WHITE PAPER

How the correct selection and specification of Isolation Valves, impact on Data Centre concurrently maintainable and Uptime Institute Tier compliant facilities.

EXECUTIVE SUMMARY

According to the Uptime Institute, “most often, the mechanical system fails Concurrent Maintenance criteria because of inadequate coordination between the number and location of Isolation Valves in the chilled water distribution path” [1].

Therefore, the selection and placement of Isolation Valves within the hydronic system of a Data Centre cooling scheme requires careful consideration during the design phase. Poor design can lead to a non-functional arrangement of Isolation Valves that can affect the system availability during both planned and unplanned maintenance.

This paper provides guidance on the selection and placement of Isolation Valves within the hydronic system topology, dependent upon the level of availability and unobstructed maintenance that is required.

The concept of a concurrently maintainable system is analysed along with the Uptime Institute paradigms from the perspective of Isolation Valves configuration.

INTRODUCTION

Limited thought may have been given to the proper arrangement of Isolation Valves for a redundant and continuously available piping system

Chilled water has been used extensively within the Data Centre industry as the primary heat exchange medium between the air moving into the data halls and the outdoor environment.

With a volumetric heat transfer capacity that is over 3,000 times greater than that of air, water based (hydronic) systems provide a much more effective solution in terms of equipment footprint and system efficiency.

However, such hydronic systems are becoming more critical and complex as they are required to provide the same standard of quality, reliability and flexibility as other computer room support systems.

The design of Data Centre cooling system topology in many existing facilities has often been limited to redundancy of the main system components like CRAH units, Chillers, Pumps and Cooling Towers, with perhaps less emphasis placed on the availability and resilience of the chilled water distribution paths. Limited thought may have been given to the proper arrangement of Isolation Valves for a redundant and continuously available piping system, with the potential for a failure across a main distribution pipe or leakage of an accessory or fitting, that cannot be resolved without a partial or complete interruption of the cooling system.

THE ROLE OF IV'S IN THE DC HYDRONIC SYSTEM

Most often, the mechanical system fails concurrent maintenance criteria because of inadequate coordination between the number and location of Isolation Valves in the chilled water distribution path.

International Industry associations and Institutes acknowledge the importance of the correct selection and placement of Isolation Valves arrangement within Data Centre chilled water distribution systems.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) records the importance of Data Centre chilled water piping and valve arrangements in ways that permit modifications or repairs without complete system shutdown [2].

ASHRAE also suggests that care must be taken to ensure valves allow bidirectional flow and tight shutoff in either direction thus, permitting maintenance on either side of the valve.

Furthermore, multiple valves may be required to permit maintenance of the valves themselves.

Similarly, the Uptime Institute has framed that "most often, the mechanical system fails concurrent maintenance criteria because of inadequate coordination between the number and location of Isolation Valves in the chilled water distribution path" [1].

As cooling system failures account for 14% of outage causes [3], the understanding of effective design and installation practices for Isolation Valves becomes essential. It is a critical aspect during system design that affects both the facility operation and it's up-time performance.

TIER STANDARDS CLASSIFICATIONS

The main scope of any Data Centre owner and its operations team, is to sustain its IT rooms and assure the successful and integrated functionality of electrical, mechanical, and building systems. Data Centre availability can be quantitatively defined by compliance with one of the most industry recognised standards, namely the Uptime Institute Tier classification system [1].

The key requirements that define the four distinct Tier classification levels, which affect the cooling system design, are:

Table 1: The Tier classification of a Data Centre is based on a 4-level approach; Tier I, Tier II, Tier III or Tier IV whereby the Tier class prescribes the criteria for the site infrastructure topology based on increasing levels of the **redundant capacity of components** and **distribution paths.**

TIER CLASSIFICATIONS	Tier I	Tier II	Tier III	Tier IV
Minimum Capacity of components to Support the IT Load	N	N+1	N+1	N after any failure
Distribution paths	1	1	1 active and 1 alternative	2 Simultaneous active
Concurrently Maintainable	No	No	Yes	Yes
Fault Tolerance	No	No	No	Yes
Compartmentalisation	No	No	No	Yes
Continuous Cooling	No	No	No	Yes

THE CONCEPT OF A CONCURRENTLY MAINTAINABLE FACILITY

Even though most Data Centre owners seek to certify their facilities under 3rd party bodies like the Uptime Institute, there are still developers that prefer to follow their own internal topology criteria, or that as prescribed by other guidelines such as ANSI/TIA-942, but regardless of the chosen method, one of the most critical design aspects that both approaches adopt is the concept of a “Concurrently maintainable” facility.

As defined by the Uptime Institue [1], Concurrently Maintainable means that each and every capacity component (CRAH, AHU, Chiller, Cooling Tower, pump etc.) and distribution path element (valves, filters, check valves, regulating valves, meters, instruments, sensors), can be taken out of service for maintenance, repair or replacement without impacting the Critical Environment or IT processes.

Below we explore further, how the various system topologies and concepts influence the usage and positioning of the Isolation Valves in relation to the differing performance requirements.

EXAMPLE OF A TYPICAL N+1 CONCURRENTLY MAINTAINABLE SYSTEM

The piping network should contain all required accessories such that, each and every part or fitting can be isolated and removed, or maintained without affecting the chilled water flow to the rest of the system. The key consideration in designing a concurrently maintainable piping system is the selection of the Isolation Valve positioning.

Figure 1 lets us examine how to arrange Isolation Valves and achieve concurrent maintainability. Consider the CRAH units topology where they serve an IT space with cooling demand of 400 kW.

The design provides a group of six units each one sized with a maximum capacity of 80 kW. We therefore have an N+1 (N=5) configuration where five CRAH's run continuously and the remaining one is a backup. According to Uptime Institute requirements, the 6th CRAH unit as a capacity component is redundant.

The 2-pipe system serves the CRAH units with chilled water from both sides, widely known as 'loop system design'. It is evident that any CRAH unit can be easily isolated without affecting the operation of the cooling system. It is not the same if a failure occurs with one of the Isolation Valves themselves or across the main distribution pipe. The system is not concurrently maintainable as maintenance or replacement cannot take place without total system shut down.

Additional Isolation Valves are needed and located in such a way that the system will become concurrently maintainable. This is achieved by locating two valves in the main distribution pipe section between each CRAH unit as shown in Figure 2.

In this example we assume that ***Valve "A"*** needs to be maintained or even replaced. It can be seen that by isolating valves "B", "C" and "D", then element (Valve "A") can easily be maintained or replaced without any disruption to the system.

The same applies to all the valves and elements within this arrangement, even allowing for complete piping sections to be maintained, extended or replaced.

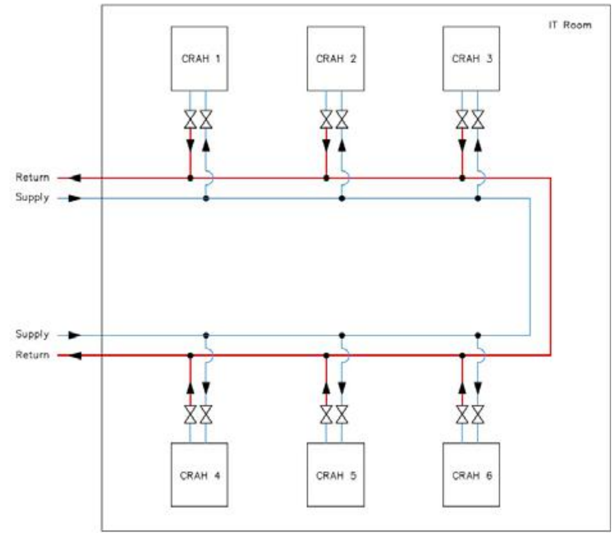

Figure 1: Chilled water distribution system with no Isolation Valves across the main distribution pipes.

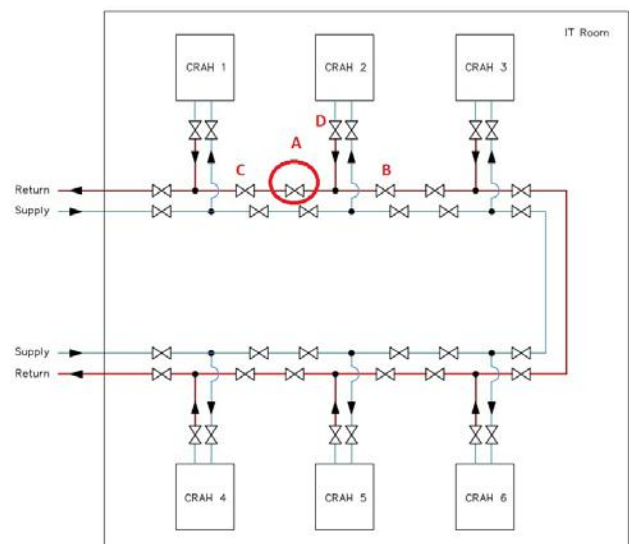

Figure 2: Chilled water distribution with the correct number and location of Isolation Valves. If ***Valve "A"*** needs replacement, it is a concurrently maintainable system and N units remain operational.

Thus, the provision of two Isolation Valves in between every two-pipe branch, creates a concurrently maintainable system whereby any CRAH unit or piping network component is replaceable without disruption to the system operation. The number and location of Isolation Valves ensures that every piece of equipment or component can always be isolated by use of both its upstream and downstream Isolation Valves.

Now consider that instead of installing two, we install only one Isolation Valve per distribution pipe section as per Figure 3 This configuration would result in the loss of two CRAH units when a component fails. If for example ***Valve "A"*** requires replacement Isolation Valves "B", "C", "D" and "E" will all need to be turned off. Both CRAH units 1 and 2 will be out of service, something that the Operator cannot afford, given that we require an N+1 system (noting that where we have an N+1 configuration, we can only afford to lose one CRAH unit).

So, it becomes very evident that the number and location of Isolation Valves across the distribution piping has a significant impact on system availability.

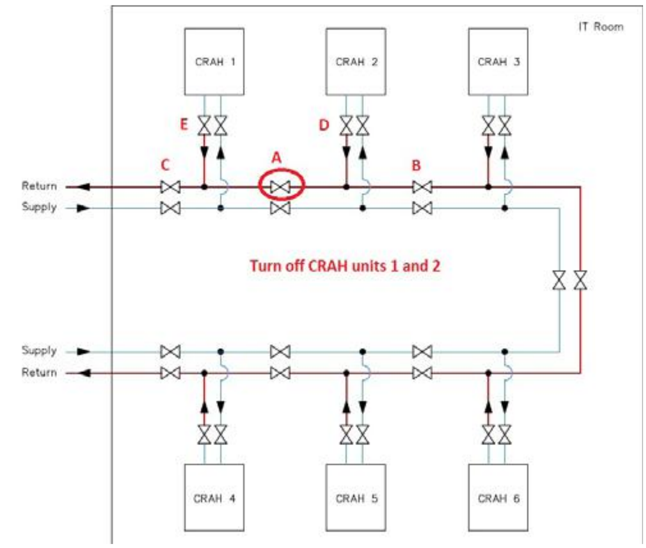

Figure 3: Chilled water distribution system with limited number of valves. ***Valve "A"*** needs replacement. No concurrent maintenance can take place without 2 CRAH units being offline.

TOWARDS AN N+1 TIER III OR IV CLASS SYSTEM

Facilities that seek to achieve a Tier III or IV level certification must apply the concept of redundant capacity components (CRAH units, Chilled Water Pumps, Chillers, Cooling Towers etc.) and concurrently maintainable distribution paths (chilled water piping, condensing water piping, makeup water piping and fuel system) for most systems.

Therefore, the usage and placement of Isolation Valves as presented above becomes a requirement for the complete cooling, make-up water and fuel systems. System designers will have to provide two Isolation Valves along each section of the distribution mains, allowing concurrent maintainability for all system components.

A representative design is shown in the Figure 4 below where, with the exception of CRAH units, the system includes a range of chillers, cooling towers and pumps, all equipped with the required number of Isolation Valves in a way that any equipment unit or accessory component can be removed without system interruption.

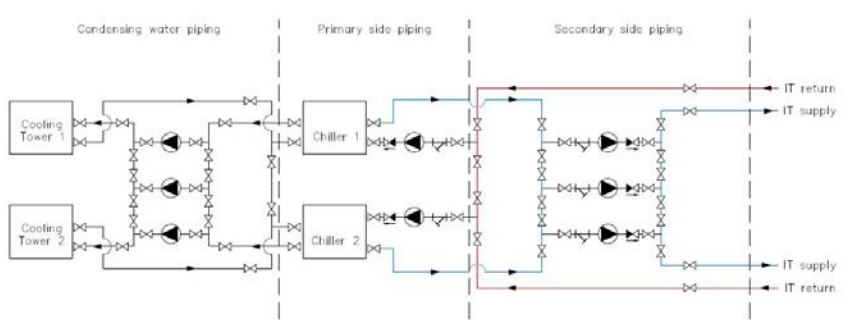

Figure 4: Application of two Isolation Valves per section design concept, on other systems distribution paths.

It is also important to note that an additional requirement for a certified Tier IV Data Centre is to provide a fault tolerant system design. According to the Uptime Institute definition [1], "fault tolerant is a system where any potential fault must be capable of being detected, isolated, and contained while maintaining N capacity to the critical load".

In other words, the distribution paths (chilled or condensing water, fuel etc.) shall be equipped with **motorised** Isolation Valves, such that the system can automatically respond and autonomously isolate either a capacity unit (CRAH, Pump, Chiller etc.) or a component (valve, filter, check valve etc.), after detection of failure or leakage.

VALVE STRUCTURE AND SYSTEM INTEGRITY DURING MAINTENANCE

Another important point of attention is the fact that a concurrently maintainable system will never cease to operate and circulate water at the required system pressure, even if a section of the circuit is isolated via the Isolation Valves or a section of distribution pipe is removed.

So, consider the case of a chilled water piping system as illustrated in the Figure 6 below. Isolation Valves "B" and "C" are closed, and the intermediate pipe (A) is removed.

Figure 5: End of line valve (Bray Series 31H) with pipe and mating flange removed.

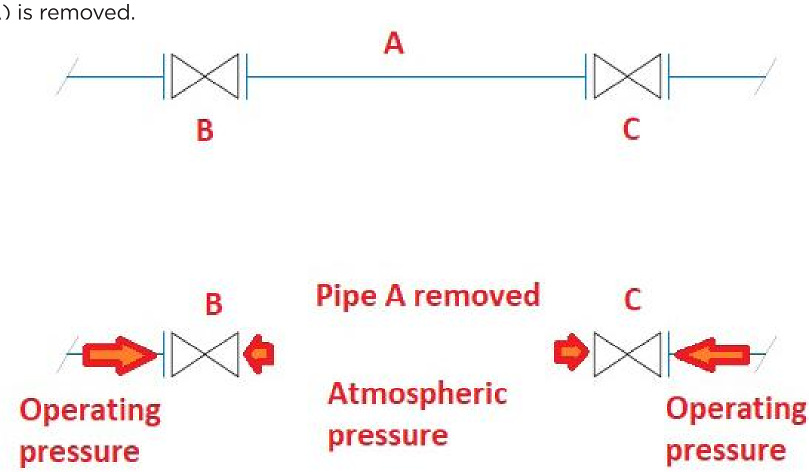

Figure 6: Removal of the middle pipe A will expose valves B and C at high pressure difference. Valves rated for high dead-end service equal to the full operating pressure should be specified.

This would expose both valves "B" and "C" to the full system pressure on one side with one of its mating flanges dis-connected, and atmospheric pressure on the other. Such condition is called Dead-End-Service and has been described by ASHRAE [4] with the following definition,

> **Valves rated for dead-end service can be placed at the end of a pipe without a cap (i.e., with one end at atmospheric pressure) and will not have any leakage of fluid across the valve at the service pressure rating of the valve.**

Based on the above, it can be seen that there is a clear benefit in specifying Isolation Valves who's rating for dead-end-service is equal to their full operating pressure. Valves rated for this level of performance will also provide the most flexible design allowing easy and secure disassembly procedures without exposing the system to any risk of a leakage.

CONCLUSION

The correct number and placement of Isolation Valves across any Data Centre system piping network is critical otherwise concurrent maintenance cannot be achieved. A concurrently maintainable system with an N+1 configuration of the capacity components requires two Isolation Valves in the main distribution piping, in between every two-pipe branch. This configuration ensures that each and every component can always be isolated via a pair of Isolation Valves, one located before and the other located after the component.

Tier III compliant systems have at least to be concurrently maintainable and for Tier IV systems, Isolation Valves will also have to be motor driven for automated fault tolerance.

Valves with a high dead end service rating should also be specified to allow the above principles to be easily apopted, thereby ensuring the greatest system design integrity and flexibility.

RESOURCES

1. Uptime Institute – Data Centre Site Infrastructure, Tier Standard: Topology, 2018 ed.
2. ASHRAE Datacom Series 3 - Design Consideration for Datacom Equipment centers 2nd ed., section 4.4, page 28.
3. Uptime Institute – UI Global Data Centre Survey 2021, page 12.
4. ASHRAE Datacom Series 3 - Design Consideration for Datacom Equipment centers 2nd ed., section 4.4, page 198.

ABOUT THE AUTHORS

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