tests and measurements	Reports validated and signed off		

2. Objective

To determine the discharging performance of the chilled water buffer tank under controlled flow and temperature conditions, and verify compliance with design intent and performance specifications.

3. Test Setup & Methodology

The test rig consists of a chilled water source, buffer tank, pump, flowmeter, inlet/outlet temperature sensors, and data logger. The test is performed at a constant flowrate while monitoring inlet and outlet temperatures over time during discharging cycles.

Specification:
Volume	:	m³
Insulation Thickness	:	mm
Design ΔT	:	°C
Max Pressure	:	bar
Holding Time	:	min
Pressure Drop	:	kPa
Flow Velocity	:	m/s

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<u>Test Condition:</u>
Flowrate   :   l/s (Constant ±3%)
Inlet Temp   :   °C (±0.5°C)
Ambient Temp   :   °C (±2°C)
Test Medium   : Water

4. Observations, Instrumentation & Calibration

- Temperature uniformity observed / not observed.
- Flowrate remained constant during test.
- Inlet/outlet temperature stable at steady state.
- Sensor calibration verified before test.

No.	Instrument	Function	Range	Accuracy	Calibration Cert. No. / Date
1	Flowmeter	Measure flowrate	0–50 l/s	±1 %	
2	PT100 Temp Sensor (Inlet)	Measure inlet temperature	0–50 °C	±0.3 °C	
3	PT100 Temp Sensor (Outlet)	Measure outlet temperature	0–50 °C	±0.3 °C	
4	Pressure Sensor	Measure inlet/outlet pressure	0–10 bar	±1 %	
5	Data Logger	Record temp vs. time	—	—	

5. Test Procedure

i)   The water within the buffer tank was pre-chilled to the specified cooling temperature and maintained for a minimum duration of 15 minutes. Continuous measurement of the water temperature inside the tank was recorded using data acquisition systems.

ii) Continuous hot water at 28°C is pumped into the tank for a duration of 5 minutes to evaluate thermal response and circulation performance.

iii) The inlet water temperature (X °C), outlet water temperature (Y °C), and flow rate (Z l/s) are measured and recorded at 5-second intervals throughout the test duration.

iv) Data logging is maintained continuously. An alert will be triggered and recorded whenever the outlet water temperature exceeded the initial temperature by more than 1.3°C.
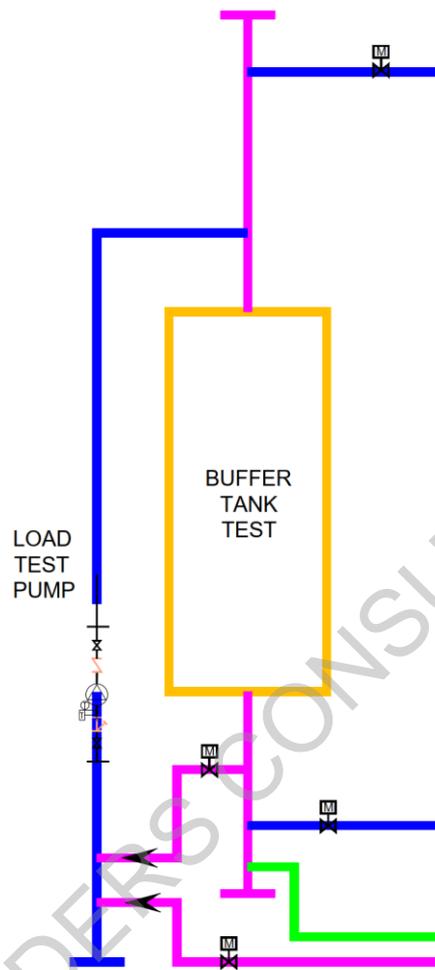
GENERAL ARRANGEMENT OF SETUP

6. Test Results

Parameter	Target Value	Measured Value	Tolerance / Limit	Result	Remarks
Temperature Range	15–25 °C	20.1 °C	±1 °C	Pass/Fail	Within limits
Temperature Stability	±1 °C	±0.5 °C	±1 °C	Pass	Stable during hold
Holding Time	5 mins	5 mins	±5 %	Pass/Fail	Slight deviation?
Pressure Drop	<20 kPa	12 kPa	N/A	Pass	System within limits
Flow Velocity	<1.5 m/s	1.2 m/s	N/A	Pass	Efficiency maintained

7. Observation & Findings

Time (sec)	Flowrate (l/s)	Inlet Temp (°C)	Outlet Temp (°C)	ΔT (°C)	Average Tank T (°C)	Volume discharged (m3)	Inlet Pressure (kPa)	Outlet Pressure (kPa)

Plot Graph Discharging Curves (Capacity vs Time)

8. Conclusion & Recommendation

a) The chilled water buffer tank performance was tested and results show that the system **ACHIEVED** the expected thermal performance under constant flowrate conditions.

b) **Temperature Stabilization:**
Confirmed tank temperature reaches target within specified tolerances.

c) **Duration:**
Confirmed the buffer tank can maintain temperature for the required holding time (e.g., 5 minutes).

d) No abnormality observed during testing.

9. Photo
(If any)

10. Appendices
(If any)

Test Carried Out By

_____
(XXXX)

Annex C
(informative)

Chiller Plant Optimisation System (CPOS) for Buffer Tank Test Rig

C.1 General

This annex provides background information on the Chiller Plant Optimisation System (CPOS) implemented for the buffer tank (BT) test rig. The content of this annex is informative and reflects a specific implementation provided by the project stakeholder. It is intended to document the CPOS concept, system configuration, and operational benefits within the buffer tank ecosystem.

This annex does not form part of the normative requirements of this standard. Inclusion of specific brands, models, and configurations is for information and reference only and does not imply endorsement or mandatory use.

C.2 Overview of CPOS for the buffer tank test rig

For the BT test rig, a CPOS based on a Programmable Logic Controller (PLC) system is adopted to manage and supervise charging, circulation, and discharging operations. The CPOS functions as a comprehensive management system to automate test execution and to support reliable and repeatable operation of the test rig.

A PC-based workstation is used as the operator interface to manage overall test rig operation, including charging, discharging, and optimisation logic. The workstation provides facilities for monitoring system performance, adjusting operational parameters, and responding to system alarms.

The primary objectives of the CPOS for the BT test rig are to:

a) automate the charging and discharging process;

b) improve repeatability and consistency of test conditions;

c) reduce manual intervention during testing; and

d) ensure reliable and uninterrupted thermal performance throughout the test duration.

C.3 CPOS-controlled test operations

C.3.1 Charging operation

During charging operation, the CPOS controls the heat pump to initiate charging mode, producing hot water and chilled water simultaneously. The hot water generated is stored in two (2) poly tanks, while the chilled water is used to cool the buffer tank pipe loop and is stored in the buffer tank.

During this operation, the CPOS monitors chilled water buffer tank temperature and pressure, hot water temperature load, and system operating conditions. The CPOS maintains steady temperature conditions on both the hot and cold sides through heat rejection at the condenser fan.

C.3.2 Circulation operation

When the required temperature conditions are achieved and the test is ready to commence, the CPOS initiates circulation operation to stabilise the buffer tank loop temperature. In this mode, the CPOS modulates the speed of the chilled water pumps (CHWP) to maintain a constant flow rate throughout the entire buffer tank discharge loop.

C.3.3 Discharging operation

Discharging operation is initiated by the CPOS to commence the buffer tank discharging test. During this operation, temperature, pressure, and flow rate data are measured and recorded continuously. The CPOS generates real-time trending of the recorded parameters for monitoring and analysis.

At the conclusion of the discharging test, the CPOS compiles the recorded data and generates the corresponding test results.

C.4 PLC system configuration (project example)

The CPOS for the BT test rig is implemented using a PLC-based control system with distributed input/output (I/O). The configuration adopted for the project includes the following components.

C.4.1 Central processing unit (CPU)

The PLC CPU implemented for the BT test rig is CPU type: SIMATIC ET 200SP CPU 1512SP-1 PN.

Key characteristics of the CPU include:

a) support for point calculations and logic algorithms based on received I/O signals;

b) non-volatile memory using a SIMATIC or equivalent memory card for programme and data storage; and

c) integrated diagnostic and communication capabilities.

C.4.2 Distributed I/O system

Distributed I/O is implemented using SIMATIC ET 200SP remote I/O modules. The remote I/O system supports:

a) hot-swap capability for signal modules;

b) detection of module faults with diagnostic data transmitted to the assigned CPU; and

c) flexible placement of I/O modules near field devices.

The interface module used for the remote I/O system is IM model: IM 155-6PN ST

The remote I/O configuration supports up to 32 I/O modules, including digital input modules, digital output modules, analogue input modules, and analogue output modules.

C.4.3 Communication

The CPOS PLC system supports high-level industrial communication via TCP/IP-based protocols. Communication capabilities include readiness for PROFINET, with support for Modbus TCP, IEC 60870-5-101/104, and DNP3 protocols.

C.5 Benefits of the CPOS implementation

The CPOS implementation for the BT test rig provides the following benefits:

a) automation of test sequences, reducing reliance on manual operation;

b) improved repeatability and consistency of test results;

c) real-time monitoring and trending of key operating parameters;

d) enhanced diagnostic capability for fault detection and troubleshooting; and

e) flexibility for future expansion through scalable PLC and I/O architecture.

Acknowledgements