Excool Zero Engineering Review

Data Centre Cooling Product Comparison Report Addendum

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Executive Summary

This addendum presents an update to the original study to include the Excool DX only unit. The original report has been left out of the addendum for brevity.

In this addendum the systems to be compared are:

- Excool Units (Water first control mode)
- Excool Units (DX first control mode)
- Excool Units (DX only)
- Fan walls with free cooling chillers
- Fan walls with hybrid coolers
- Direct Air Excool units

The addendum study uses 16 assessment criteria relevant to data centre design to assign a score out of 5 to each system. 5 being the highest score and 0 being the lowest. Each system therefore can achieve a maximum of 80. No weighting has been applied to the scoring to avoid human influence on the results. The colocation and hyperscale scenarios are the same as the original report. The direct air system is not included in the colocation scenario as outlined in section 2.3 of the main report.

Compared to the original report two new criteria have been introduced. This has been done to better distinguish performance between Excool units. The new criterions are:

- Refrigerant quantity
- Peak total mechanical power

The final scoring of the four systems for a colocation end user is given below.

	Score
Excool zero (Water first)	69
Excool zero (DX first)	67
Excool zero (DX only)	64 (See note)
Fan wall with free cooling chiller	56
Fan wall with hybrid cooler	45

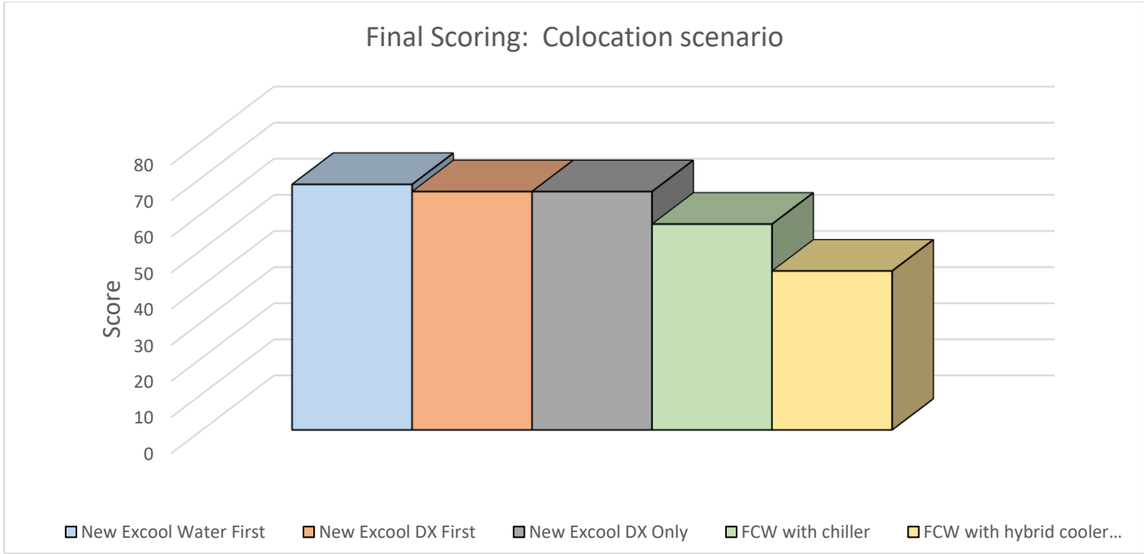
The final scoring of the five systems for a hyperscale end user is given below.

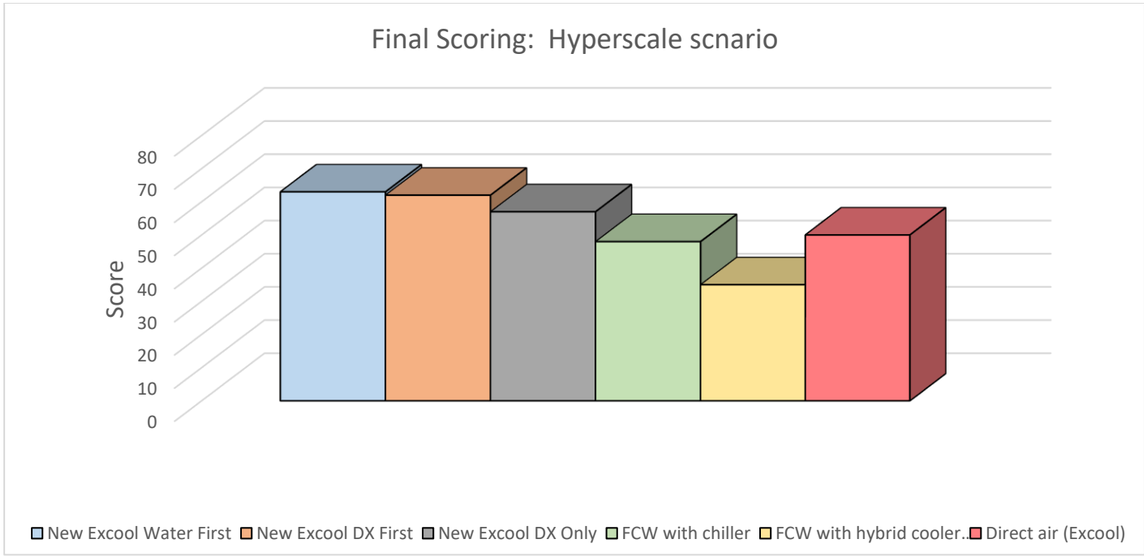
	Score
Excool zero (Water first)	63
Excool zero (DX first)	62
Excool zero (DX only)	57 (See note)
Fan wall with free cooling chiller	48
Fan wall with hybrid cooler	35
Direct Air Excool Unit	50

The study concludes that, similarly to the original report, the Excool zero (water first) unit scores the best in both colocation and hyperscale users.

The Excool DX only units can offer an alternative mode of operation to the Excool Zero unit. The waterless nature of it means it scores well in installation complexity, WUE and reliability.

However, the omission of water in the Excool DX only unit means the heat rejection at peak summer ambient is done by a DX system twice as large as the standard Excool zero unit. This results in twice the level of refrigerant required and the worst performing peak total power. The latter results in the highest stranded power, resulting in oversized electrical infrastructure and site utility application. This limits the options during a site selection process. The inclusion of water to the Excool unit allows half of the refrigerant of the Excool DX only unit and a much lower peak total power.





Note:

The final scoring of the Excool DX only unit is competitive amongst the Excool Zero units. However, it should be stated that the issue of peak total power and total refrigerant is significant. The inclusion of water into the Excool Zero unit allows for a significant improvement in both total power requirements and refrigerant volumes.

Contents

1.0 Introduction

Further to the original Excool performance study, Cundall has been commissioned by Excool to perform an addendum to include the Excool Zero DX only unit.

The methodology follows the same principles and format as the original study. Please refer to the original report for information on calculations, assumptions, and system descriptions.

2.0 Power Consumption

Figures for annualised mPUE have been calculated in the same process as the original report but with the inclusion of the Excool DX only unit. Refer to section 4 of the original report for details of the calculation method.

2.1 Colocation Results

mPUE						
100% Load						
	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
London	1.090	1.120	1.121	1.106	1.070	excluded
Frankfurt	1.095	1.121	1.124	1.107	1.075	excluded
Oslo	1.092	1.108	1.108	1.094	1.072	excluded
Dublin	1.087	1.106	1.106	1.092	1.067	excluded
Amsterdam	1.093	1.115	1.115	1.101	1.073	excluded
75% Load						
London	1.060	1.080	1.080	1.060	1.050	excluded
Frankfurt	1.061	1.078	1.078	1.058	1.051	excluded
Oslo	1.059	1.070	1.070	1.050	1.049	excluded
Dublin	1.055	1.067	1.067	1.047	1.045	excluded
Amsterdam	1.059	1.073	1.073	1.053	1.049	excluded

Table 2.1: Breakdown of mPUE values per system and per region for a colocation scenario

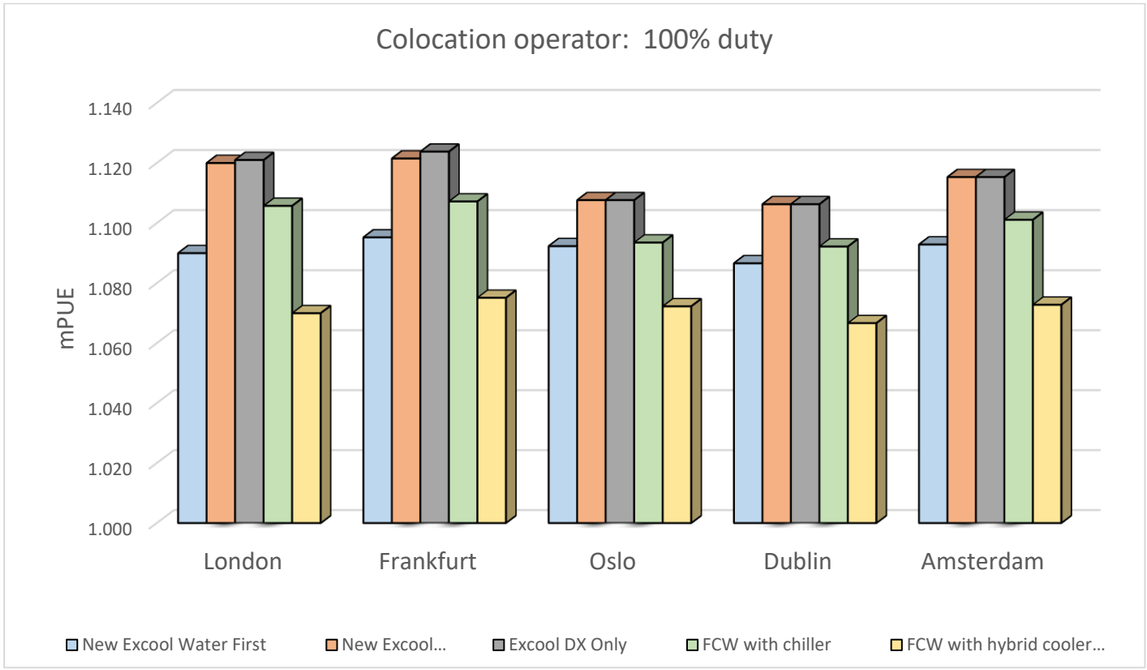


Figure 2.1: Bar chart to illustrate the mPUE for all systems per region at 100% IT load.

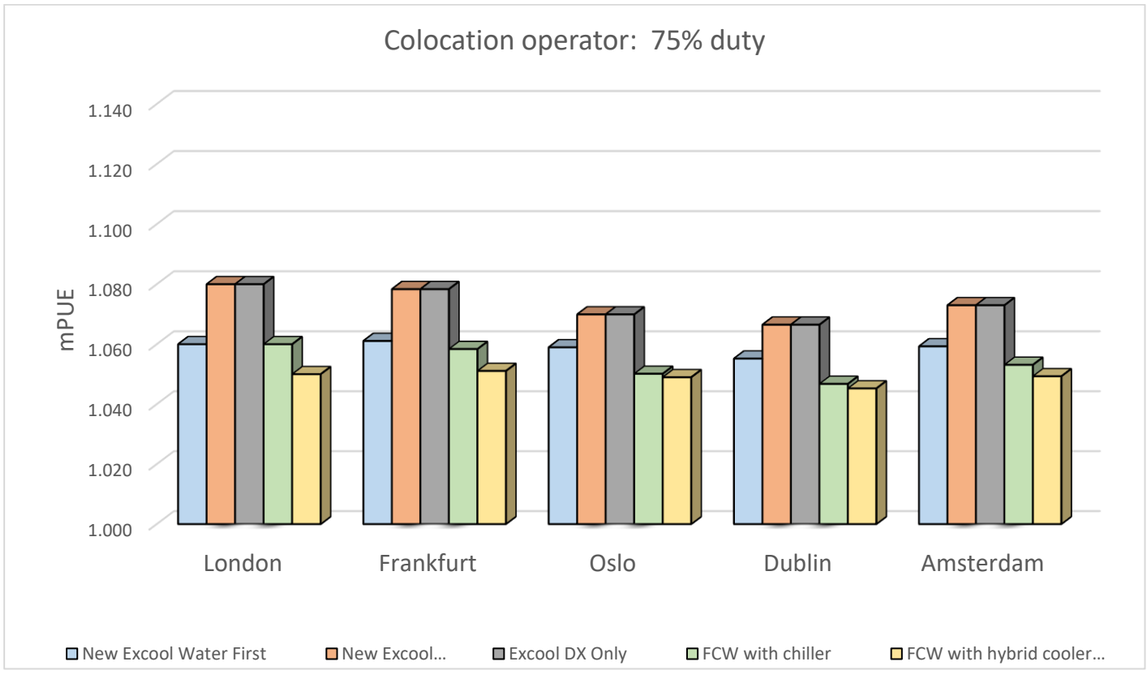


Figure 2.2: Bar chart to illustrate the mPUE for all systems per region at 75% IT load.

2.2 Colocation Discussion

The values of Table 2.1 are given to 3 decimal points in this study to distinguish between Excool systems that are very similar in PUE.

The Excool DX Only mode has a slightly higher PUE than that the Excool DX first unit in the colocation scenario. This is because the DX first unit is using water to supplement the heat rejection – but this happens only in the higher ambient temperatures. Using London as an example, the Excool DX first is only using water for 80 hours in a typical year. For the rest of the year, the Excool DX first and Excool DX only are practically the same unit. This explains why the difference between the PUE between DX first and DX only is so small at 100% load. At 75% load, this difference is not significant to three decimal places.

The rest of the PUE figures follow the same pattern and discussion as the main report.

2.3 Colocation PUE score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	4	2	1	3	5	n/a

2.4 Hyperscale Results

mPUE						
100% Load						
	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
London	1.094	1.110	1.110	1.107	1.067	1.052
Frankfurt	1.093	1.108	1.110	1.106	1.066	1.053
Oslo	1.089	1.103	1.103	1.101	1.062	1.053
Dublin	1.086	1.104	1.104	1.101	1.060	1.053
Amsterdam	1.091	1.107	1.107	1.104	1.064	1.053
75% Load						
London	1.057	1.067	1.067	1.067	1.049	1.030
Frankfurt	1.059	1.068	1.068	1.067	1.050	1.034
Oslo	1.059	1.066	1.066	1.065	1.050	1.031
Dublin	1.055	1.064	1.064	1.064	1.046	1.034
Amsterdam	1.057	1.066	1.066	1.066	1.049	1.030

Table 2.2: Breakdown of mPUE values per system and per region for a hyperscale scenario

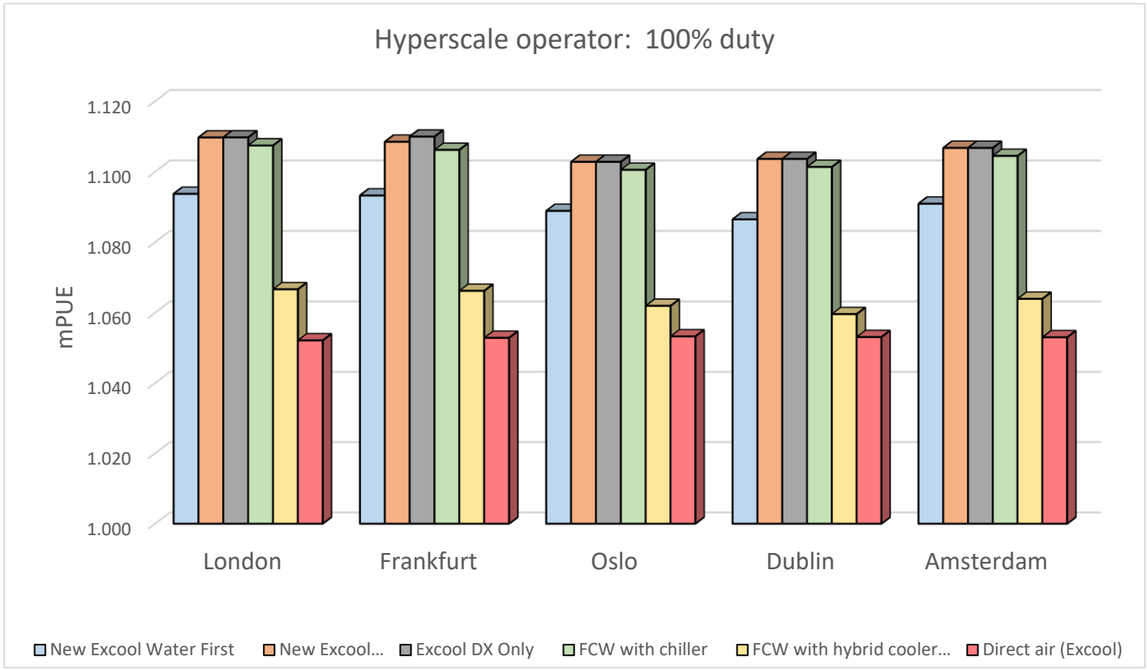


Figure 2.3: Bar chart to illustrate the mPUE for all systems per region at 100% IT load.

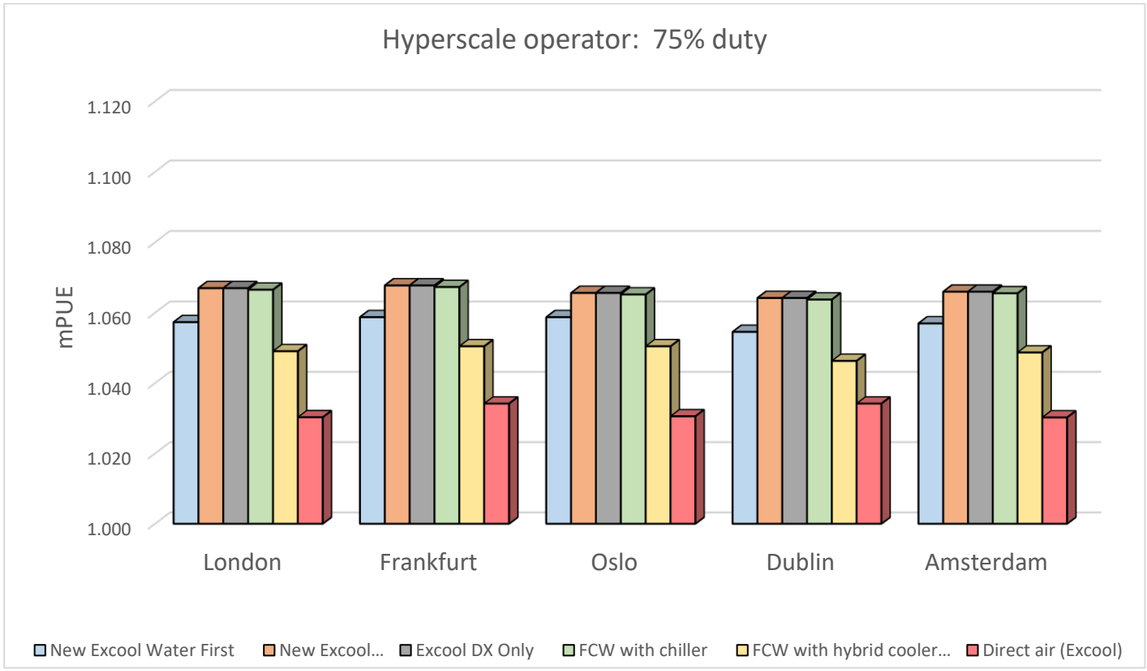


Figure 2.4: Bar chart to illustrate the mPUE for all systems per region at 75% IT load.

2.5 Hyperscale Discussion

The PUE values for the hyperscale scenario follow the same pattern as the colocation scenario. The PUEs are lower throughout due to the relaxed data hall envelope.

Using London as an example, the Excool DX first unit is only using water for fewer than 2 hours in a typical year. The difference between PUE between DX first unit and DX only unit therefore is not significant in three decimal places at both 100% and 75% load.

The rest of the PUE figures follow the same pattern and discussion as the main report.

2.6 Hyperscale PUE Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	3	1	0	2	4	5

3.0 Water Consumption

Figures for annualised WUE have been calculated in the same process as the original report but with the inclusion of the Excool DX only unit. Refer to section 4 of the original report for details of the calculation method.

3.1 Colocation Results

WUE						
100% Load						
	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
London	0.160	0.0118	0.0000	0.0000	0.256	excluded
Frankfurt	0.190	0.0337	0.0000	0.0000	0.303	excluded
Oslo	0.119	0.0001	0.0000	0.0000	0.191	excluded
Dublin	0.054	0.0000	0.0000	0.0000	0.087	excluded
Amsterdam	0.109	0.0068	0.0000	0.0000	0.174	excluded
75% Load						
London	0.160	0.012	0.000	0.000	0.177	excluded
Frankfurt	0.190	0.034	0.000	0.000	0.210	excluded
Oslo	0.119	0.000	0.000	0.000	0.132	excluded
Dublin	0.054	0.000	0.000	0.000	0.060	excluded
Amsterdam	0.109	0.007	0.000	0.000	0.120	excluded

Table 3.1: Breakdown of WUE values per system and per region for a colocation scenario

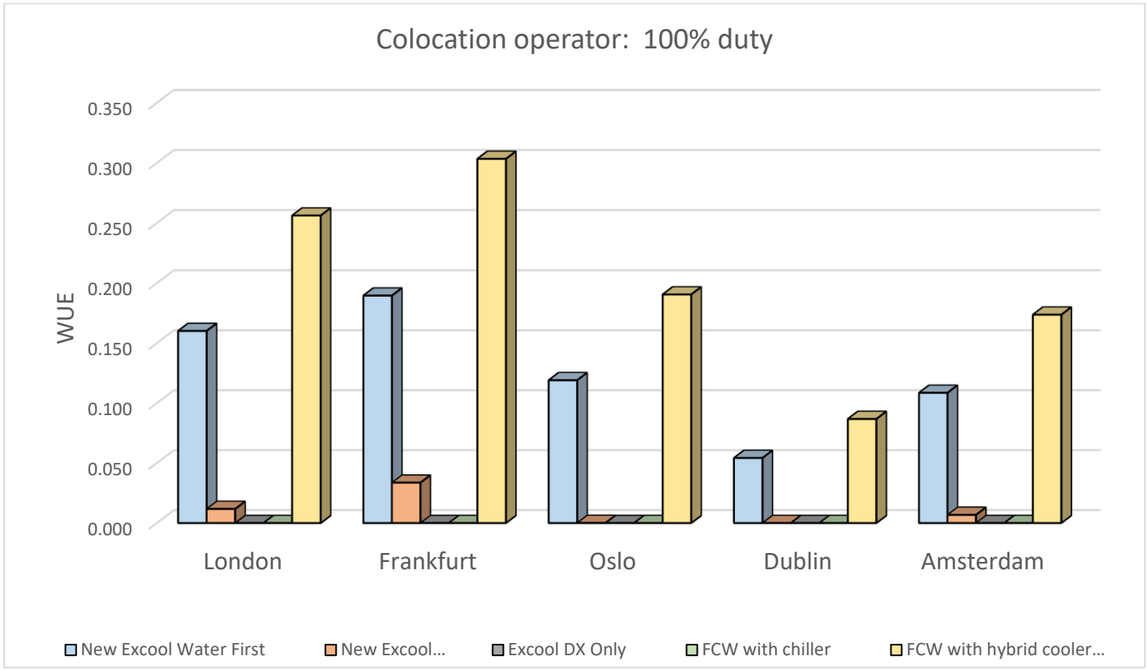


Figure 3.1: Bar chart to illustrate the WUE for all systems per region at 100% IT load.

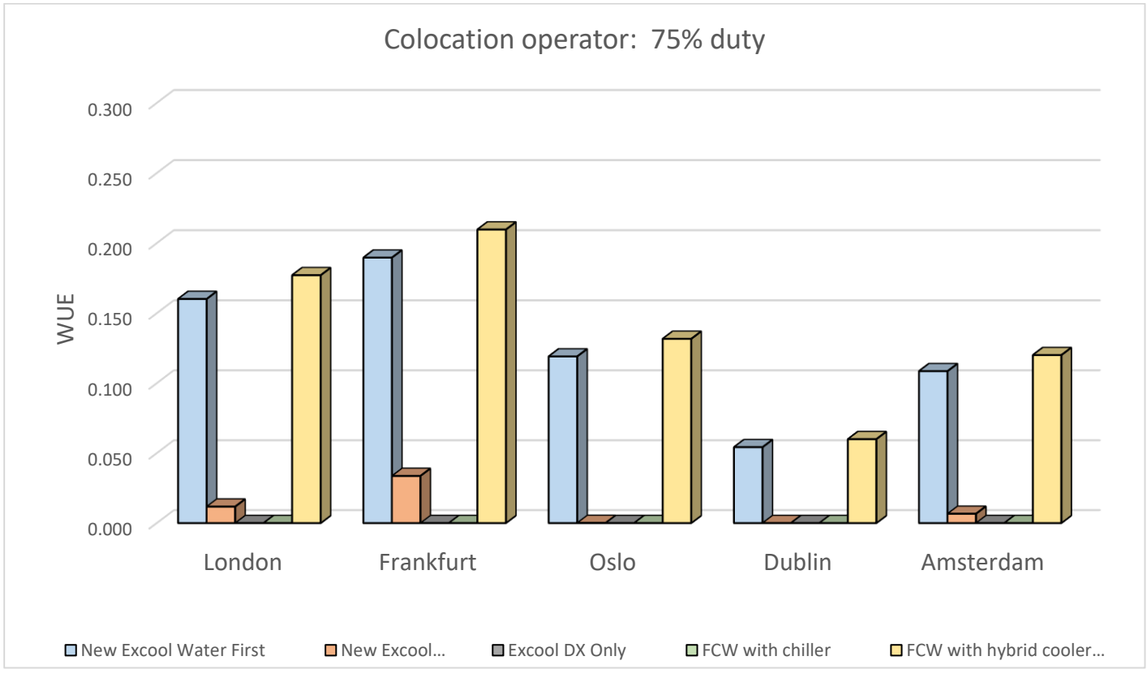


Figure 3.2: Bar chart to illustrate the WUE for all systems per region at 75% IT load.

3.2 Colocation Discussion

The DX Only Excool unit is waterless. Therefore, there is zero water used for cooling. The WUE is exactly zero.

The WUE values of the remaining systems follow the same pattern and discussion as the main report.

3.3 Colocation Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	2	3	5	5	1	n/a

3.4 Hyperscale Results

WUE						
100% Load						
	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
London	0.041	0.0003	0.0000	0.0000	0.063	0.017
Frankfurt	0.083	0.0020	0.0000	0.0000	0.129	0.027
Oslo	0.027	0.0000	0.0000	0.0000	0.042	0.044
Dublin	0.002	0.0000	0.0000	0.0000	0.003	0.018
Amsterdam	0.026	0.0000	0.0000	0.0000	0.040	0.018
75% Load						
London	0.041	0.0003	0.0000	0.0000	0.042	0.017
Frankfurt	0.083	0.0020	0.0000	0.0000	0.086	0.027
Oslo	0.027	0.0000	0.0000	0.0000	0.028	0.044
Dublin	0.002	0.0000	0.0000	0.0000	0.002	0.027
Amsterdam	0.026	0.0000	0.0000	0.0000	0.027	0.018

Table 3.2: Breakdown of WUE values per system and per region for a hyperscale scenario

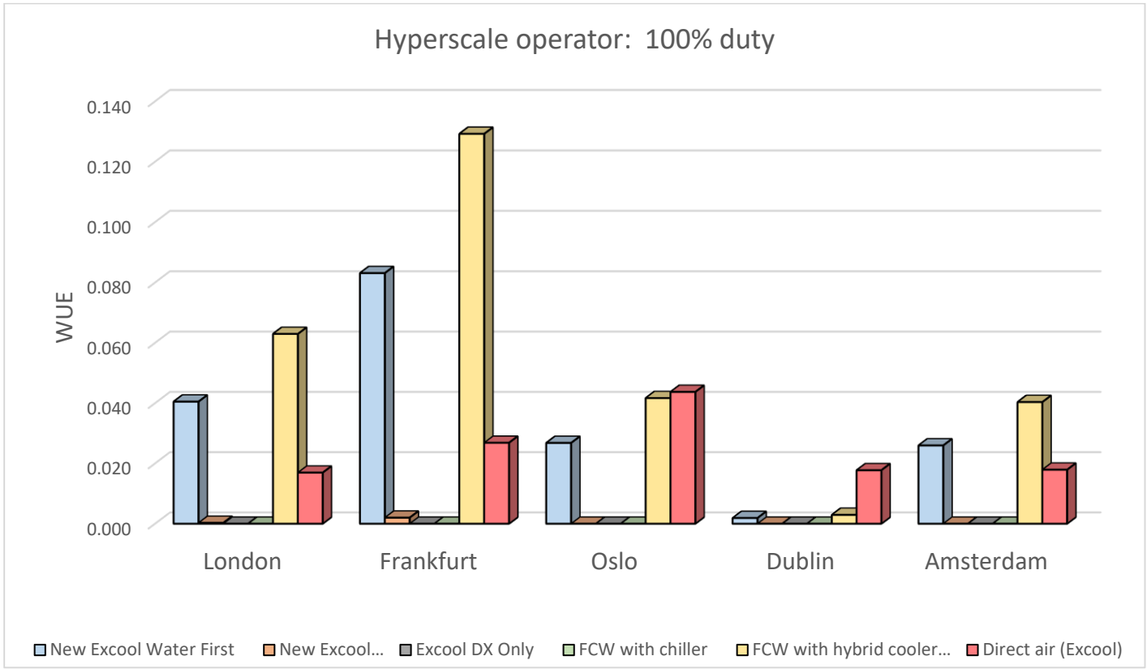


Figure 3.3: Bar chart to illustrate the WUE for all systems per region at 100% IT load.

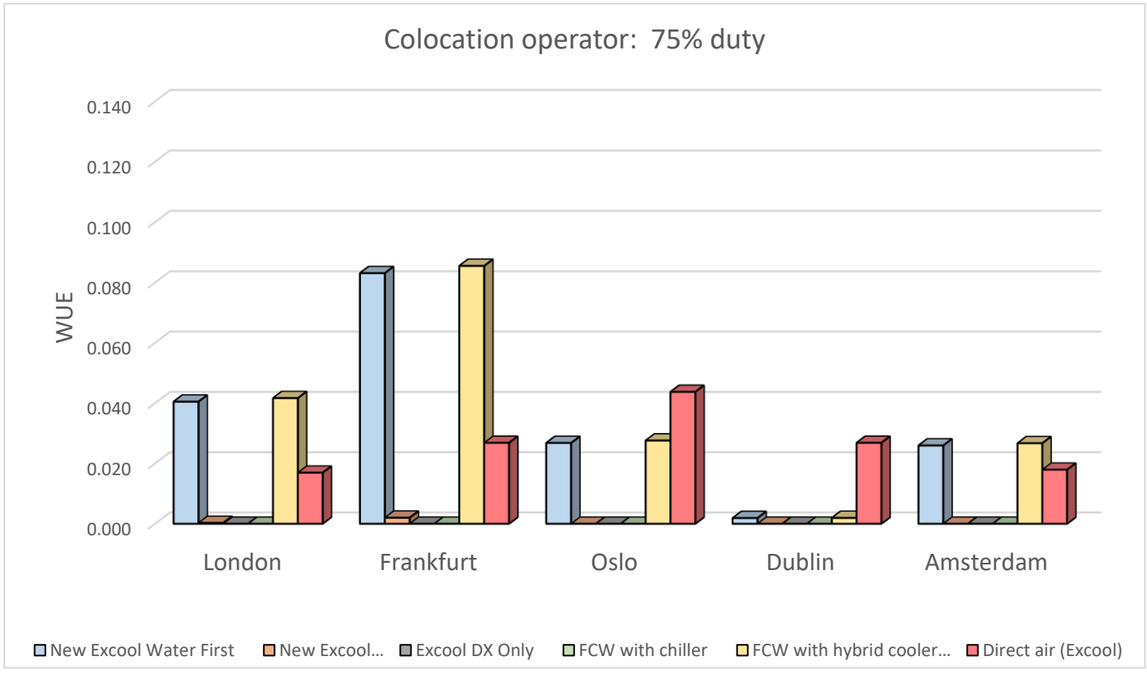


Figure 3.4: Bar chart to illustrate the WUE for all systems per region at 75% IT load.

3.5 Hyperscale Discussion

The DX Only Excool unit is waterless. The only water consumed is for the pressurisation AHUs to maintain pressure and humidity levels. Therefore, the DX only Excool unit has the same WUE as the fan wall and chiller system and both systems have the joint best WUE.

The WUE values of the remaining systems follow the same pattern and discussion as the main report.

3.6 Hyperscale Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	1	3	5	5	0	2

4.0 Drainage Quantity

Table 4.1 shows the annual drainage values for each system including the Excool DX only unit. The calculated follows the same methodology in the original report.

			Drainage Volume (litres)	Rank	Score
Colocation	100%	New Excool Water First	0	1	5
		New Excool DX First	0	1	5
		New Excool DX Only	0	1	5
		FCW with chiller	0	1	5
		FCW with hybrid cooler (chiller top up)	5612822	5	1
		Direct air (Excool)	n/a	n/a	n/a
Hyperscale	100%	New Excool Water First	0	1	5
		New Excool DX First	0	1	5
		New Excool DX Only	0	1	5
		FCW with chiller	0	1	5
		FCW with hybrid cooler (chiller top up)	1379130	6	0
		Direct air (Excool)	989441	5	1

Table 4.1: Drainage values for each system for both colocation and hyperscale operators.

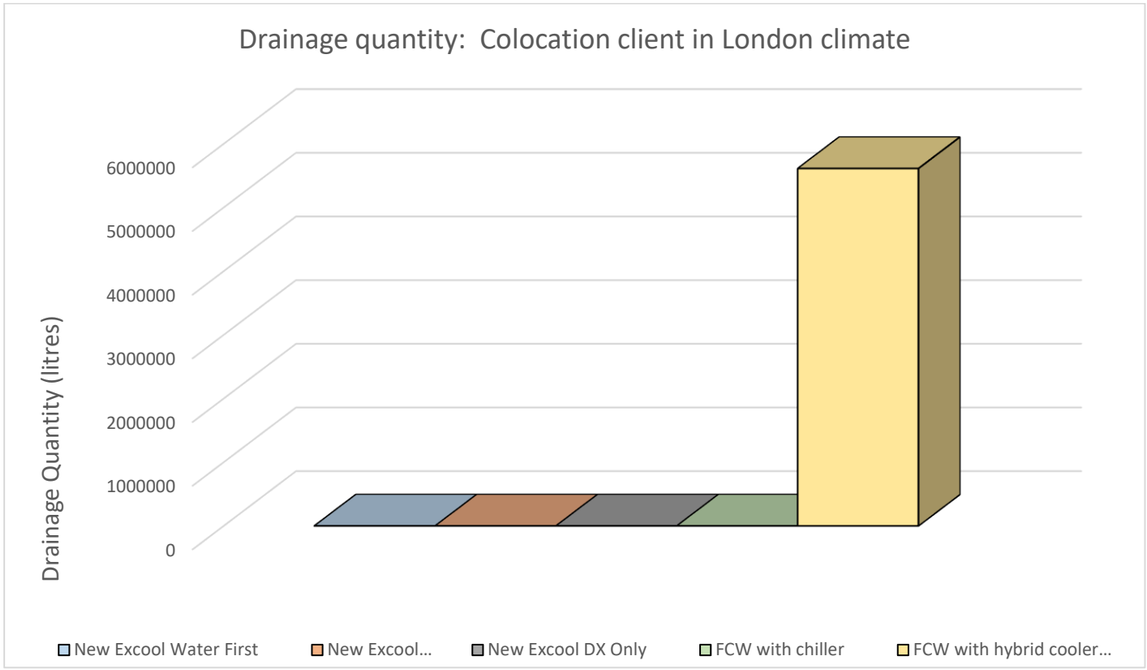


Figure 4.1: Drainage values for each system for colocation operators.

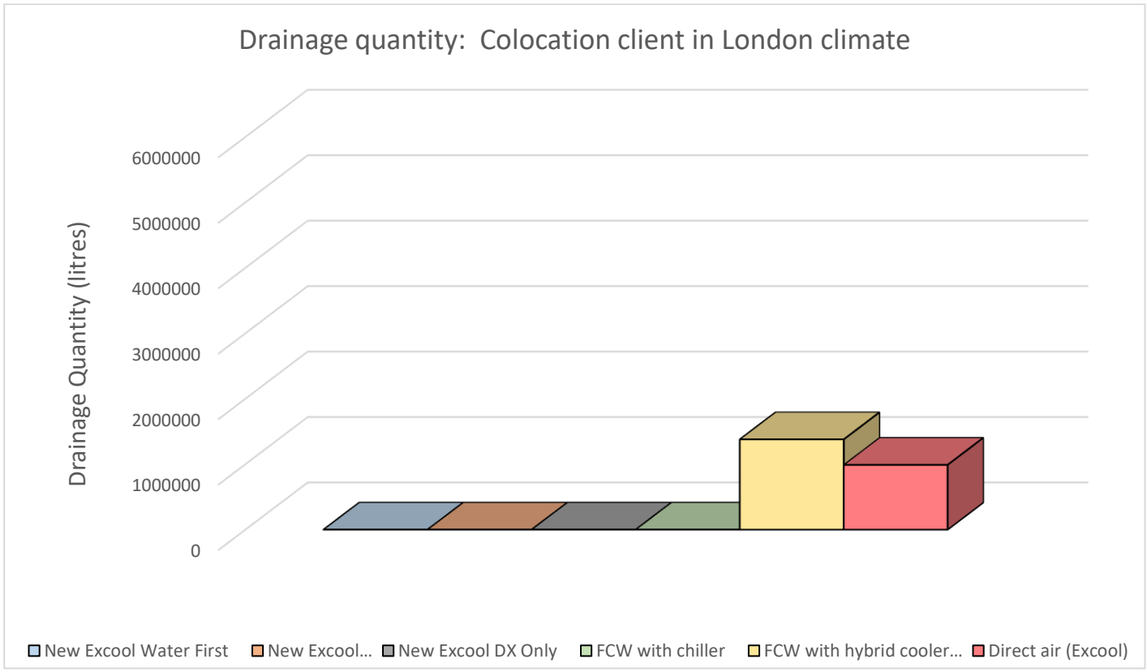


Figure 4.2: Drainage values for each system for hyperscale operators.

4.1 Drainage Quantity Discussion

The Excool zero unit is a waterless unit and therefore has zero drainage rate. There is no drainage associated with this system.

The remaining systems follow the same pattern and discussion as the original report.

Note that drainage rates associated with the pressurisation AHU is not included.

4.2 Drainage Quantity Colocation Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	5	5	5	5	1	5

4.3 Drainage Quantity Hyperscale Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	3	3	5	5	0	1

5.0 External Water Storage

Table 5.1 shows the required water storage values for each system including the Excool DX only unit. The calculated follows the same methodology in the original report.

			External Water Storage (m3)	Rank	Score
Colocation	100%	New Excool Water First	12	3	3
		New Excool DX First	12	3	3
		New Excool DX Only	0	1	5
		FCW with chiller	0	1	5
		FCW with hybrid cooler (chiller top up)	929	5	1
		Direct air (Excool)	n/a	n/a	n/a
Hyperscale	100%	New Excool Water First	0	1	5
		New Excool DX First	0	1	5
		New Excool DX Only	0	1	5
		FCW with chiller	0	1	5
		FCW with hybrid cooler (chiller top up)	609	6	0
		Direct air (Excool)	393	5	1

Table 5.1: External Water Storage values for each system for both colocation and hyperscale operators.

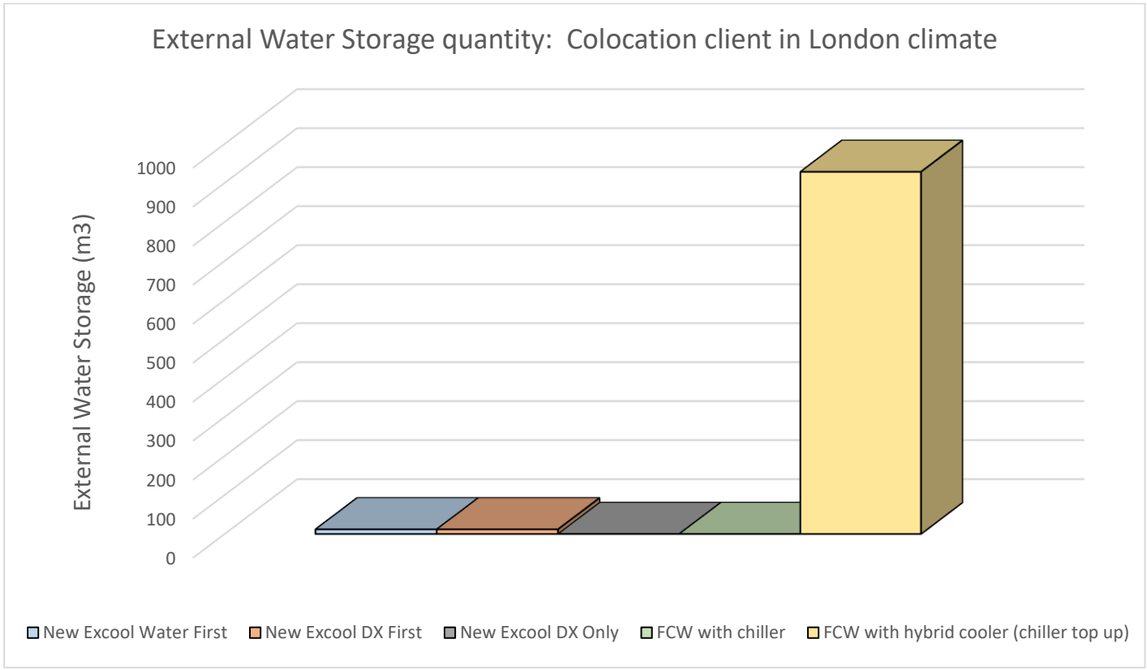


Figure 5.1: External water storage values for each system for a colocation operator.

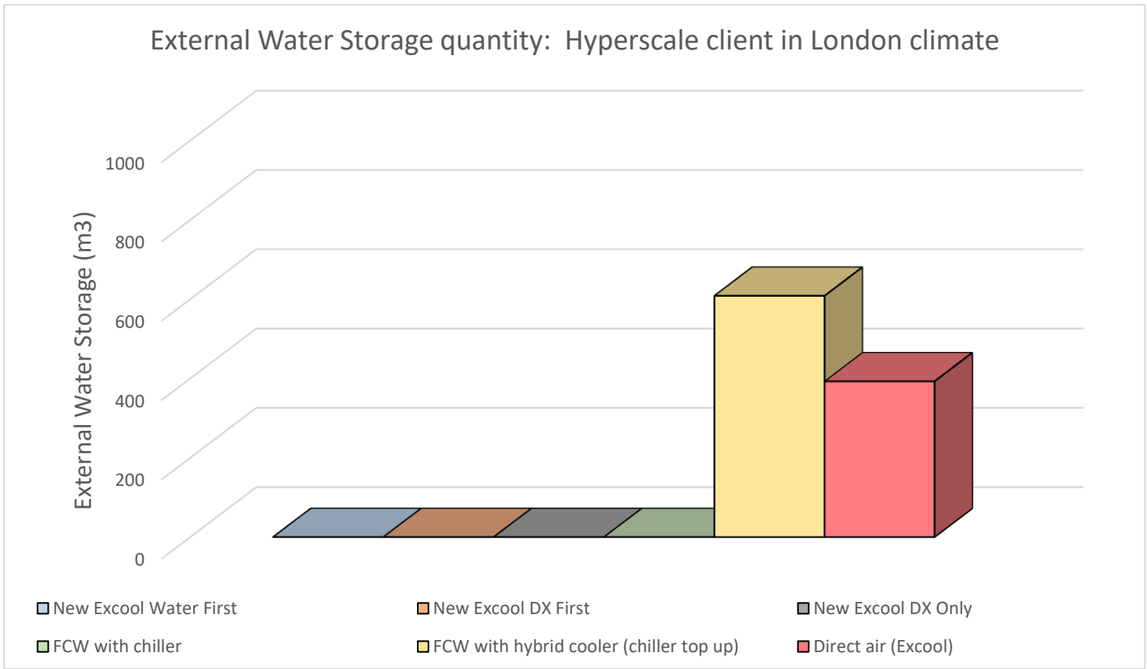


Figure 5.2: External water storage values for each system for hyperscale operator.

5.1 Discussion

The DX Only Excool unit is waterless. Therefore, there is zero water used for cooling. The required external water storage requirements then is exactly zero.

The external water storage values of the remaining systems follow the same pattern and discussion as the main report.

5.2 Colocation External Water Storage Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	3	3	5	5	1	-

5.3 Hyperscale External Water Storage Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	5	5	5	5	0	1

6.0 External Water Treatment

Table 6.1 shows the required water storage values for each system including the Excool DX only unit. The calculation follows the same methodology as the original report.

			Rank	Score
Colocation	100%	New Excool Water First	1	5
		New Excool DX First	1	5
		New Excool DX Only	1	5
		FCW with chiller	1	5
		FCW with hybrid cooler (chiller top up)	5	1
		Direct air (Excool)		
Hyperscale	100%	New Excool Water First	1	5
		New Excool DX First	1	5
		New Excool DX Only	1	5
		FCW with chiller	1	5
		FCW with hybrid cooler (chiller top up)	6	0
		Direct air (Excool)	1	5

Table 6.1: External Water Treatment scoring for each system for both colocation and hyperscale operators.

6.1 Discussion

The Excool DX only unit is waterless and therefore has no requirement for external water treatment.

The scoring of the remaining systems follows the same pattern and discussion as the main report.

6.2 Colocation External Water Treatment Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	5	5	5	5	1	

6.3 Hyperscale External Water Treatment Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	5	5	5	5	0	5

7.0 Legionella risk

Table 7.1 shows the Legionella risk for each system including the Excool DX only unit.

			Rank	Score
Colocation	100%	New Excool Water First	1	5
		New Excool DX First	1	5
		New Excool DX Only	1	5
		FCW with chiller	1	5
		FCW with hybrid cooler (chiller top up)	1	5
		Direct air (Excool)	n/a	n/a
Hyperscale	100%	New Excool Water First	1	5
		New Excool DX First	1	5
		New Excool DX Only	1	5
		FCW with chiller	1	5
		FCW with hybrid cooler (chiller top up)	1	5
		Direct air (Excool)	1	5

Table 7.1: Legionella risk scoring for each system for both colocation and hyperscale operators.

7.1 Discussion

The Excool DX only unit is waterless and therefore has no risk of legionella.

The scoring of the remaining systems follows the same pattern and discussion as the main report.

7.2 Colocation Legionella Risk Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	5	5	5	5	5	-

7.3 Hyperscale Legionella Risk Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	5	5	5	5	5	5

8.0 Maintenance

Table 8.1 shows the maintenance requirements for each system including the Excool DX only unit.

			Rank	Score
Colocation	100%	New Excool Water First	1	5
		New Excool DX First	1	5
		New Excool DX Only	1	5
		FCW with chiller	4	2
		FCW with hybrid cooler (chiller top up)	5	1
		Direct air (Excool)	n/a	n/a
Hyperscale	100%	New Excool Water First	2	4
		New Excool DX First	2	4
		New Excool DX Only	2	4
		FCW with chiller	5	1
		FCW with hybrid cooler (chiller top up)	6	0
		Direct air (Excool)	1	5

Table 8.1: Maintenance requirements for each system for both colocation and hyperscale operators.

8.1 Discussion

The Excool DX only unit requires the same weekly visual inspection and quarterly full inspections as the Excool water first and DX first units. Therefore, these units score the same for maintenance.

The scoring of the remaining systems follows the same pattern and discussion as the main report.

8.2 Colocation Maintenance Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	5	5	5	2	1	n/a

8.3 Hyperscale Maintenance Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	4	4	4	1	0	5

9.0 Reliability

An assessment for reliability has been performed for each system. The methodology is the same as the original report. The results from the calculation for colocation and hyperscale scenarios are given in Table 9.1 and Table 9.2 respectively.

	New Excool DX Only	New Excool Water First	New Excool DX first	Chiller & Fan wall only	Hybrid Cooler&Chiller & Fan wall
MTTF (hours)	274732	276795	224442	141581	77240
Availability of System	0.999990	0.999992	0.999990	0.999948	0.999903
Time Online (% of year)	99.9990%	99.9992%	99.9990%	99.9948%	99.9903%
Average annual failure time (minutes of year)	6.77	4.16	5.47	50.80	12.93
Rank	3	1	2	5	4
Score	**3**	**5**	**4**	**1**	**2**

Table 9.1: Reliability scoring for each system in colocation scenario.

	New Excool DX Only	New Excool Water First	New Excool DX first	New Excool Direct Air	Chiller & Fan wall only	Hybrid Cooler & Fan wall only (no chiller)
MTTF (hours)	274732	276795	224442	4358224	141581	246722
Availability of System	99.9990%	99.9992%	99.9990%	99.999980%	99.9948%	99.9975%
Time Online (% of year)	99.9990%	99.9992%	99.9990%	99.999980%	99.9948%	99.9975%
Average annual failure time (minutes of year)	6.77	4.16	5.47	0.11	27.23	12.93
Rank	4	2	3	1	6	5
Score	**2**	**4**	**3**	**5**	**0**	**1**

Table 9.2: Reliability scoring for each system in hyperscale scenario.

9.1 Discussion

The Excool DX only unit is waterless. Therefore, all water components which contribute to unit MTTF are not included. There are more compressors in the Excool DX only which see high usage which does contribute to increasing the MTTF . However, this is not enough to overcome the increase in reliability from the omission of all water components.

9.2 Colocation Reliability Score

	New Excool DX Only	New Excool Water First	New Excool DX first	Chiller & Fan wall only	Hybrid Cooler&Chiller & Fan wall	Direct air (Excool)
Score	3	5	4	1	2	-

9.3 Hyperscale Reliability Score

	New Excool DX Only	New Excool Water First	New Excool DX first	New Excool Direct Air	Chiller & Fan wall only	Hybrid Cooler & Fan wall only (no chiller)
Score	2	4	3	5	0	1

10.0 System complexity

Values for system complexity for all the systems is given in Table 10.1

			Rank	Score
Colocation	100%	New Excool Water First	2	4
		New Excool DX First	2	4
		New Excool DX Only	1	5
		FCW with chiller	4	2
		FCW with hybrid cooler (chiller top up)	5	1
		Direct air (Excool)	n/a	n/a
Hyperscale	100%	New Excool Water First	3	3
		New Excool DX First	3	3
		New Excool DX Only	2	4
		FCW with chiller	5	1
		FCW with hybrid cooler (chiller top up)	6	0
		Direct air (Excool)	1	5

Table 10.1: System complexity scoring for each system for both colocation and hyperscale operators.

10.1 Discussion

The Excool DX only unit is waterless and therefore does not need any water or drainage connections. Therefore, it has less complexity and risk for on-site installation as the Excool water first / DX first.

The scoring of the remaining systems follows the same pattern and discussion as the main report.

10.2 Colocation System Complexity Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	4	4	5	2	1	-

10.3 Hyperscale System Complexity Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	3	3	4	1	0	5

11.0 Spatial Requirements

An assessment of spatial requirements has been performed for each system. The results of this are given in Table 11.1

This has been done using the same methodology as the main report.

			Area needed (m^2)	Rank	Score
Colocation	100%	New Excool Water First	2367	1	5
		New Excool DX First	2367	1	5
		New Excool DX Only	2367	1	5
		FCW with chiller	5545	4	2
		FCW with hybrid cooler (chiller top up)	6045	5	1
		Direct air (Excool)	n/a	n/a	n/a
Hyperscale	100%	New Excool Water First	2367	2	4
		New Excool DX First	2367	2	4
		New Excool DX Only	2367	2	4
		FCW with chiller	5545	6	0
		FCW with hybrid cooler (chiller top up)	5065	5	1
		Direct air (Excool)	1723	1	5

Table 11.1: Spatial requirements for each system for both colocation and hyperscale scenarios

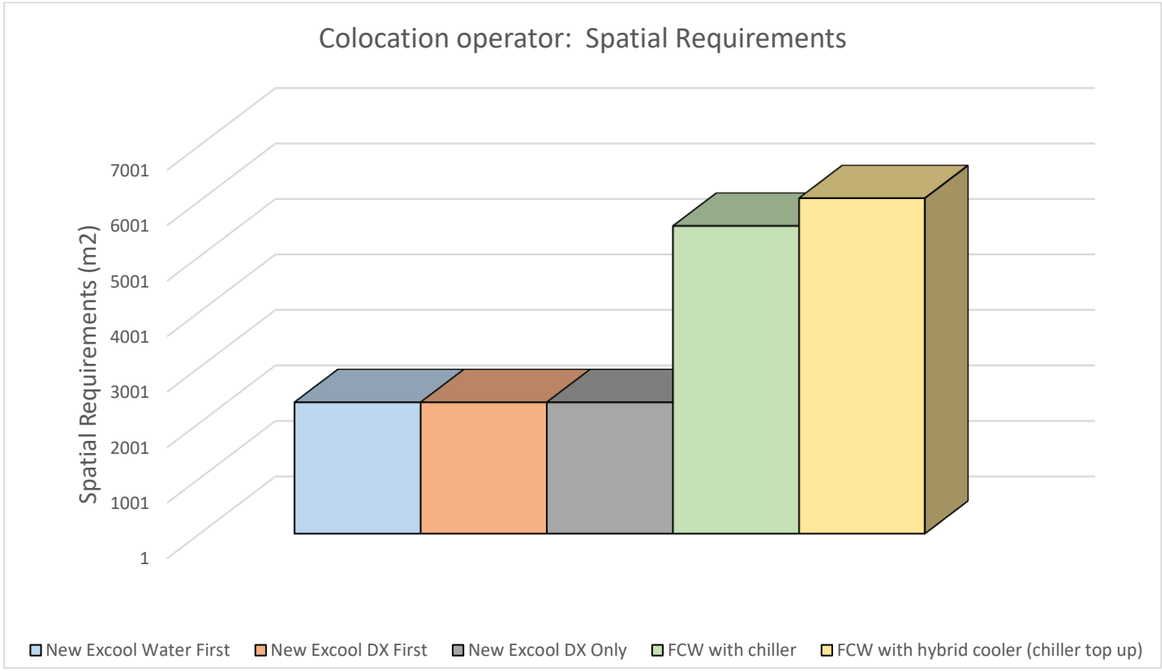


Figure 11.1: Spatial requirement for each system for colocation operator.

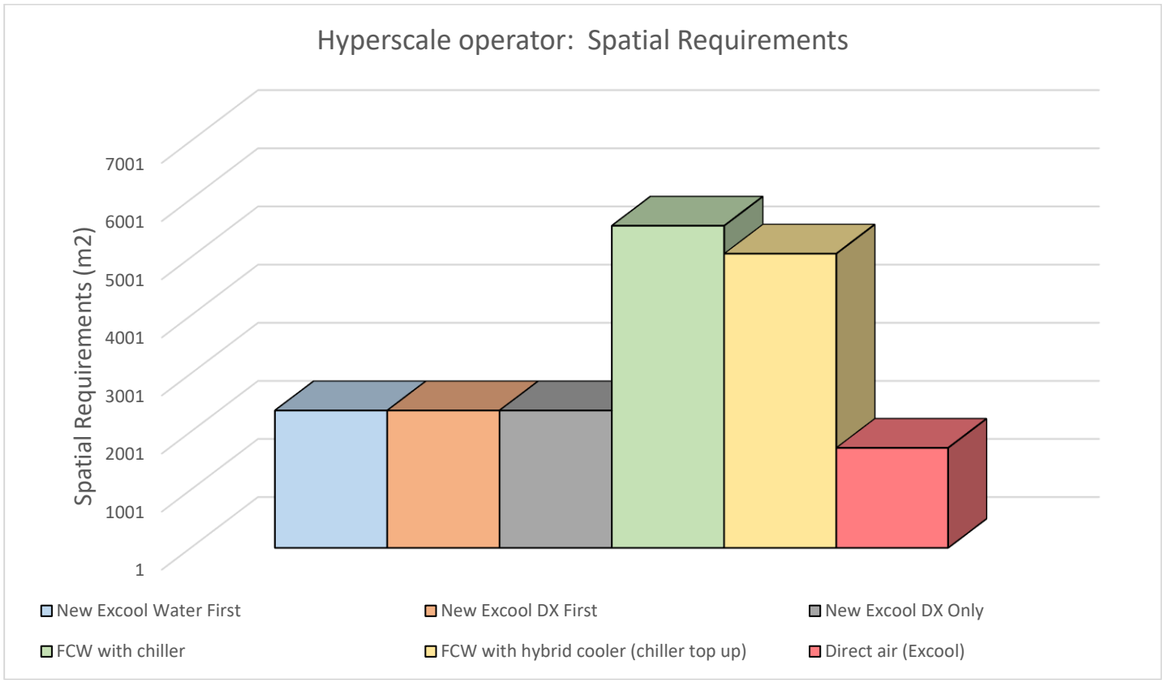


Figure 11.2: Spatial requirement for each system for hyperscale operator.

11.1 Discussion

The space needed for the Excool units is identical between the Excool DX only units and the Excool water first and DX first units.

The scoring of the remaining systems follows the same pattern and discussion as the main report.

11.2 Colocation Spatial Requirements Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	5	5	5	2	1	-

11.3 Hyperscale Spatial Requirements Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	4	4	4	0	1	5

12.0 Humidity Control

An assessment of humidity control has been performed for each system. The results of this are given in Table 12.1

This has been done using the same methodology as the main report.

			Rank	Score
Colocation	100%	New Excool Water First	1	5
		New Excool DX First	1	5
		New Excool DX Only	1	5
		FCW with chiller	1	5
		FCW with hybrid cooler (chiller top up)	1	5
		Direct air (Excool)	n/a	n/a
Hyperscale	100%	New Excool Water First	1	5
		New Excool DX First	1	5
		New Excool DX Only	1	5
		FCW with chiller	1	5
		FCW with hybrid cooler (chiller top up)	1	5
		Direct air (Excool)	6	0

Table 12.1: Humidity control for each system for both colocation and hyperscale scenarios

12.1 Discussion

Humidity control for the DX only unit is done via a pressurisation AHU in the same manner as the Excool water first / DX first systems.

The scoring of the remaining systems follows the same pattern and discussion as the main report.

12.2 Colocation Humidity Control Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	5	5	5	5	5	-

12.3 Hyperscale Humidity Control Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	5	5	5	5	5	0

13.0 Airside Filtration

An assessment of airside filtration has been performed for each system. The results of this are given in Table 13.1

This has been done using the same methodology as the main report.

			Rank	Score
Colocation	100%	New Excool Water First	3	3
		New Excool DX First	3	3
		New Excool DX Only	3	3
		FCW with chiller	1	5
		FCW with hybrid cooler (chiller top up)	1	5
		Direct air (Excool)	n/a	n/a
Hyperscale	100%	New Excool Water First	3	3
		New Excool DX First	3	3
		New Excool DX Only	3	3
		FCW with chiller	1	5
		FCW with hybrid cooler (chiller top up)	1	5
		Direct air (Excool)	6	0

Table 13.1: Airside filtration for each system for both colocation and hyperscale scenarios

13.1 Discussion

Airside filtration for the Excool DX only unit is done in the same manner as the Excool water first / DX first units and so receives the same score.

The scoring of the remaining systems follows the same pattern and discussion as the main report.

13.2 Colocation Airside Filtration Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	3	3	3	5	5	-

13.3 Hyperscale Airside Filtration Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	3	3	3	5	5	0

14.0 Air Quality

An assessment of air quality has been performed for each system. The results of this are given in Table 14.1

This has been done using the same methodology as the main report.

			Rank	Score
Colocation	100%	New Excool Water First	1	5
		New Excool DX First	1	5
		New Excool DX Only	1	5
		FCW with chiller	1	5
		FCW with hybrid cooler (chiller top up)	1	5
		Direct air (Excool)	n/a	n/a
Hyperscale	100%	New Excool Water First	1	5
		New Excool DX First	1	5
		New Excool DX Only	1	5
		FCW with chiller	1	5
		FCW with hybrid cooler (chiller top up)	1	5
		Direct air (Excool)	6	0

Table 14.1: Airside air quality for each system for both colocation and hyperscale scenarios

14.1 Discussion

The Excool DX only unit is an indirect air unit the same as Excool water first / DX first and so therefore has the same data hall quality and receives the same score.

The scoring of the remaining systems follows the same pattern and discussion as the main report.

14.2 Colocation Airside Filtration Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	5	5	5	5	5	-

14.3 Hyperscale Airside Filtration Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	5	5	5	5	5	0

15.0 Acoustics

An assessment of internal and external acoustics has been performed for each system.

This exercise is done qualitatively with a score being assessed based on understanding of the requirements in the system as is justified in the discussion section.

			External Sound Power dB(a)	Internal Sound Power dB(a)	Score
Colocation	100%	New Excool Water First	88	83	5
		New Excool DX First	88	83	5
		New Excool DX Only	88	83	5
		FCW with chiller	88	96	2
		FCW with hybrid cooler (chiller top up)	94	96	1
		Direct air (Excool)	n/a	n/a	n/a
Hyperscale	100%	New Excool Water First	88	83	5
		New Excool DX First	88	83	5
		New Excool DX Only	88	83	5
		FCW with chiller	88	96	2
		FCW with hybrid cooler (chiller top up)	94	96	0
		Direct air (Excool)	89	89	1

Table 15.1: Acoustics for each system for both colocation and hyperscale scenarios.

15.1 Discussion

The Excool unit has the dominant source of external/internal acoustic levels from the fans. Therefore, the Excool DX only unit has the same acoustic values as the Excool water first and DX first units.

The scoring of the remaining systems follows the same pattern and discussion as the main report.

15.2 Colocation Air Quality Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	5	5	5	2	1	-

15.3 Hyperscale Air Quality Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	5	5	5	2	0	1

16.0 Total Peak Mechanical Power

An assessment on total peak mechanical power has been given in Table 16.1 below.

The peak mechanical power will occur at the highest ambient dry bulb temperature. The figures given below are taken from the systems operating under the London ASHRAE N=50 peak dry bulb with mean co-incidence wet bulb.

			Total Power (kW, London N=50 condition)	Rank	Score
Colocation	100%	New Excool Water First	6560	2	4
		New Excool DX First	6560	2	4
		New Excool DX Only	9760	5	1
		FCW with chiller	6604	4	2
		FCW with hybrid cooler (chiller top up)	3652	1	5
		Direct air (Excool)	n/a	n/a	n/a
Hyperscale	100%	New Excool Water First	6560	3	3
		New Excool DX First	6560	3	3
		New Excool DX Only	9760	6	0
		FCW with chiller	6604	5	1
		FCW with hybrid cooler (chiller top up)	1979	2	4
		Direct air (Excool)	972	1	5

Table 16.1: Peak mechanical power for each system for both colocation and hyperscale scenarios

16.1 Discussion

In the colocation scenario the hybrid cooler and fan wall solution has the lowest total peak mechanical power. Since this system only has a chiller operating in trim cooling the compressor power is the lowest. The Excool unit water first / DX first unit has the second best performing peak total power. The chiller system has a slightly higher total peak power than the Excool units, although this difference is very small. The Excool DX only unit has the largest peak total power since, without water to supplement cooling during the most extreme external ambient condition, it has the most compressor power required for heat rejection.

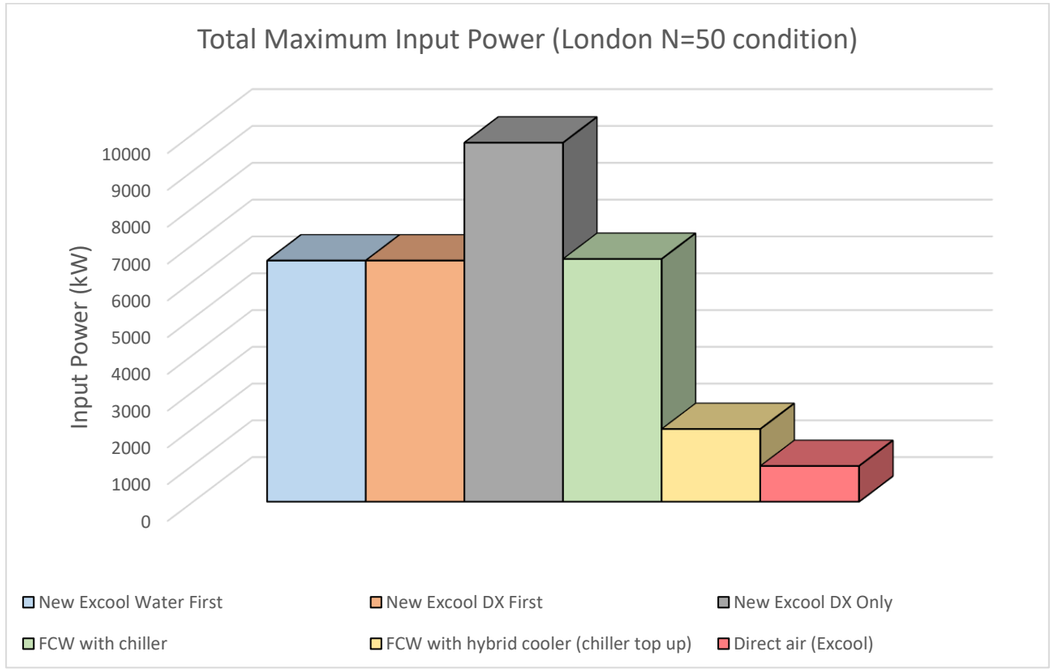
In the hyperscale scenario the Excool direct air is included. The direct air Excool unit is a complete modular cooling unit with low internal resistances and so has the lowest total peak mechanical power. The values amongst the remaining systems follows the same trends as the colocation scenario.

16.2 Colocation Total Peak Mechanical Power Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	4	4	1	2	5	-

16.3 Hyperscale Total Peak Mechanical Power Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	3	3	0	1	4	5



17.0 Refrigerant Quantity

An assessment on total system refrigerant has been given in Table 17.1 below.

			Refrigerant (kg)	Rank	Score
Colocation	100%	New Excool Water First	1320	2	4
		New Excool DX First	1320	2	4
		New Excool DX Only	2640	5	1
		FCW with chiller	1932	4	2
		FCW with hybrid cooler (chiller top up)	1260	1	5
		Direct air (Excool)	n/a	n/a	n/a
Hyperscale	100%	New Excool Water First	1320	3	3
		New Excool DX First	1320	3	3
		New Excool DX Only	2640	6	0
		FCW with chiller	1932	5	1
		FCW with hybrid cooler (chiller top up)	0	1	5
		Direct air (Excool)	0	1	5

Table 17.1: Refrigerant weight for each system for both colocation and hyperscale scenarios

17.1 Discussion

The DX system in the Excool DX only unit is twice as big as the water first / DX first unit since there is no water to supplement the heat rejection in the higher external ambient temperatures. Therefore, it has twice the refrigeration charge as the Excool water first / DX first units and scores the worst in this section.

The hybrid cooler option has the least refrigeration in the colocation option since the chiller is sized for trim cooling only. In the hyperscale scenario both the hybrid cooler and direct air system does not have any DX systems. Therefore, these systems score the best in the hyperscale scenario.

17.2 Colocation Refrigerant Quantity Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	4	4	1	2	5	-

17.3 Hyperscale Refrigerant Quantity Score

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
Score	3	3	0	1	5	5

18.0 Selection Matrix Summary

18.1 Colocation Summary

The summary of the scoring for all systems assessed for the colocation scenario is given in Table 18.1 below.

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)
PUE	4	2	1	3	5
WUE	2	3	5	5	1
Drainage Quantity	5	5	5	5	1
External Water Storage	3	3	5	5	1
External Water treatment	5	5	5	5	1
Legionella	5	5	5	5	5
Maintenance	5	5	5	2	1
Reliability	5	4	3	1	2
Complexity	4	4	5	2	1
Spatial Requirements	5	5	5	2	1
Humidity Control	5	5	5	5	5
Filtration	3	3	3	5	5
Air Quality	5	5	5	5	5
Acoustics	5	5	5	2	1
Peak Total Power	4	4	1	2	5
Refrigerant	4	4	1	2	5
Total	**69**	**67**	**64**	**56**	**45**

Table 18.1: Final scoring for all systems in the colocation scenario.

In the hyperscale scenario the Excool Water first unit score first with a final score of 69 out of 80. The Excool unit DX first unit scores second with 67 out of 80. The Excool unit DX only unit is third place, and worst performing of the indirect Excool units, with a score of 64.

With the introduction of water into the unit, the Excool unit can deliver a better performing PUE with a much lower peak total power and refrigerant requirements. Further, by having the Excool unit operating in water first mode – the unit will use more water but lower greatly the compressor usage. This ultimately leads to higher reliability and lower failure rates.

The scoring trends overall follow the same pattern and discussion as the original report.

18.2 Hyperscale Summary

The summary of the scoring for all systems assessed for the colocation scenario is given in Table 18.2 below.

	New Excool Water First	New Excool DX First	New Excool DX Only	FCW with chiller	FCW with hybrid cooler (chiller top up)	Direct air (Excool)
PUE	3	1	0	2	4	5
WUE	1	3	5	5	0	2
Drainage Quantity	5	5	5	5	0	1
External Water Storage	5	5	5	5	0	1
External Water treatment	5	5	5	5	0	5
Legionella	5	5	5	5	5	5
Maintenance	4	4	4	1	0	5
Reliability	4	3	2	0	1	5
Complexity	3	3	4	1	0	5
Spatial Requirements	4	4	4	0	1	5
Humidity Control	5	5	5	5	5	0
Filtration	3	3	3	5	5	0
Air Quality	5	5	5	5	5	0
Acoustics	5	5	5	2	0	1
Peak Total Power	3	3	0	1	4	5
Refrigerant	3	3	0	1	5	5
Total	**63**	**62**	**57**	**48**	**35**	**50**

Table 18.2: Final scoring for all systems in the hyperscale scenario.

In the hyperscale scenario the Excool Water first unit score first with a final score of 63 out of 80. The Excool unit DX first unit scores second with 62 out of 80. The Excool unit DX only unit is third place, and worst performing of the indirect Excool units, with a score of 57.

In the same way as the colocation scenario - the introduction of water into the unit delivers a better performing PUE with a much lower peak total power and refrigerant requirements. Further, by having the Excool unit operating in water first mode – the unit will use more water but lower greatly the compressor usage. This ultimately leads to higher reliability and lower failure rates.

The scoring trends overall follow the same pattern and discussion as the original report.

19.0 Conclusion

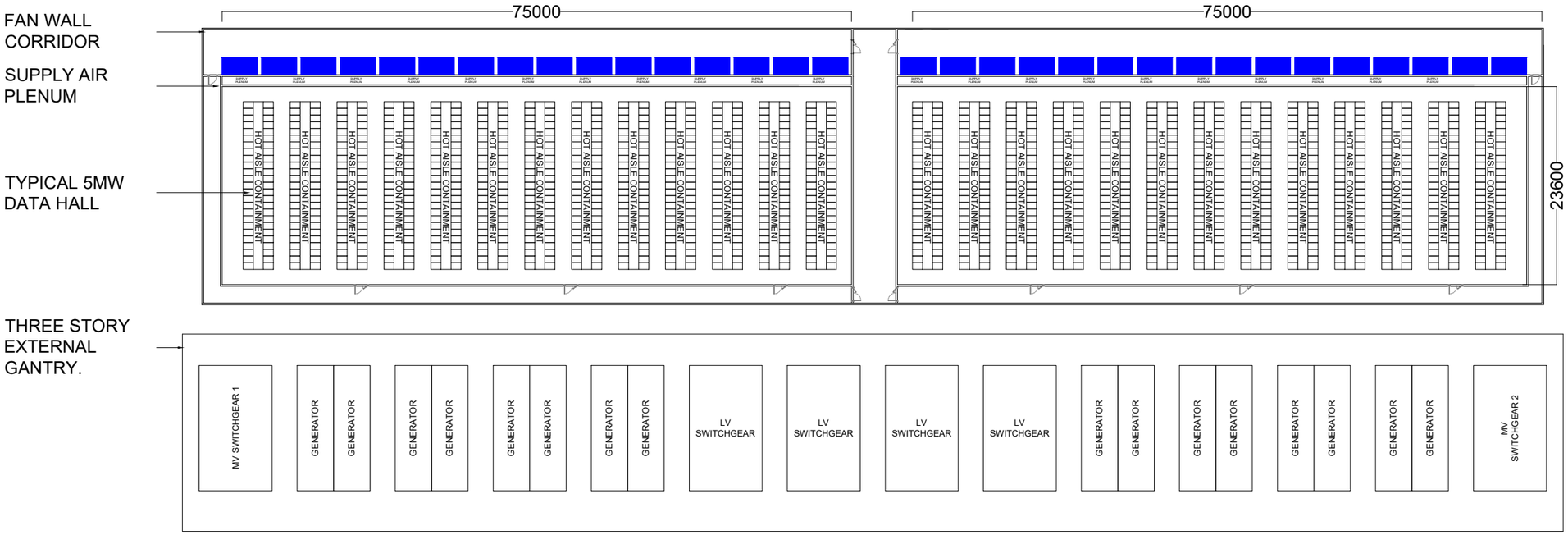
The Excool DX only units can offer an alternative mode of operation to the Excool Zero unit. The waterless nature of it means it scores well in installation complexity, WUE and reliability.

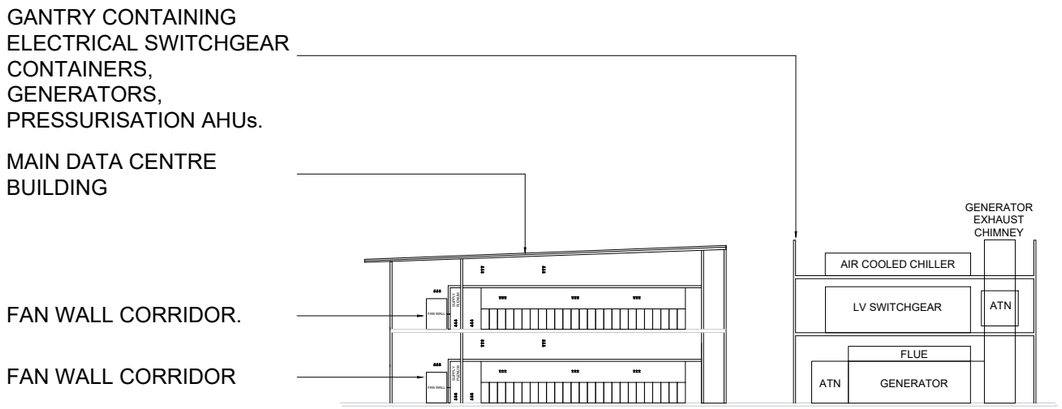
However, the omission of water means the heat rejection at peak summer ambient is done by a DX system twice as large as the standard Excool zero unit. This results in twice the level of refrigerant required and the worst performing peak total power. The latter results in the highest stranded power, resulting in oversized electrical infrastructure and site utility application. This limits the options during a site selection process.

The inclusion of water to the Excool unit allows half of the refrigerant of the Excool DX only unit and a much lower peak total power.

The Excool zero unit in water first operation scores the highest out of all systems in this study for both colocation and hyperscale scenarios.

Appendix A Outline Drawings and Schematics





A3

Notes

Issue	Date	Description	By	Chkd	Verfd

Project
EXCOOL PERFORMANCE REVIEW

Client
EXCOOL

Architect
N/A

Title
CHILLER AND FAN WALL OPTION

GROUND FLOOR LAYOUT

Drawing No.	Drawing Status
SKM-03-01	
Job No.	Scale
1027420	1:600

CUNDALL

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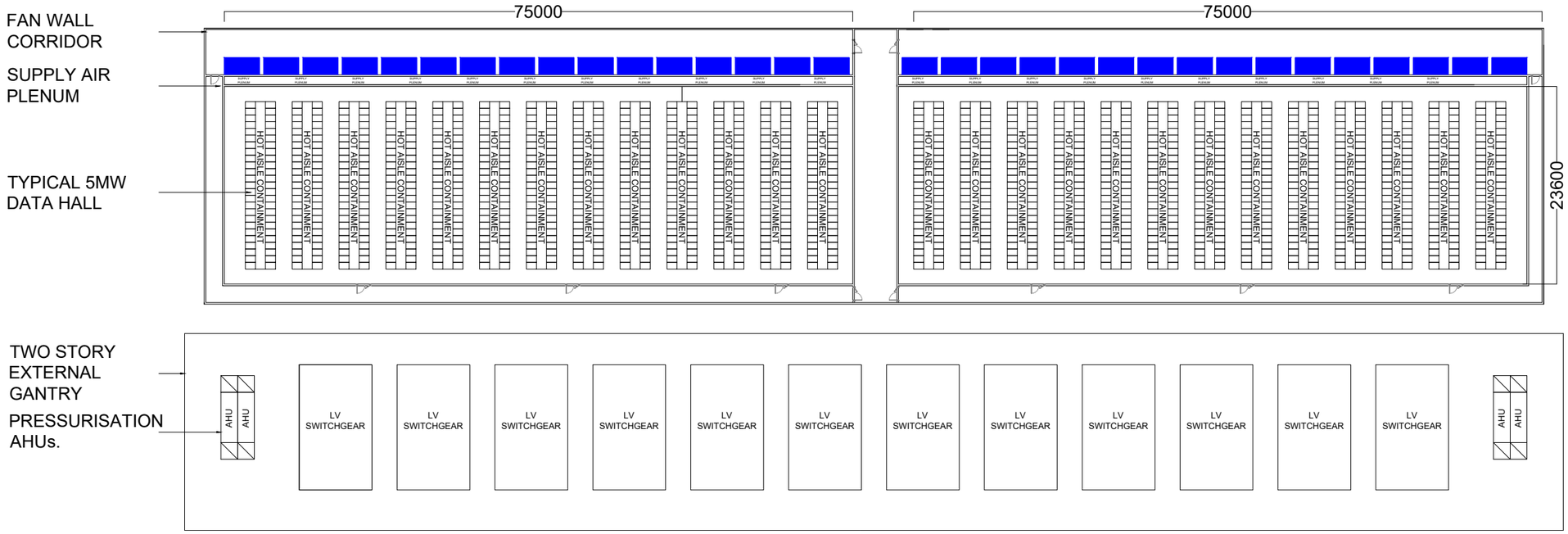
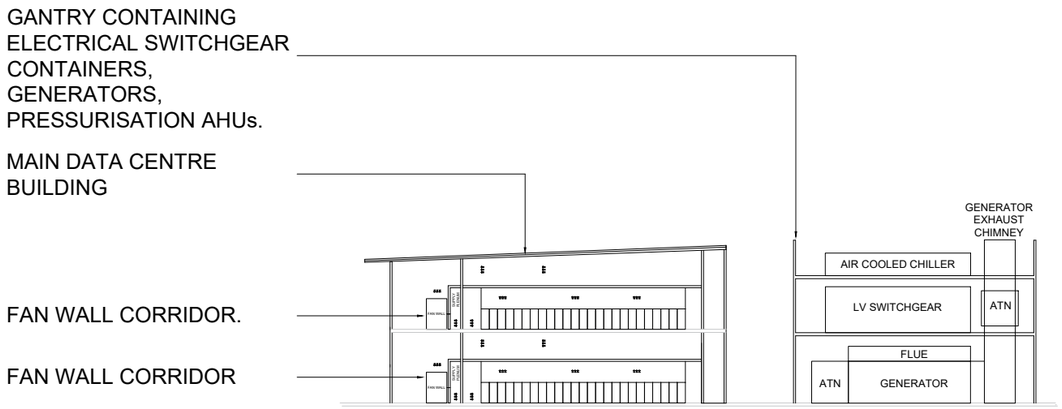
London, EC4V 5ER
Telephone: +44(0)20 7438 1600

Website: www.cundall.com





A3

Notes

Issue	Date	Description	By	Chkd	Verfd

Project
EXCOOL PERFORMANCE REVIEW

Client
EXCOOL

Architect
N/A

Title
CHILLER AND FAN WALL OPTION

FIRST FLOOR LAYOUT

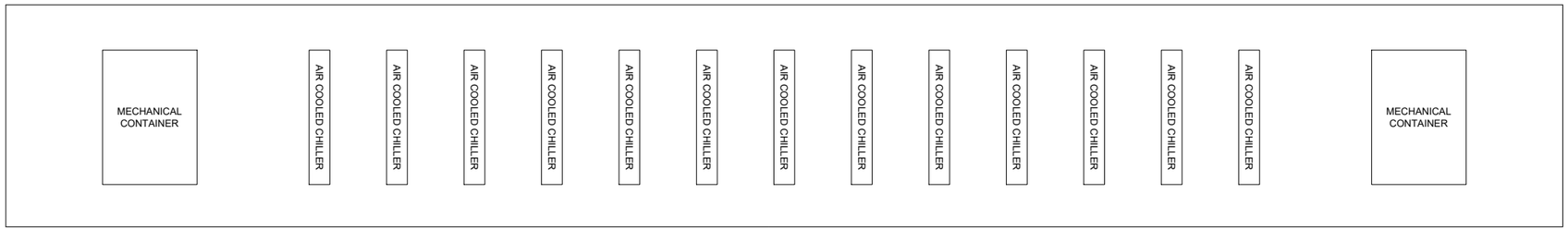
Drawing No.	Drawing Status
SKM-03-02	
Job No.	Scale
1027420	1:600

CUNDALL

One Carter Lane
London, EC4V 5ER
Telephone: +44(0)20 7438 1600

Website: www.cundall.com

ROOF OF MAIN DATA CENTRE BUILDING

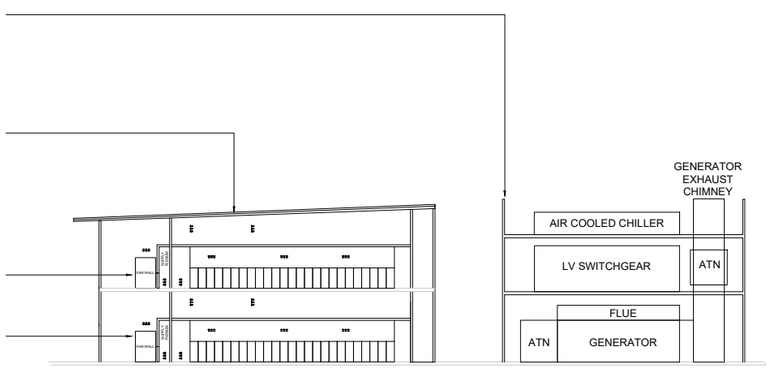


GANTRY CONTAINING ELECTRICAL SWITCHGEAR CONTAINERS, GENERATORS, PRESSURISATION AHUs.

MAIN DATA CENTRE BUILDING

FAN WALL CORRIDOR.

FAN WALL CORRIDOR



A3

Notes

Issue	Date	Description	By	Chkd	Verfd

Project
EXCOOL PERFORMANCE REVIEW

Client
EXCOOL

Architect
N/A

Title
CHILLER AND FAN WALL OPTION

ROOF LAYOUT

Drawing No.	Drawing Status
SKM-03-03	
Job No.	Scale
1027420	1:600

CUNDALL

One Carter Lane
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MECHANICAL PLANT SCHEDULE

ITEM	DESCRIPTION	LOCATION	QUANTITY	RESLIENCE	RATED DUTY	ACCESSORIES
FAN WALL UNITS	INDIRECT AIR COOLING UNITS TO SERVE AS MAIN COOLING PLANT FOR DATA HALL	SERVICES CORRIDOR ADJACENT TO DATA HALL	16 PER HALL 64 UNITS TOTAL	N+2 PER HALL	357 kW SENSIBLE COOLING (EACH)	
AIR COOLED CHILLERS	HEAT REJECTION PLANT FOR DATA CENTRE. WATER CIRCUIT IS 21 / 31 °C WITH ASSUMED 20% GLYCOL	THIRD LEVEL OF EXTERNAL GANTRY COMPOUND	13 TOTAL	N+1	1660 kW PER CHILLER	PUMPS
PRESSURISATION AHUS	SUPPLY ONLY AHU TO PROVIDE HUMIDIFICATION AND PRESSURISATION TO DATA HALL SPACES	EXTERNAL MULTI LEVEL GANTRY ADJACENT TO MAIN DATA CENTER BUILDING	4 TOTAL	N+1 UNITS PER 2 HALLS	2.6 m3/s SUPPLY AIR EACH	ELECTRIC PRE-HEAT COIL G4/F7 FILTERS 2No SUPPLY FANS WETTED MEDIA HUMIDIFIER

ELECTRICAL PLANT SCHEDULE

ITEM	DESCRIPTION	LOCATION	QUANTITY	RATED DUTY	ACCESSORIES
MV - LV TRANSFORMER	22kV TO 0.4kV TRANSFORMER	EXTERNAL MULTI LEVEL GANTRY	4 PER HALL 16 UNITS TOTAL	3000 kVA	
MAIN LV SWITCHGEAR	SWITCHGEAR THAT FEEDS CRITICAL LOADS (VIA UPS) AND NON CRITICAL LOADS (NON CRITICAL MECH + ANCILLARIES)	EXTERNAL MULTI LEVEL GANTRY	4 PER HALL 16 UNITS TOTAL	5000 A	
UPS	UPS SYSTEM TO SERVE CRITICAL LOADS. INCLUDES BATTERIES RATED AT 15 MINUTES OF FULL LOAD	EXTERNAL MULTI LEVEL GANTRY	4 PER HALL 16 UNITS TOTAL	1660kW UPS 3000 A UPS SWITCHBOARD	
GENERATOR	BACKUP GENERATOR SERVING THE MAIN LV SWITCHGEAR	EXTERNAL MULTI LEVEL GANTRY	4 PER HALL 16 UNITS TOTAL	3000 kW	INTEGRAL FUEL BELLY TANK RATED AT 24 HOURS OF DIESEL STORAGE

A3

Notes

Issue	Date	Description	By	Chkd	Verfd

Project
EXCOOL PERFORMANCE REVIEW

Client
EXCOOL

Architect
N/A

Title
CHILLER AND FAN WALL OPTION

MAIN EQUIPMENT SCHEDULE

Drawing No.
SKM-03-04

Drawing Status

Job No.
1027420

Scale
1:600

CUNDALL

One Carter Lane
London, EC4V 5ER
Telephone: +44(0)20 7438 1600

Website: www.cundall.com

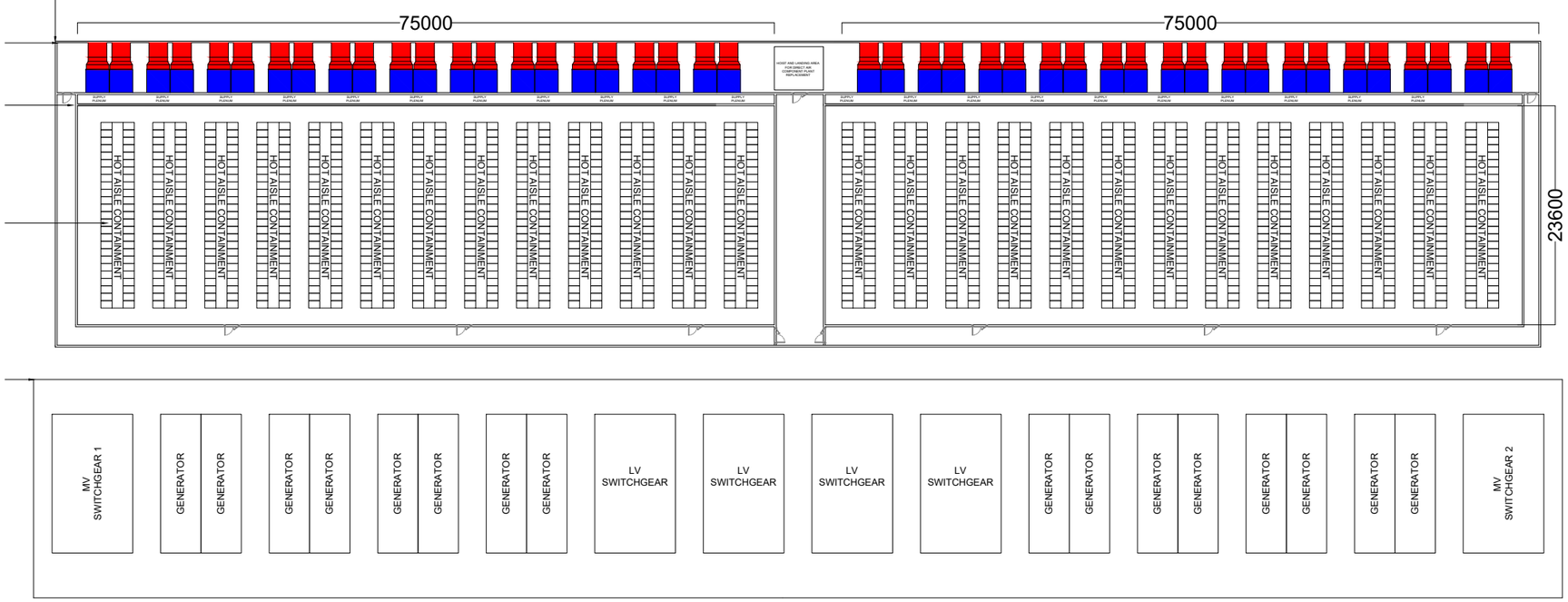
EXTERNAL GANTRY.

INTAKE LOUVRE

SUPPLY AIR PLENUM

TYPICAL 5MW DATA HALL

TWO STORY EXTERNAL GANTRY TO ACCOMMODATE ELECTRICAL CONTAINERS.

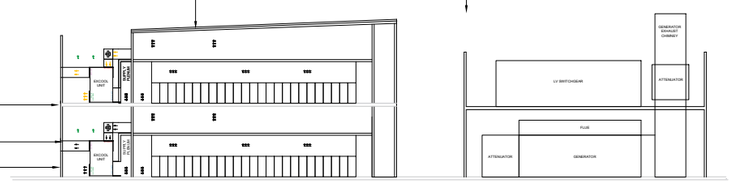


EXTERNAL MULTI LEVEL GANTRY TO HOUSE ELECTRICAL SWITCHGEAR CONTAINERS, GENERATORS

MAIN DATA CENTRE BUILDING

FLOOR GRATING.

EXHAUST LOUVRE SOLID FACE



A3

Notes

Issue	Date	Description	By	Chkd	Verfd

Project
EXCOOL PERFORMANCE REVIEW

Client
EXCOOL

Architect
N/A

Title
EXCOOL DIRECT AIR

GROUND FLOOR LAYOUT

Drawing No.	Drawing Status
SKM-01-01	
Job No.	Scale
1027420	1:600

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One Carter Lane
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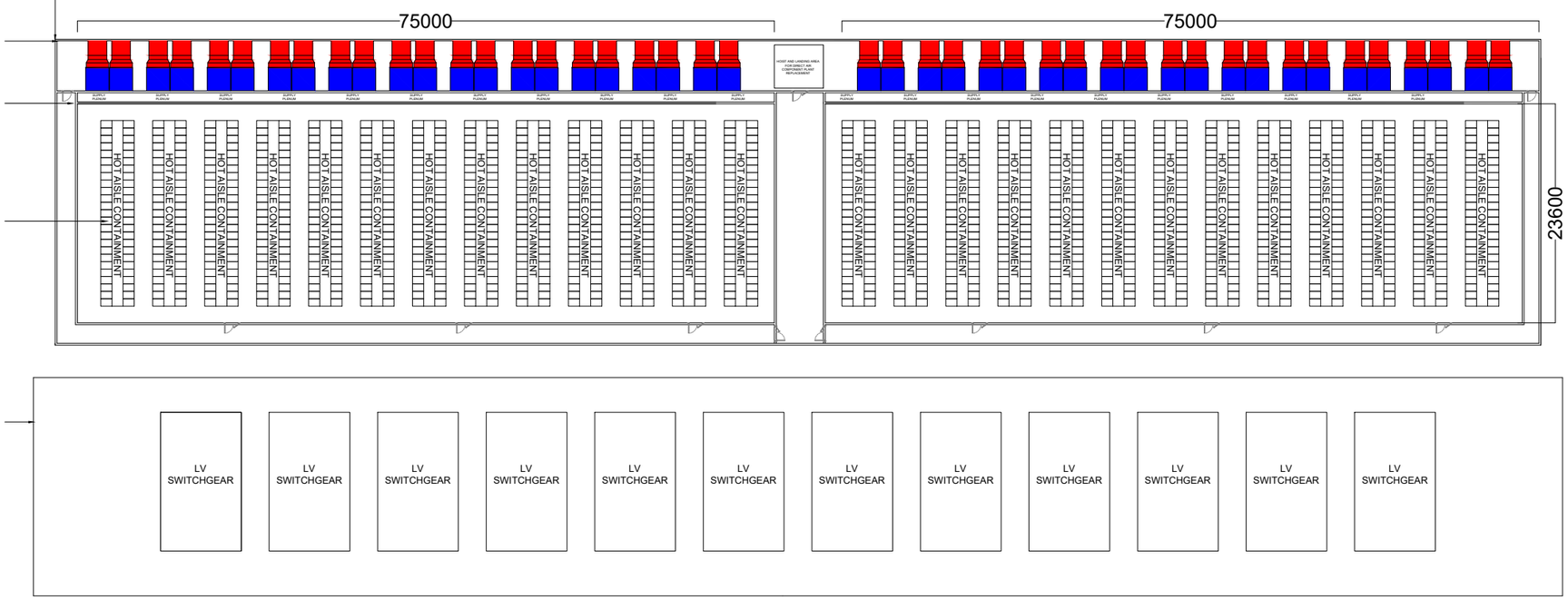
EXTERNAL GANTRY.

INTAKE LOUVRE

SUPPLY AIR PLENUM

TYPICAL 5MW DATA HALL

TWO STORY EXTERNAL GANTRY TO ACCOMMODATE ELECTRICAL CONTAINERS.

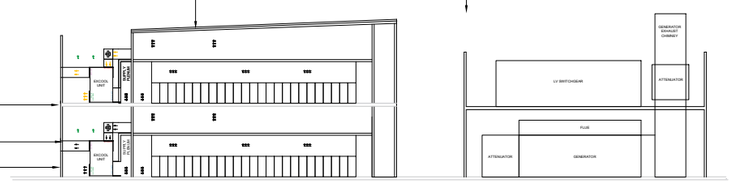


EXTERNAL MULTI LEVEL GANTRY TO HOUSE ELECTRICAL SWITCHGEAR CONTAINERS, GENERATORS

MAIN DATA CENTRE BUILDING

FLOOR GRATING.

EXHAUST LOUVRE SOLID FACE



A3

Notes

Issue	Date	Description	By	Chkd	Verfd

Project
EXCOOL PERFORMANCE REVIEW

Client
EXCOOL

Architect
N/A

Title
EXCOOL DIRECT AIR

FIRST FLOOR LAYOUT

Drawing No.	Drawing Status
SKM-01-02	
Job No.	Scale
1027420	1:600

CUNDALL

One Carter Lane
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Telephone: +44(0)20 7438 1600

Website: www.cundall.com

MECHANICAL PLANT SCHEDULE

ITEM	DESCRIPTION	LOCATION	QUANTITY	RESLIENCE	RATED DUTY	ACCESSORIES
IAC UNITS	DIRECT AIR COOLING UNITS TO SERVE AS MAIN COOLING PLANT FOR DATA HALL	GANTRY ADJACENT TO DATA HALL	22 PER HALL 88 UNITS TOTAL	N+2 PER HALL	250 kW SENSIBLE COOLING	

ELECTRICAL PLANT SCHEDULE

ITEM	DESCRIPTION	LOCATION	QUANTITY	RATED DUTY	ACCESSORIES
MV - LV TRANSFORMER	22kV TO 0.4kV TRANSFORMER	EXTERNAL MULTI LEVEL GANTRY	4 PER HALL 16 UNITS TOTAL	2500 kVA	
MAIN LV SWITCHGEAR	SWITCHGEAR THAT FEEDS CRITICAL LOADS (VIA UPS) AND NON CRITICAL LOADS (NON CRITICAL MECH + ANCILLARIES)	EXTERNAL MULTI LEVEL GANTRY	4 PER HALL 16 UNITS TOTAL	4000 A	
UPS	UPS SYSTEM TO SERVE CRITICAL LOADS. INCLUDES BATTERIES RATED AT 15 MINUTES OF FULL LOAD	EXTERNAL MULTI LEVEL GANTRY	4 PER HALL 16 UNITS TOTAL	1660kW UPS 3000 A UPS SWITCHBOARD	
GENERATOR	BACKUP GENERATOR SERVING THE MAIN LV SWITCHGEAR	EXTERNAL MULTI LEVEL GANTRY	4 PER HALL 16 UNITS TOTAL	2000 kW	INTEGRAL FUEL BELLY TANK RATED AT 24 HOURS OF DIESEL STORAGE

A3

Notes

Issue	Date	Description	By	Chkd	Verfd

Project
EXCOOL PERFORMANCE REVIEW

Client
EXCOOL

Architect
N/A

Title
EXCOOL DIRECT AIR

MAIN EQUIPMENT SCHEDULE

Drawing No.	Drawing Status
SKM-01-03	
Job No.	Scale
1027420	1:600

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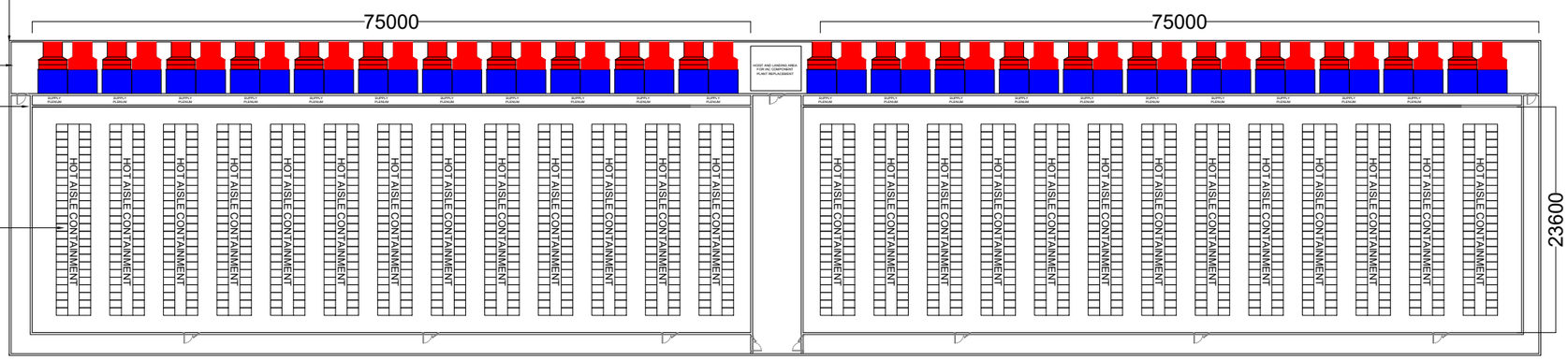
Website: www.cundall.com

EXTERNAL GANTRY.

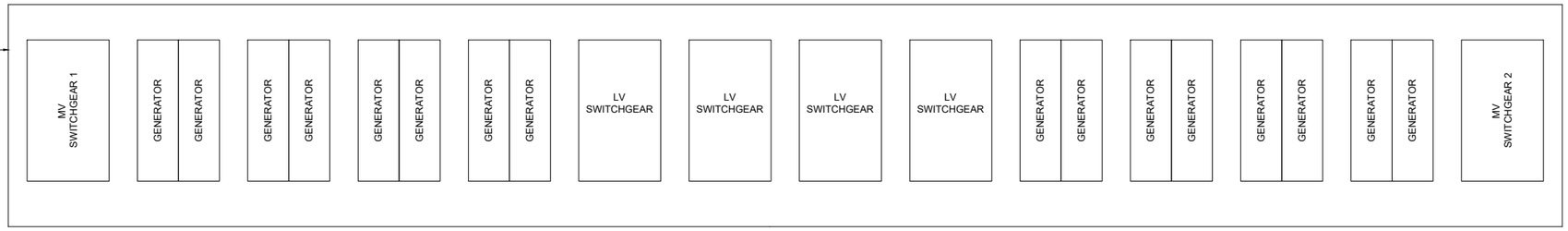
INTAKE LOUVRE

SUPPLY AIR PLENUM

TYPICAL 5MW DATA HALL.



TWO STORY EXTERNAL GANTRY

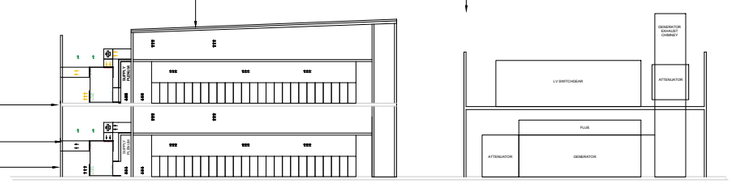


EXTERNAL MULTI LEVEL GANTRY TO HOUSE ELECTRICAL SWITCHGEAR CONTAINERS, GENERATORS

MAIN DATA CENTRE BUILDING

FLOOR GRATING.

EXHAUST LOUVRE SOLID FACE



A3

Notes

Issue	Date	Description	By	Chkd	Verfd

Project
EXCOOL PERFORMANCE REVIEW

Client
EXCOOL

Architect
N/A

Title
EXCOOL ZERO

GROUND FLOOR LAYOUT

Drawing No.	Drawing Status
SKM-02-01	
Job No.	Scale
1027420	1:600

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One Carter Lane
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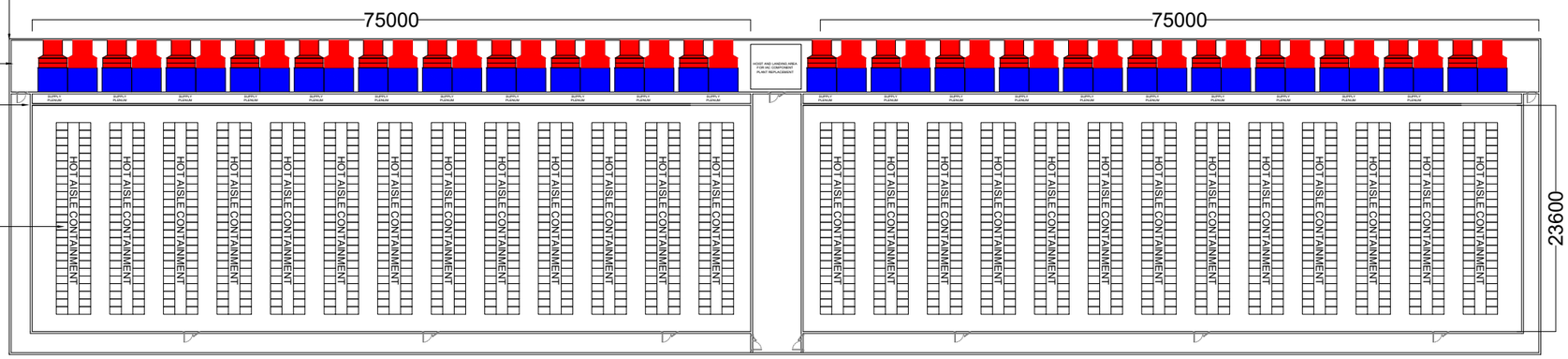
Website: www.cundall.com

EXTERNAL GANTRY.

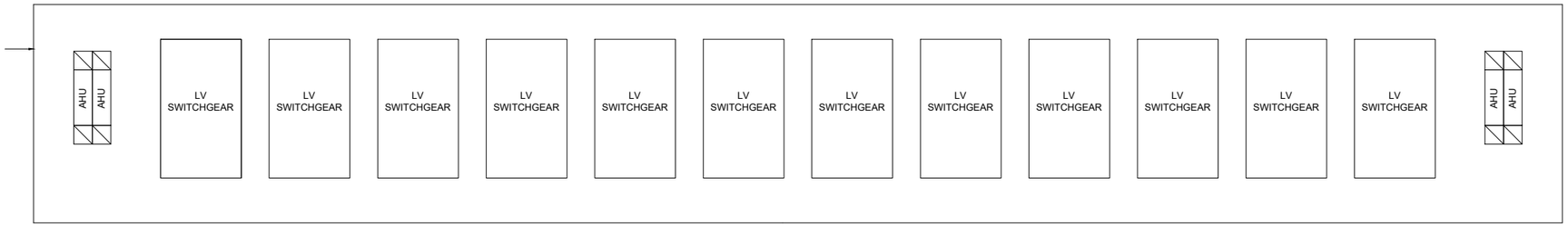
INTAKE LOUVRE

SUPPLY AIR PLENUM

TYPICAL 5MW DATA HALL.



TWO STORY EXTERNAL GANTRY



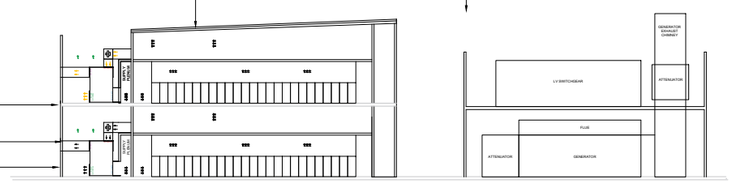
EXTERNAL MULTI LEVEL GANTRY TO HOUSE ELECTRICAL SWITCHGEAR CONTAINERS, GENERATORS

MAIN DATA CENTRE BUILDING

FLOOR GRATING.

EXHAUST LOUVRE

SOLID FACE



A3

Notes

Issue	Date	Description	By	Chkd	Verfd

Project
EXCOOL PERFORMANCE REVIEW

Client
EXCOOL

Architect
N/A

Title
EXCOOL ZERO

FIRST FLOOR LAYOUT

Drawing No.	Drawing Status
SKM-02-02	
Job No.	Scale
1027420	1:600

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Telephone: +44(0)20 7438 1600

Website: www.cundall.com

MECHANICAL PLANT SCHEDULE

ITEM	DESCRIPTION	LOCATION	QUANTITY	RESLIENCE	RATED DUTY	ACCESSORIES
IAC UNITS	INDIRECT AIR COOLING UNITS TO SERVE AS MAIN COOLING PLANT FOR DATA HALL	GANTRY ADJACENT TO DATA HALL	22 PER HALL 88 UNITS TOTAL	N+2 PER HALL	250 kW SENSIBLE COOLING	
PRESSURISATION AHUS	SUPPLY ONLY AHU TO PROVIDE HUMIDIFICATION AND PRESSURISATION TO DATA HALL SPACES	EXTERNAL MULTI LEVEL GANTRY ADJACENT TO MAIN DATA CENTER BUILDING	4 TOTAL	N+1 UNITS PER 2 HALLS	2.6 m3/s SUPPLY AIR EACH	ELECTRIC PRE-HEAT COIL G4/F7 FILTERS 2No SUPPLY FANS WETTED MEDIA HUMIDIFIER

ELECTRICAL PLANT SCHEDULE

ITEM	DESCRIPTION	LOCATION	QUANTITY	RATED DUTY	ACCESSORIES
MV - LV TRANSFORMER	22kV TO 0.4kV TRANSFORMER	EXTERNAL MULTI LEVEL GANTRY	4 PER HALL 16 UNITS TOTAL	3000 kVA	
MAIN LV SWITCHGEAR	SWITCHGEAR THAT FEEDS CRITICAL LOADS (VIA UPS) AND NON CRITICAL LOADS (NON CRITICAL MECH + ANCILLARIES)	EXTERNAL MULTI LEVEL GANTRY	4 PER HALL 16 UNITS TOTAL	5000 A	
UPS	UPS SYSTEM TO SERVE CRITICAL LOADS. INCLUDES BATTERIES RATED AT 15 MINUTES OF FULL LOAD	EXTERNAL MULTI LEVEL GANTRY	4 PER HALL 16 UNITS TOTAL	1660kW UPS 3000 A UPS SWITCHBOARD	
GENERATOR	BACKUP GENERATOR SERVING THE MAIN LV SWITCHGEAR	EXTERNAL MULTI LEVEL GANTRY	4 PER HALL 16 UNITS TOTAL	3000 kW	INTEGRAL FUEL BELLY TANK RATED AT 24 HOURS OF DIESEL STORAGE

A3

Notes

Issue	Date	Description	By	Chkd	Verfd

Project
EXCOOL PERFORMANCE REVIEW

Client
EXCOOL

Architect
N/A

Title
EXCOOL ZERO

MAIN EQUIPMENT SCHEDULE

Drawing No.	Drawing Status
SKM-02-03	
Job No.	**Scale**
1027420	1:600

CUNDALL

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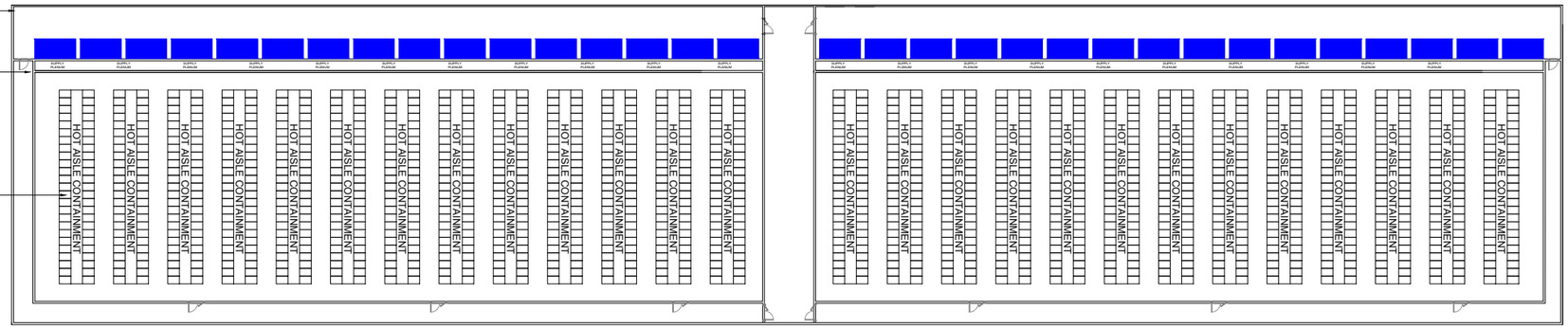
London, EC4V 5ER
Telephone: +44(0)20 7438 1600

Website: www.cundall.com

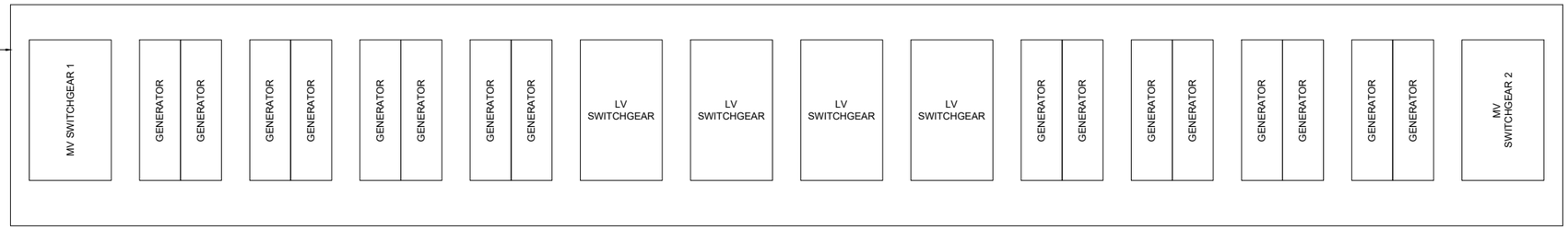
FAN WALL CORRIDOR

SUPPLY AIR PLENUM

TYPICAL 5MW DATA HALL.



THREE STORY EXTERNAL GANTRY



PROCESS WATER PLANT ROOM 2

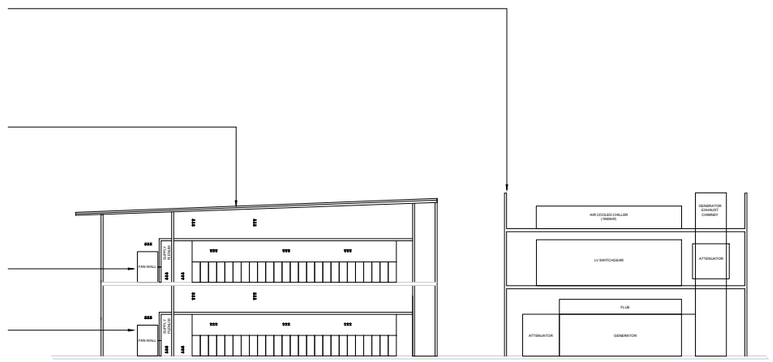
PROCESS WATER PLANT ROOM 2

EXTERNAL MULTI LEVEL GANTRY CONTAINING ELECTRICAL SWITCHGEAR CONTAINERS, GENERATORS, PRESSURISATION AHUs.

MAIN DATA CENTRE BUILDING

FAN WALL CORRIDOR.

FAN WALL CORRIDOR



A3

Notes

Issue	Date	Description	By	Chkd	Verfd

Project

EXCOOL PERFORMANCE REVIEW

Client

EXCOOL

Architect

N/A

Title

HYBRID COOLER AND CHILLER

GROUND FLOOR LAYOUT

Drawing No.	Drawing Status
SKM-04-01	
Job No.	Scale
1027420	1:600

CUNDALL

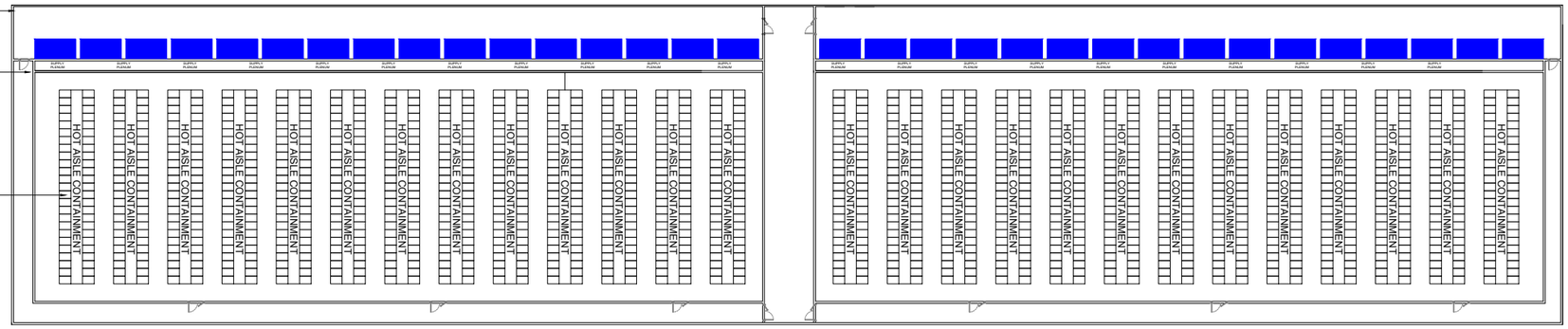
One Carter Lane
London, EC4V 5ER
Telephone: +44(0)20 7438 1600

Website: www.cundall.com

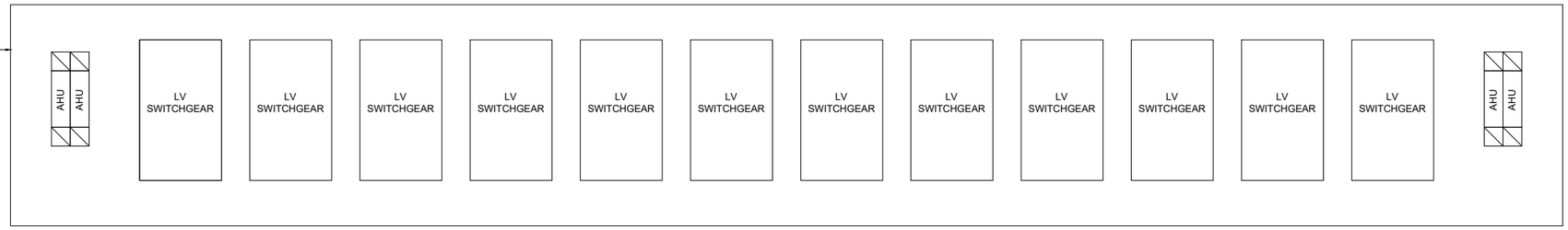
FAN WALL CORRIDOR

SUPPLY AIR PLENUM

TYPICAL 5MW DATA HALL.



THREE STORY EXTERNAL GANTRY

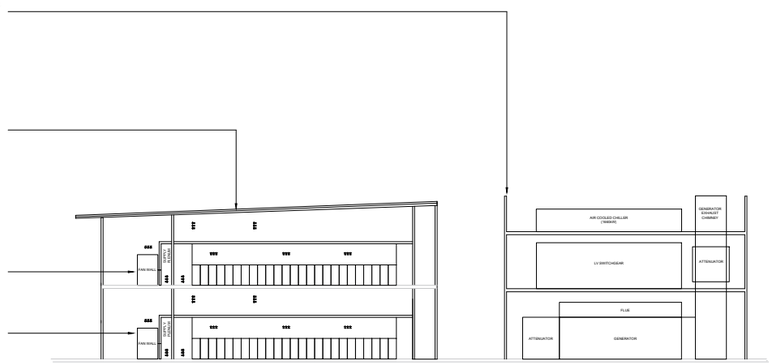


EXTERNAL MULTI LEVEL GANTRY CONTAINING ELECTRICAL SWITCHGEAR CONTAINERS, GENERATORS, PRESSURISATION AHUs.

MAIN DATA CENTRE BUILDING

FAN WALL CORRIDOR.

FAN WALL CORRIDOR



A3

Notes

Issue	Date	Description	By	Chkd	Verfd

Project

EXCOOL PERFORMANCE REVIEW

Client

EXCOOL

Architect

N/A

Title

HYBRID COOLER AND CHILLER

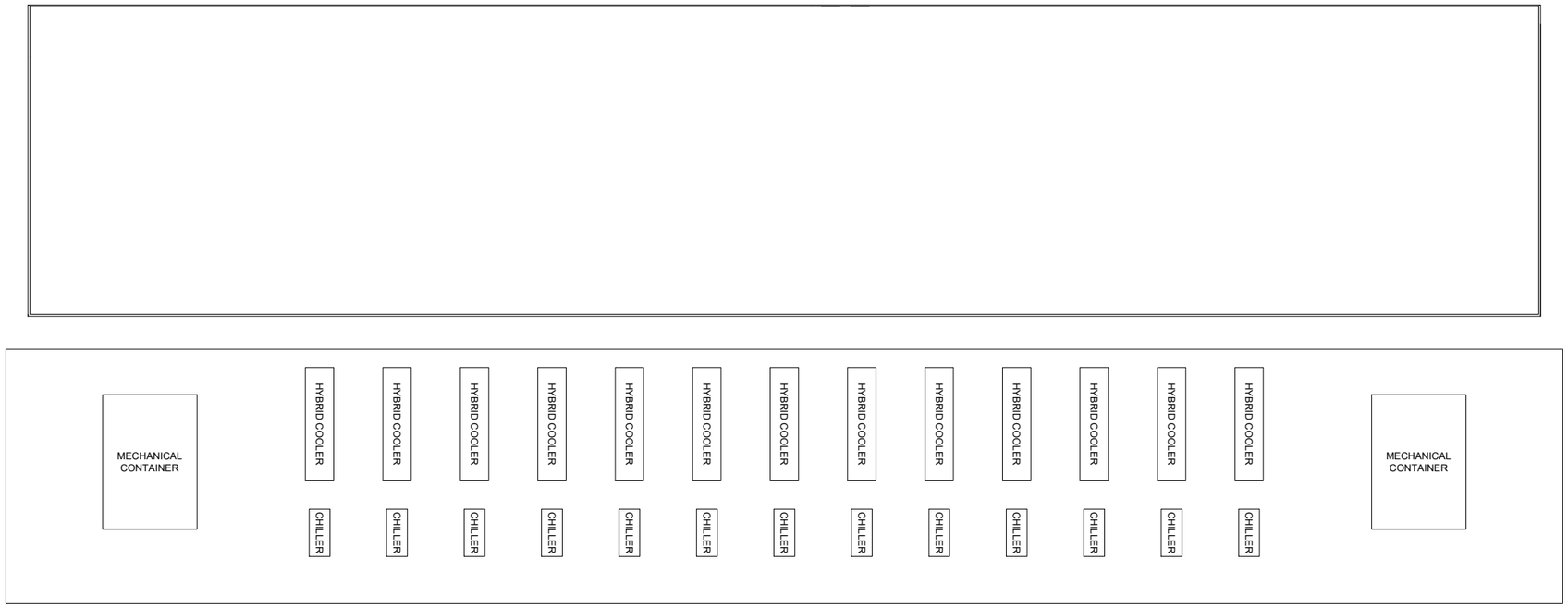
FIRST FLOOR LAYOUT

Drawing No.	Drawing Status
SKM-04-02	
Job No.	Scale
1027420	1:600

CUNDALL

One Carter Lane
London, EC4V 5ER
Telephone: +44(0)20 7438 1600

Website: www.cundall.com

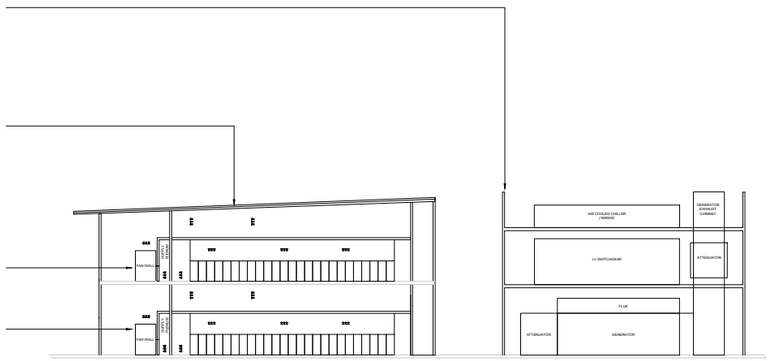


EXTERNAL MULTI LEVEL GANTRY CONTAINING ELECTRICAL SWITCHGEAR CONTAINERS, GENERATORS, PRESSURISATION AHUs.

MAIN DATA CENTRE BUILDING

FAN WALL CORRIDOR.

FAN WALL CORRIDOR



Notes

Issue	Date	Description	By	Chkd	Verfd

Project
EXCOOL PERFORMANCE REVIEW

Client
EXCOOL

Architect
N/A

Title
HYBRID COOLER AND CHILLER

ROOF LAYOUT

Drawing No.	Drawing Status
SKM-04-03	
Job No.	Scale
1027420	1:600

CUNDALL

One Carter Lane
London, EC4V 5ER
Telephone: +44(0)20 7438 1600

Website: www.cundall.com

MECHANICAL PLANT SCHEDULE
COLOCATION SCENARIO

ITEM	DESCRIPTION	LOCATION	QUANTITY	RESLIENCE	RATED DUTY	ACCESSORIES
FAN WALL UNITS	INDIRECT AIR COOLING UNITS TO SERVE AS MAIN COOLING PLANT FOR DATA HALL	SERVICES CORRIDOR ADJACENT TO DATA HALL	16 PER HALL 64 UNITS TOTAL	N+2 PER HALL	357 kW SENSIBLE COOLING (EACH)	
HYBRID COOLERS	PRIMARY PLANT FOR HEAT REJECTION FROM DATA HALL. CAN PROVIDE FULL COOLING FOR 99% OF YEAR (TYPICAL)	THIRD LEVEL OF EXTERNAL GANTRY COMPOUND	13 UNITS TOTAL	N+1	1660 kW PER UNIT	PUMPS DOSING UNIT ASSOCIATE VALVES AND FITTINGS
AIR COOLED CHILLERS	TRIM CHILLER USED IN 1% OF YEAR THAT HYBRID COOLER CANNOT ACHIEVE 100% COOLING DUTY.	THIRD LEVEL OF EXTERNAL GANTRY COMPOUND	13 UNITS TOTAL	N+1	550 kW PER UNIT	
PRESSURISATION AHUS	SUPPLY ONLY AHU TO PROVIDE HUMIDIFICATION AND PRESSURISATION TO DATA HALL SPACES	EXTERNAL MULTI LEVEL GANTRY ADJACENT TO MAIN DATA CENTER BUILDING	4 TOTAL	N+1 UNITS PER 2 HALLS	2.6 m3/s SUPPLY AIR EACH	ELECTRIC PRE-HEAT COIL G4/F7 FILTERS 2No SUPPLY FANS WETTED MEDIA HUMIDIFIER

ELECTRICAL PLANT SCHEDULE
COLOCATION SCENARIO

ITEM	DESCRIPTION	LOCATION	QUANTITY	RATED DUTY	ACCESSORIES
MV - LV TRANSFORMER	22kV TO 0.4kV TRANSFORMER	EXTERNAL MULTI LEVEL GANTRY	4 PER HALL 16 UNITS TOTAL	3000 kVA	
MAIN LV SWITCHGEAR	SWITCHGEAR THAT FEEDS CRITICAL LOADS AND NON CRITICAL LOADS	EXTERNAL MULTI LEVEL GANTRY	4 PER HALL 16 UNITS TOTAL	5000 A	
UPS	UPS SYSTEM TO SERVE CRITICAL LOADS. INCLUDES BATTERIES RATED AT 15 MINUTES OF FULL LOAD	EXTERNAL MULTI LEVEL GANTRY	4 PER HALL 16 UNITS TOTAL	1660KW UPS 3000 A UPS SWITCHBOARD	
GENERATOR	BACKUP GENERATOR SERVING THE MAIN LV SWITCHGEAR	EXTERNAL MULTI LEVEL GANTRY	4 PER HALL 16 UNITS TOTAL	2500 kW	INTEGRAL FUEL BELLY TANK RATED AT 24 HOURS OF DIESEL STORAGE

A3

Notes

Issue	Date	Description	By	Chkd	Verfd

Project
EXCOOL PERFORMANCE REVIEW

Client
EXCOOL

Architect
N/A

Title
HYBRID COOLER AND CHILLER

MAIN EQUIPMENT SCHEDULE 1

Drawing No.	Drawing Status
SKM-04-04	
Job No.	Scale
1027420	1:600

CUNDALL

One Carter Lane
London, EC4V 5ER
Telephone: +44(0)20 7438 1600

Website: www.cundall.com

MECHANICAL PLANT SCHEDULE
HYPERSCALE SCENARIO

ITEM	DESCRIPTION	LOCATION	QUANTITY	RESLIENCE	RATED DUTY	ACCESSORIES
FAN WALL UNITS	INDIRECT AIR COOLING UNITS TO SERVE AS MAIN COOLING PLANT FOR DATA HALL	SERVICES CORRIDOR ADJACENT TO DATA HALL	16 PER HALL 64 UNITS TOTAL	N+2 PER HALL	357 kW SENSIBLE COOLING (EACH)	
HYBRID COOLERS	PRIMARY PLANT FOR HEAT REJECTION FROM DATA HALL. CAN PROVIDE FULL COOLING FOR 100% OF YEAR	THIRD LEVEL OF EXTERNAL GANTRY COMPOUND	7 UNITS PER 2 DATA HALLS	N+1 PER 2 HALLS	1660 kW PER UNIT	PUMPS DOSING UNIT ASSOCIATE VALVES AND FITTINGS
PRESSURISATION AHUS	SUPPLY ONLY AHU TO PROVIDE HUMIDIFICATION AND PRESSURISATION TO DATA HALL SPACES	EXTERNAL MULTI LEVEL GANTRY ADJACENT TO MAIN DATA CENTER BUILDING	4 TOTAL	N+1 UNITS PER 2 HALLS	2.6 m3/s SUPPLY AIR EACH	ELECTRIC PRE-HEAT COIL G4/F7 FILTERS 2No SUPPLY FANS WETTED MEDIA HUMIDIFIER

ELECTRICAL PLANT SCHEDULE
HYPERSCALE SCENARIO

ITEM	DESCRIPTION	LOCATION	QUANTITY	RATED DUTY	ACCESSORIES
MV - LV TRANSFORMER	22kV TO 0.4kV TRANSFORMER	EXTERNAL MULTI LEVEL GANTRY	4 PER HALL 16 UNITS TOTAL	3000 kVA	
MAIN LV SWITCHGEAR	SWITCHGEAR THAT FEEDS CRITICAL LOADS AND NON CRITICAL LOADS	EXTERNAL MULTI LEVEL GANTRY	4 PER HALL 16 UNITS TOTAL	4000 A	
UPS	UPS SYSTEM TO SERVE CRITICAL LOADS. INCLUDES BATTERIES RATED AT 15 MINUTES OF FULL LOAD	EXTERNAL MULTI LEVEL GANTRY	4 PER HALL 16 UNITS TOTAL	3000 A	
GENERATOR	BACKUP GENERATOR SERVING THE MAIN LV SWITCHGEAR	EXTERNAL MULTI LEVEL GANTRY	4 PER HALL 16 UNITS TOTAL	2000 kW	INTEGRAL FUEL BELLY TANK RATED AT 24 HOURS OF DIESEL STORAGE

A3

Notes

Issue	Date	Description	By	Chkd	Verfd

Project
EXCOOL PERFORMANCE REVIEW

Client
EXCOOL

Architect
N/A

Title
HYBRID COOLER AND CHILLER

MAIN EQUIPMENT SCHEDULE 2

Drawing No.	Drawing Status
SKM-04-05	
Job No.	**Scale**
1027420	1:600

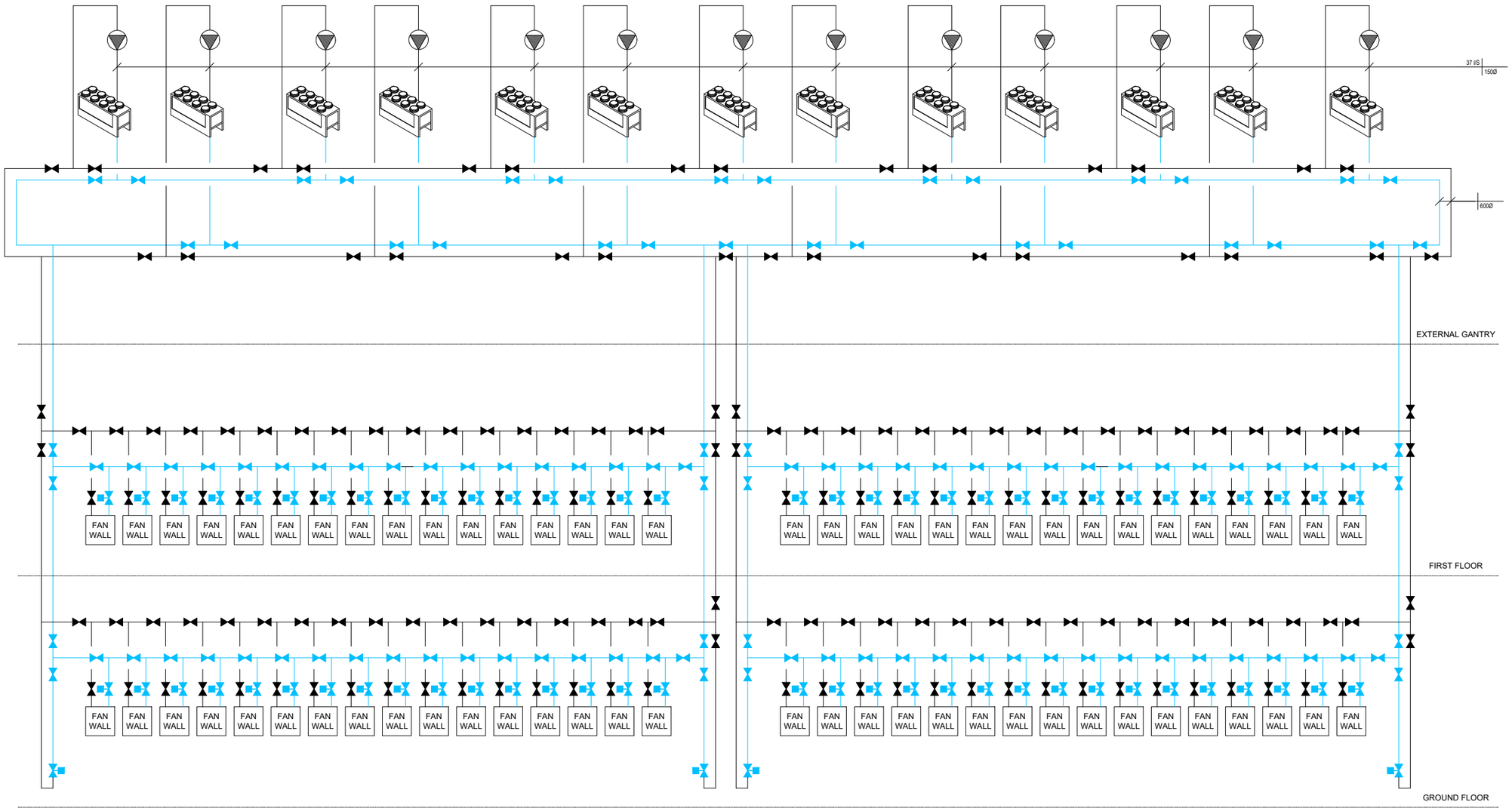
CUNDALL

One Carter Lane
London, EC4V 5ER
Telephone: +44(0)20 7438 1600

Website: www.cundall.com

A3

Notes



Issue	Date	Description	By	Chkd	Verfd

Project
EXCOOL PERFORMANCE REVIEW

Client
EXCOOL

Architect
N/A

Title
CHILLER AND FAN WALL OPTION

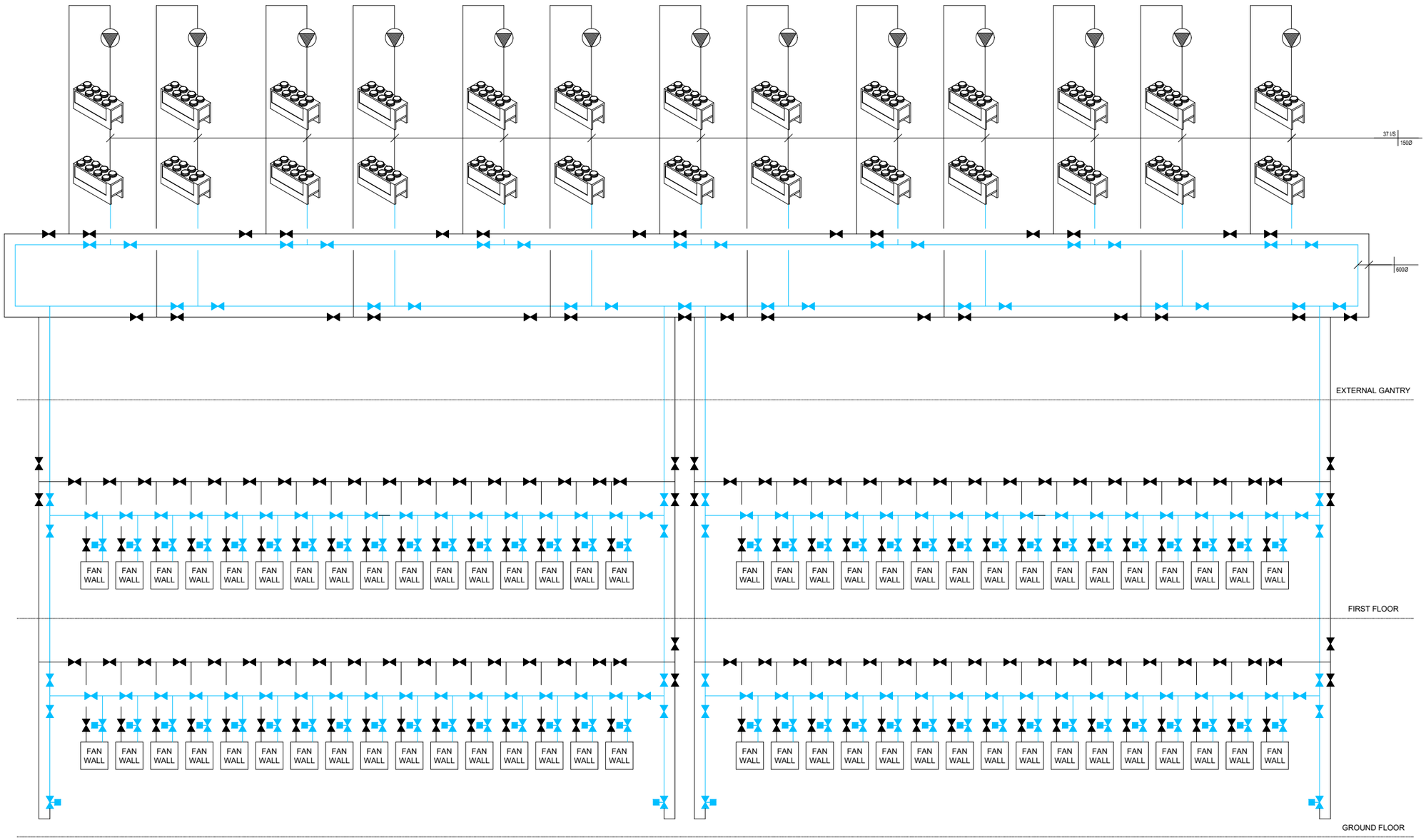
CHILLED WATER SCHEMATIC

Drawing No.	Drawing Status
SKM-03-05	
Job No.	Scale
1027420	1:600

CUNDALL

One Carter Lane
London, EC4V 5ER
Telephone: +44(0)20 7438 1600

Website: www.cundall.com



A3

Notes

Issue	Date	Description	By	Chkd	Verfd

Project
EXCOOL PERFORMANCE REVIEW

Client
EXCOOL

Architect
N/A

Title
HYBRID COOLER OPTION

CHILLED WATER SCHEMATIC

Drawing No.	Drawing Status
SKM-04-06	
Job No.	Scale
1027420	1:600

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Appendix B Maintenance Calculation

Description

This sheet attempts to outline maintenance requirements for each system to assign a score out of 10.

For each system - major mechanical plant items are listen and weekly, quarterly, semi-annually and annual expected maintenance items.

This is then summed and a total points is awarded per system - then this score gives a ranking and then score out of 10.

New Excool Water First

Mechanical Item	Weekly Item	Complexity	Quarterly Item	Complexity	Semi Annual Item	Complexity	Annual Item	Complexity	Number of units	Points
Excool Units	Visual Inspection	0.5	Complete Inspection	4					88	3696
Pressurisation AHU	Visual Inspection	0.5	Complete Inspection	4					2	84
Total										**3780**

New Excool DX First

Mechanical Item	Weekly Item	Complexity	Quarterly Item	Complexity	Semi Annual Item	Complexity	Annual Item	Complexity	Number of units	Points
Excool Units	Visual Inspection	0.5	Complete Inspection	4					88	3696
Pressurisation AHU	Visual Inspection	0.5	Complete Inspection	4					2	84
Total										**3780**

New Excool DX Only

Mechanical Item	Weekly Item	Complexity	Quarterly Item	Complexity	Semi Annual Item	Complexity	Annual Item	Complexity	Number of units	Points
Excool Units	Visual Inspection	0.5	Complete Inspection	4					88	3696
Pressurisation AHU	Visual Inspection	0.5	Complete Inspection	4					2	84
Total										**3780**

FCW with chiller

Mechanical Item	Weekly Item	Complexity	Quarterly Item	Complexity	Semi Annual Item	Complexity	Annual Item	Complexity	Number of units	Points
Chillers	Visual Inspection	0.5			Complete Inspection	8			14	588
Fan Walls	Visual Inspection	0.5	Complete Inspection	4					64	2688
Pumps	Visual Inspection	0.5			Complete Inspection	4			14	476
CHW sensors	Visual Inspection	0.5			Complete external inspection	4	Complete internal inspection	8	4	168
CHW valves	Visual Inspection	0.5			Complete external inspection	4	Complete internal inspection	8	4	168
CHW pipework	Visual Inspection	0.5					Check supports & insulation	2	4	112
Pressurisation AHU	Visual Inspection	0.5	Complete Inspection	4					2	84
Total										**4284**

FCW with hybrid cooler (chiller top up)

Mechanical Item	Weekly Item	Complexity	Quarterly Item	Complexity	Semi Annual Item	Complexity	Annual Item	Complexity	Number of units	Points
Chillers	Visual Inspection	0.5			Complete Inspection	8			14	588
Hybrid Cooler	Visual Inspection	0.5			Complete Inspection	4			14	476
RO Plant	Visual Inspection	0.5	Membrane clean	4	Complete Inspection	8			2	116
Fan Walls	Visual Inspection	0.5	Complete Inspection	4					64	2688
Pumps	Visual Inspection	0.5			Complete Inspection	4			14	476
CHW sensors	Visual Inspection	0.5			Complete external inspection	4	Complete internal inspection	8	4	168
CHW valves	Visual Inspection	0.5			Complete external inspection	4	Complete internal inspection	8	4	168
CHW pipework	Visual Inspection	0.5					Check supports & insulation	2	4	112
Pressurisation AHU	Visual Inspection	0.5	Complete Inspection	4					2	84
Total										**4876**

Direct Air

Mechanical Item	Weekly Item	Complexity	Quarterly Item	Complexity	Semi Annual Item	Complexity	Annual Item	Complexity	Number of units	Points
Excool Units	Visual Inspection	0.5	Complete Inspection	4					88	3696
Total										**3696**

	Colocation			Hyperscale		
	Points	Rank	Score	Points	Rank	Score
New Excool Water First	3780			3780		
New Excool DX First	3780	1	9	3780	2	8
New Excool DX Only	3780	1	9	3780	2	8
FCW with chiller	4284	3	7	4284	4	6
FCW with hybrid cooler (chiller top up)	4876	4	6	4876	5	5
Direct Air	-	-	-	3696	1	9

Appendix C Reliability Calculation

Description

This sheet attempts to measure reliability/uptime for each system to assign a score out of 10.

For each system - major mechanical plant items are listed and the failure rate / MTTF rates are listed. Where multple components exist in a system - these are considered in 'series' and appropriate formulas are used

Where a system has redundant units - these are considered as active (i.e always one but at part load) and the appropriate formulas are used.

For non-Excool systems - values for failure rates are derived from Weibell Distribution Functions with parameters sourced from established databases for mechanical items. Values for time to repair are from estabished database of surveyed data for HVAC systems.

New Excool Water First						
MECHANICAL ITEM	**COMPONENT**	**QUANTITY**	**MEAN TIME TO FAILURE (MTTF)**	**MEAN TIME TO REPAIR (MTTR) UNITS**	**FAILURE RATE**	**COMMENTS**
Excool Units	Compressor	3	87600	8.0	0.000034	
	External Fans	4.0	65700	0.5	0.000061	
	Internal Fans	4.0	65700	0.5	0.000061	
	Expansion Valve	1.0	87600	7.0	0.000011	
	Evaporator Coil	1.0	175200	12.0	0.000006	
	Condenser Coils	1.0	175200	7.0	0.000006	
	High Pressure Water Pump	1.0	87600	1.0	0.000011	
	ATS	1.0	87600	1.0	0.000011	
	Contactors / Relays	1.0	87600	0.5	0.000011	
	Damper Actuator	1.0	175200	1.0	0.000006	
	Water Nozzles	1.0	43800	0.5	0.000023	
	Plate Heat Exchanger	2.0	175200	8.0	0.000011	
	Water Tank	1.0	175200	4.0	0.000006	
	Water Valves	4.0	87600	2	0.000046	
	High Pressure Hoses	1.0	43800	1	0.000023	
	Control Panel Display	1.0	87600	1	0.000011	
	Controller	1.0	87600	1	0.000011	
	Supply and Return Air Sensors	3.0	43800	2	0.000068	
	Pump Inverter	1.0	65700	1	0.000015	

Failure rate Per Unit	4.34E-04
MTTF Per Unit	2305
Total Units	22
Redundant Units	2
Time from failure to start of repair	0
Average time to recovery	2
Effective Failure Rate of Whole System	0.000003613
MTTF of Whole System (hours)	276795
MTTF of Whole System (years)	31.6
Availability of Unit	0.99905
Availability of System	0.999992
Time Online (% of year)	99.9992%

New Excool DX First						
MECHANICAL ITEM	**COMPONENT**	**QUANTITY**	**MEAN TIME TO FAILURE (MTTF)**	**MEAN TIME TO REPAIR (MTTR) UNITS**	**FAILURE RATE**	**COMMENTS**
Excool Units	Compressor	3	65700	8.0	0.000046	
	External Fans	4.0	65700	0.5	0.000061	
	Internal Fans	4.0	65700	0.5	0.000061	
	Expansion Valve	1.0	87600	7.0	0.000011	
	Evaporator Coil	1.0	175200	12.0	0.000006	
	Condenser Coils	1.0	175200	7.0	0.000006	
	High Pressure Water Pump	1.0	87600	1.0	0.000011	
	ATS	1.0	87600	1.0	0.000011	
	Contactors / Relays	1.0	87600	0.5	0.000011	
	Damper Actuator	1.0	175200	1.0	0.000006	
	Water Nozzles	1.0	43800	0.5	0.000023	
	Plate Heat Exchanger	2.0	175200	8.0	0.000011	
	Water Tank	1.0	175200	4.0	0.000006	
	Water Valves	4.0	87600	2	0.000046	
	High Pressure Hoses	1.0	43800	1	0.000023	
	Control Panel Display	1.0	87600	1	0.000011	
	Controller	1.0	87600	1	0.000011	
	Supply and Return Air Sensors	3.0	43800	2	0.000068	
	Pump Inverter	1.0	65700	1	0.000015	

Failure rate Per Unit	4.45E-04
MTTF Per Unit	2246
Total Units	22
Redundant Units	2
Time from failure to start of repair	0
Average time to recovery	2
Effective Failure Rate of Whole System	0.000004455
MTTF of Whole System (hours)	224442
MTTF of Whole System (years)	25.6
Availability of Unit	0.99896
Availability of System	0.9999896
Time Online (% of year)	99.99896%

New Excool DX Only						
MECHANICAL ITEM	**COMPONENT**	**QUANTITY**	**MEAN TIME TO FAILURE (MTTF)**	**MEAN TIME TO REPAIR (MTTR) UNITS**	**FAILURE RATE**	**COMMENTS**
Excool Units	Compressor	6	65700	8.0	0.000091	
	External Fans	4.0	65700	0.5	0.000061	
	Internal Fans	4.0	65700	0.5	0.000061	
	Expansion Valve	1.0	87600	7.0	0.000011	
	Evaporator Coil	1.0	175200	12.0	0.000006	
	Condenser Coils	1.0	175200	7.0	0.000006	
	ATS	1.0	87600	1.0	0.000011	
	Contactors / Relays	1.0	87600	0.5	0.000011	
	Damper Actuator	1.0	175200	1.0	0.000006	
	Plate Heat Exchanger	1.0	175200	8.0	0.000006	
	Control Panel Display	1.0	87600	1	0.000011	
	Controller	1.0	87600	1	0.000011	
	Supply and Return Air Sensors	1.0	43800	2	0.000023	

Failure rate Per Unit	3.16E-04
MTTF Per Unit	3166
Total Units	22
Redundant Units	2
Time from failure to start of repair	0
Average time to recovery	4
Effective Failure Rate of Whole System	0.000003640
MTTF of Whole System (hours)	274732
MTTF of Whole System (years)	31.4
Availability of Unit	0.99888
Availability of System	0.99999
Time Online (% of year)	99.9990%

New Excool Direct Air						
MECHANICAL ITEM	**COMPONENT**	**QUANTITY**	**MEAN TIME TO FAILURE (MTTF)**	**MEAN TIME TO REPAIR (MTTR) UNITS**	**FAILURE RATE**	**COMMENTS**
Excool Units						
	External Fans	4.0	65700	0.5	0.000061	
	Internal Fans	4.0	65700	0.5	0.000061	
	High Pressure Water Pump	1.0	87600	1.0	0.000011	
	ATS	1.0	87600	1.0	0.000011	
	Contactors / Relays	1.0	87600	0.5	0.000011	
	Damper Actuator	1.0	175200	0.5	0.000006	
	Water Nozzles	1.0	43800	0.5	0.000023	
	Water Tank	1.0	175200	4.0	0.000006	
	Water Valves	4.0	87600	1.5	0.000046	
	High Pressure Hoses	1.0	43800	1.0	0.000023	
	Control Panel Display	1.0	87600	1.0	0.000011	
	Controller	1.0	87600	1.0	0.000011	
	Supply and Return Air Sensors	1.0	43800	1.0	0.000023	
	Pump Inverter	1.0	65700	1	0.000015	
					0.000	

Failure rate Per Unit	3.20E-04
MTTF Per Unit	3129
Total Units	22
Redundant Units	2
Time from failure to start of repair	0
Average time to recovery	1
Effective Failure Rate of Whole System	0.000000229
MTTF of Whole System (hours)	4358224
MTTF of Whole System (years)	497.5
Availability of Unit	0.99972
Availability of System	0.9999998
Time Online (% of year)	99.99998%

Chiller & Fan wall only		
Water System		Comments
Total Units	13	
Redundant Units	1	
Time to start of repair	0	
Chiller		
Failure Rate of Chiller (per hour)	2.80E-05	Estimated using a Weibell Distribution with values of β,η taken for compressor&fans in ref [1]. Total replacement assumed after 15 years.
Total time to recovery	12.620000	Taken from database [2]
Pumps		
Failure Rate of Pump (per hour)	3.00E-05	Estimated using a Weibell Distribution with values of β,η taken for pumps in ref [1]. Total replacement assumed after 15 years.
Total time to recovery	6.75	Taken from database [2]
Chiller valves		
Failure Rate of Chiller Valves (per hour)	1.67E-05	Estimated using a Weibell Distribution with values of β,η taken for slide valves & linear actuator in ref [1]. Total replacement assumed after 15 years.
Total time to recovery	3.000000	Taken from database [2]
Average time to recovery	8.111914	
Effective Failure Rate per Unit	0.000075	
Effective Failure Rate per System	0.00000706	
Air System		
Total Units	16	
Redundant Units	2	
Fan Walls		
Failure Rate of Fan Wall (per hour)	0.000010	Estimated using a Weibell Distribution with values of β,η taken for fans in ref [1]. Total replacement assumed after 15 years.
Total time to recovery	2.50	Taken from database [2]
Fan Wall Valves		
Failure Rate of Fan Wall Valves (per hour)	0.000017	Estimated using a Weibell Distribution with values of β,η taken for slide valves & linear actuator in ref [1]. Total replacement assumed after 15 years.
Total time to recovery	6.75	Taken from database [2]
Average time to recovery	5.158240	
Effective Failure Rate per Unit	0.000027	
Effective Failure Rate per System	0.000000002	
Entire System		
Average time to repair	7.334172	
Effective Failure Rate per System	0.00000706	
Effect MTTF of System (hours)	141581	
MTTF of Whole System (years)	16.2	
Availability of System	0.999948	
Time Online (% of year)	99.99482%	

Hybrid Cooler & Chiller & Fan wall		
Water System		Comments
Total Units	13	
Redundant Units	1	
Time to start of repair	0	
Hybrid Cooler		
Failure Rate of Chiller (per hour)	3.00E-05	Estimated using a Weibell Distribution with values of β,η taken for fans&circulating pump in ref [1]. Total replacement assumed after 15 years.
Total time to recovery	7.910000	Taken from database [2]
Chiller		
Failure Rate of Chiller (per hour)	2.80E-05	Estimated using a Weibell Distribution with values of β,η taken for compressor&fans in ref [1]. Total replacement assumed after 15 years.
Total time to recovery	12.620000	Taken from database [2]
Pumps		
Failure Rate of Pump (per hour)	3.00E-05	Estimated using a Weibell Distribution with values of β,η taken for pumps in ref [1]. Total replacement assumed after 15 years.
Total time to recovery	6.75	Taken from database [2]
Chiller valves		
Failure Rate of Chiller Valves (per hour)	1.67E-05	Estimated using a Weibell Distribution with values of β,η taken for slide valves & linear actuator in ref [1]. Total replacement assumed after 15 years.
Total time to recovery	3.000000	Taken from database [2]
Average time to recovery	8.054059	
Effective Failure Rate per Unit	0.000105	
Effective Failure Rate per System	0.00001295	
Air System		
Total Units	16	
Redundant Units	2	
Fan Walls		
Failure Rate of Fan Wall (per hour)	0.000010	Estimated using a Weibell Distribution with values of β,η taken for fans in ref [1]. Total replacement assumed after 15 years.
Total time to recovery	2.50	Taken from database [2]
Fan Wall Valves		
Failure Rate of Fan Wall Valves (per hour)	0.000017	Estimated using a Weibell Distribution with values of β,η taken for slide valves & linear actuator in ref [1]. Total replacement assumed after 15 years.
Total time to recovery	6.75	Taken from database [2]
Average time to recovery	5.158240	
Effective Failure Rate per Unit	0.000027	
Effective Failure Rate per System	0.000000001	
Entire System		
Average time to repair	7.465639	
Effective Failure Rate per System	0.00001295	
Effect MTTF of System (hours)	77240	
MTTF of Whole System (years)	8.8	
Availability of System	0.999903	
Time Online (% of year)	99.99033%	

Hybrid Cooler & Fan wall only (no chiller)		
Water System		Comments
Total Units	13	
Redundant Units	1	
Time to start of repair	0	
Hybrid Cooler		
Failure Rate of Chiller (per hour)	3.00E-05	Estimated using a Weibell Distribution with values of β,η taken for fans&circulating pump in ref [1]. Total replacement assumed after 15 years.
Total time to recovery	7.910000	Taken from database [2]
Chiller		
Failure Rate of Chiller (per hour)	0.00E+00	Estimated using a Weibell Distribution with values of β,η taken for compressor&fans in ref [1]. Total replacement assumed after 15 years.
Total time to recovery	0.000000	Taken from database [2]
Pumps		
Failure Rate of Pump (per hour)	3.00E-05	Estimated using a Weibell Distribution with values of β,η taken for pumps in ref [1]. Total replacement assumed after 15 years.
Total time to recovery	6.75	Taken from database [2]
Hybrid valves		
Failure Rate of Chiller Valves (per hour)	1.67E-05	Estimated using a Weibell Distribution with values of β,η taken for slide valves & linear actuator in ref [1]. Total replacement assumed after 15 years.
Total time to recovery	3.000000	Taken from database [2]
Average time to recovery	6.387223	
Effective Failure Rate per Unit	0.000077	
Effective Failure Rate per System	0.00000405	
Air System		
Total Units	16	
Redundant Units	2	
Fan Walls		
Failure Rate of Fan Wall (per hour)	0.000010	Estimated using a Weibell Distribution with values of β,η taken for fans in ref [1]. Total replacement assumed after 15 years.
Total time to recovery	2.50	Taken from database [2]
Fan Wall Valves		
Failure Rate of Fan Wall Valves (per hour)	0.000017	Estimated using a Weibell Distribution with values of β,η taken for slide valves & linear actuator in ref [1]. Total replacement assumed after 15 years.
Total time to recovery	6.75	Taken from database [2]
Average time to recovery	5.158240	
Effective Failure Rate per Unit	0.000027	
Effective Failure Rate per System	0.000000001	
Entire System		
Average time to repair	6.069874	
Effective Failure Rate per System	0.00000405	
Effect MTTF of System (hours)	246722	
MTTF of Whole System (years)	28.2	
Availability of System	0.999975	
Time Online (% of year)	99.99754%	

Colocation Comparrison

	New Excool DX Only	New Excool Water First	New Excool DX first	Chiller & Fan wall only	Hybrid Cooler&Chiller & Fan wall
Summary					
MTTF	274732	276795	224442	141581	77240
Availability of System	0.999990	0.999992	0.999990	0.999948	0.999903
Time Online (% of year)	99.9990%	99.9992%	99.9990%	99.9948%	99.9903%
Average annual failure time (minutes of year)	6.77	4.16	5.47	50.80	12.93
Rank	3	1	2	5	4
Score	7	9	8	5	6

Hyperscale Comparrison

	New Excool DX Only	New Excool Water First	New Excool DX first	New Excool Direct Air	Chiller & Fan wall only	Hybrid Cooler & Fan wall only (no chiller)
Summary						
MTTF	274732	276795	224442	4358224	141581	246722
Availability of System	99.9990%	99.9992%	99.9990%	99.999980%	99.9948%	99.9975%
Time Online (% of year)	99.9990%	99.9992%	99.9990%	99.999980%	99.9948%	99.9975%
Average annual failure time (minutes of year)	6.77	4.16	5.47	0.11	27.23	12.93
Rank	4	2	3	1	6	5
Score	6	8	7	9	4	5

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