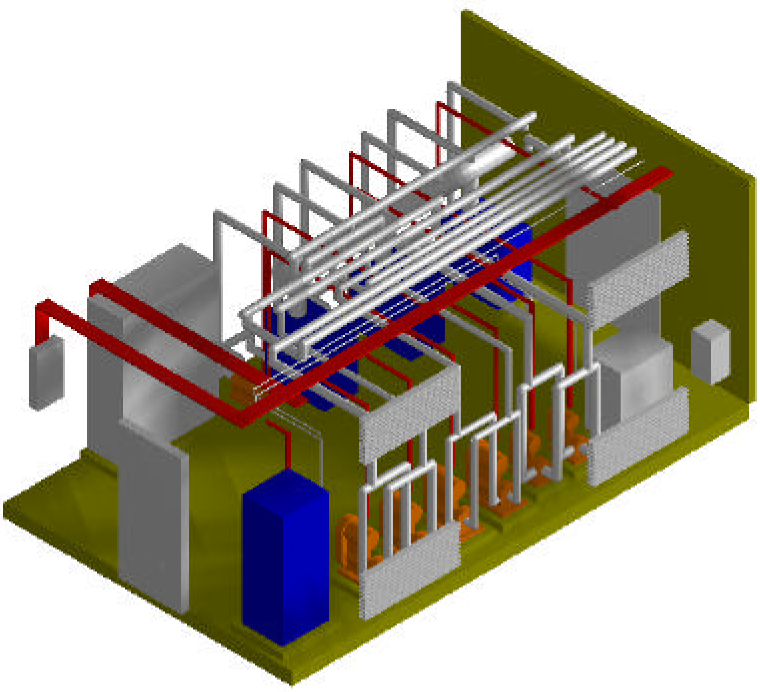
LINK MCNS Programme

Building Services Standard Solutions Implemented in CAD



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Building Services Standard Solutions Implemented in CAD

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1 Introduction

This report documents the work and findings of the DETR/EPSRC funded LINK MCNS project "Building Services Standard Solutions implemented in CAD". Standardisation is widely recognised as a key element in reducing design time, cutting construction costs and ensuring efficient design solutions. The project was set up to research the use of standard solutions used in conjunction with IT and the ensuing potential benefits including reduced design time, more efficient solutions (space, cost, etc.), and better data for downstream activities such as prefabrication.

Oscar Faber were lead partner for the project with the Martin Centre at Cambridge University as the academic partner. A feature of the project was the number of additional industrial partners who provided a broad range of expertise on which the project could draw (see Acknowledgements).

The objectives of the project were to:

- identify a set of rules governing the selection, sizing and location of equipment in plant rooms, ceiling voids and vertical risers
- define a set of standard solutions
- implement the standard solutions in an industry standard CAD (Computer Aided Design) system
- test and evaluate the standard solutions against conventional ones in a benchmarking exercise
- report the findings and conclusions as widely as possible to potential beneficiaries.

A summary of the work undertaken and the findings is given in Section 2 of this report. Sections 3 to 5 provide more detail on the work stages undertaken to define, implement and benchmark the solutions. The outputs from the project include implemented versions of these standard solutions. These can be downloaded via the project web site (www.arct.cam.ac.uk/research/cadlab/standardsolutions).

Section 6 summarises the work done by the Martin Centre to extend the application of the solutions to more complex geometries. This builds on the work described in Sections 3 to 5. A full account of this is given in the Martin Centre Final Report to EPSRC "Building Services Standard Solutions". This report and the resulting Java demonstration tool are also available via the project web site.

Section 7 draws together a number of conclusions from the project and highlights issues raised by the work.

2 Summary

The overall aim of the project was to research the potential benefits of using standard solutions in conjunction with IT, in particular to improve design productivity and quality. The project has developed solutions for plant rooms, ceiling voids and vertical risers.

The work undertaken has included the following key tasks:

- Definition of the solutions in terms of schematics, written rules and geometric layouts.
- Implementation of the solutions in Visual Basic software with drawing outputs to CAD (Bentley MicroStation).
- Benchmarking of the solutions against conventional design solutions, primary in terms of space requirements.

The results from the research indicate that it is possible to define and implement standard solutions to produce designs comparable with current practice. Conclusions and observations from the work include the following:

- The use of standard solutions in conjunction with IT has the potential to significantly reduce design costs (10-20%), improve quality, and produce additional benefits elsewhere in the supply chain.
- IT implementation of the solutions performs a critical role in maximising productivity improvements by automating generation of the design.
- Applications most suited to standardisation are characterised by:
  - a high degree of repetition between jobs
  - a limited number of practical variations
  - minimal interaction with other disciplines and services.

  Plant rooms and risers are good examples of suitable applications.
- Partially standardised solutions can be of significant benefit for some applications such as ceiling voids.
- Reducing the scope of a solution may increase suitability for standardisation by reducing the number of variations and interactions.
- The standard solutions should act as templates that can subsequently be adapted to suit an increased range of applications.
- A significant barrier to the widespread implementation is the current lack of manufacturers equipment data in a suitable electronic format to underpin the solutions.
- Standard solutions should be seen as tools for aiding progress by way of propagating good practice and releasing resources for innovation.

3 Definition of Standard Solutions

The standard solutions were developed in consultation with practicing engineers. They are essentially a collection of rules that address the selection, sizing and location of services equipment. The rules are in a number of different forms including:

- schematics (Figure 1)
- written rules (Figure 2)
- geometric layouts (Figure 3).

The rules are documented in Appendix A1. The preferred approach to developing generic solutions was to collate rules for one application, and them to modify and extend the rules by testing against other applications. Although more protracted than the alternative of trying to generate a set of generic rules in a one-off exercise, it was found to be more effective.

Due to limited resources, the rules have necessarily been collated for selected example system types. The heating plant room solution is a gas-fired closed system with cast iron sectional boilers. The ceiling void solution is based on a 4 pipe fan coil system. Similar rules could be developed for other system types in future.

The rules for selection of equipment define what equipment will be required to perform the specified function. For a plant room this may be heating, air handling, etc. The number of plant items and the configuration are typically manifested in the form of schematics (see Figure 1). There may be more than one schematic option (or standard solution) defined. Four different heating system options have been defined to suit a range of system sizes and loads to be served. In many cases the type of plant has also been standardised, for example in-line pumps for shunt pump applications, belt-driven for system pumps.

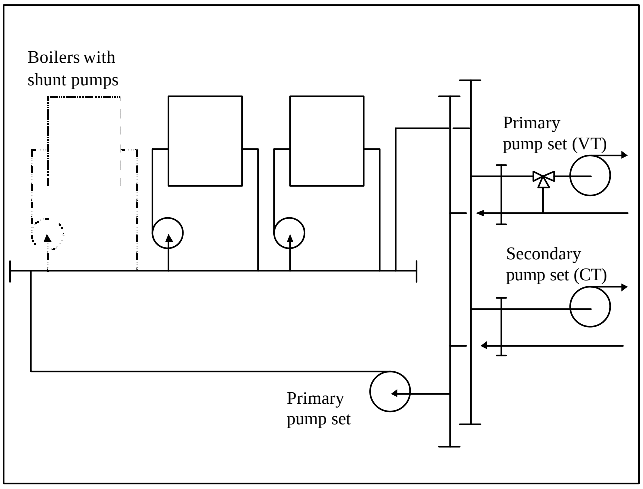


Figure 1: Heating system schematic

The sizing rules normally require data in the form of loads. The data may be provided by:

- rules-of-thumb
- input by the user
- an attribute of another plant object.

Examples of rules-of-thumb are the system volume rules per kW for sizing the heating and chilled water pressurisation units. Data required as input by the user include the heating and cooling loads. The use of attribute values from other plant objects is particularly relevant to electrical distribution equipment, for which load data is taken from the selected mechanical equipment. This automates the manual data transfer process of electrical requirements from mechanical to electrical engineer, with consequent savings in time and reduced risk of error.

Plant	Type	Rules/Standardisation
Pumps	Selection	Use close coupled end suction for energy efficiency where head predictable (shunt pumps). Use belt drive with motor above for flexibility where head less predictable (system pumps).
	Sizing	Always use impeller housing one size up to allow for future expansion of the system. Select at 75% of maximum flow for efficiency from pump curves. LPHW flow rates based on loads and flow/return temperatures of 82/71°C. CHW flow rates based on loads and flow/return temperatures of 6/12°C. Allowance for shunt pump head 100 kPa. Allowance for system pump head 250 kPa.
	Location	Refer to General Location. Arrange duty/standby pump sets in pairs. Locate shunt pump next to boiler. Arrange so pump sets on same systems are close together. Allow for an "A" frame gantry to roll over the pump for maintenance. Allow for "stool" piece so that motor can be removed with impeller housing in place.

Figure 2: Written rules for pumps

Preferred layouts for the location of plant have been developed. Figure 3 illustrates a simple plant room layout with a central access corridor, main door at one end, and escape door at other end. Plant objects are located either side of access corridor with shared maintenance space. Pipework, ductwork and cable tray are routed above the access corridor. These layouts are mainly appropriate for new build applications where the size and configuration of a plant room can be prescribed.

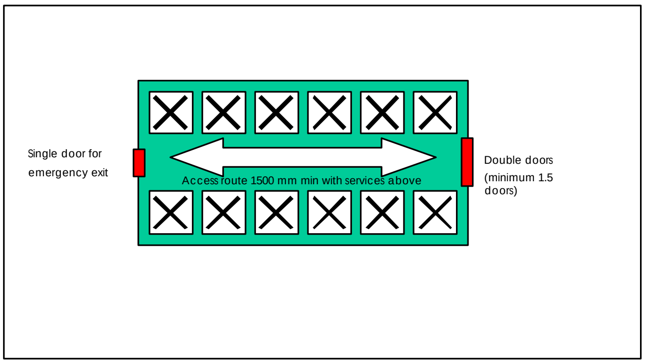


Figure 3: Generic plant room layout

For more complex configurations, it is more difficult to provide rules to pre-define solutions. The preferred approach was to generate a number of possible solutions that meet the geometric constraints. The best can then be selected according to judgement criteria such as minimum space and cost. This is the area of work developed by the Martin Centre as described in Section 6.

4 Implementation of Standard Solutions

Having defined the standard solutions, the next stage was to implement them in a software environment. It was originally intended that the rules be implemented directly into the Bentley CAD MicroStation software. However, due to a delay in the release of the appropriate version of the MicroStation software the solutions were implemented using Visual Basic. The solutions are then output from Visual Basic to MicroStation as a series of drawing commands.

The use of Visual Basic has the advantage that solutions can also be output in a similar manner to current versions of AutoCAD. The ability to use the solutions with more than one CAD package greatly increases the potential impact of the work.

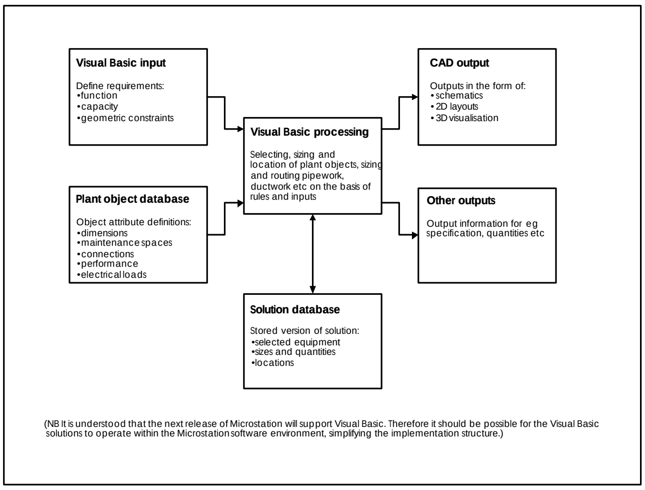
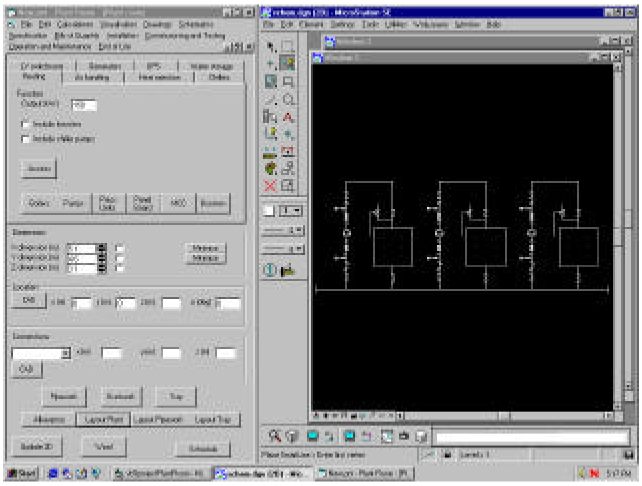


Figure 4: Implementation structure

The implementation structure is illustrated in Figure 4. User input to the solution is via Visual Basic forms (see Figure 5). The input data defines the function, capacity and geometrical constraints of the solution. For a heating plant room this includes how much heat is required and what circuits are to be served. Geometrical constraints



include the dimensions of the plant room.

Figure 5: Visual Basic input/ MicroStation output

The database contains attribute definitions of all the plant objects that are available for selection and inclusion in the standard solution (see Figure 6). As well as physical dimensions data and maintenance spatial requirements, the plant object definitions also include performance data for selection purposes and connection details for routing pipework etc. Data for the objects was provided by the manufacturers. In a number of cases this was aided by the recent development of software selection tools for their own equipment. As a result much of the data was already in a software format that could be directly incorporated in to the objects.

"Description","Belt Driven Pump"
"Manufacturer"," Pullen"
"ModelRef","C125L-5C-1910"
"Width (mm)",500
"Depth (mm)",661
"Height (mm)",1014
"Maintainance space left (mm)",300
"Maintainance space right (mm)",300
"Maintainance space front (mm)",51
"Maintainance space back (mm)",300
"Maintainance space above (mm)",0
"Maintainance space below (mm)",0
"Access width (mm)",600
"Access height (mm)",2000
"Motor rating (kW)",18.5
"Power 1",14.9
"Power 2",14.46597
"Power 3",14.08066
"Power 4",13.69758
"Power 5",13.31674
"Power 6",12.93813
"Power 7",12.56176
"Power 8",12.18762
"Power 9",11.81571
"Power 10",11.44604
"Flow 1",65
"Flow 2",61.579
"Flow 3",58.158
"Flow 4",54.737
"Flow 5",51.31599
"Flow 6",47.89499
"Flow 7",44.47399
"Flow 8",41.05299
"Flow 9",37.63199
"Flow 10",34.21099
"Pressure 1",161.865
"Pressure 2",175.5152226
"Pressure 3",187.2712323
"Pressure 4",198.2569608
"Pressure 5",208.47231
"Pressure 6",217.9172799
"Pressure 7",226.5920667
"Pressure 8",234.4963761
"Pressure 9",241.6305024
"Pressure 10",247.9941513
"LPHW inlet connection size (mm)",100
"LPHW inlet connection location x",310
"LPHW inlet connection location y",661
"LPHW inlet connection location z",256
"LPHW inlet connection direction X",0
"LPHW inlet connection direction Y",1
"LPHW inlet connection direction Z",0
"LPHW outlet connection size (mm)",100
"LPHW outlet connection location x",500
"LPHW outlet connection location y",566
"LPHW outlet connection location z",256
"LPHW outlet connection direction x",1
"LPHW outlet connection direction y",0
"LPHW outlet connection direction z",0
"Electrical connection size (mm)",10
"Electrical connection location x",250
"Electrical connection location y",330.5
"Electrical connection location z",1014
"Electrical connection direction x",1
"Electrical connection direction y",0
"Electrical connection direction z",0
"Running Current (Amps)",35.1
"Starting Current (Amps)",76.167
"Phases",3
"Weight (kg)",50
"Costs",2847
"Web address", www.pullenpumps.co.uk

Figure 6: Pump object definition

It was intended that the attribute definitions should follow those of the IAI (Industry Alliance for Interoperability) [1]. However, at the time these were not considered at a suitable level of detail or development to be appropriate. Therefore, the attributes were defined on the basis of what was required to generate the standard solution. Lists of the defined attributes for each of the items of plant are given in Appendix A2.

The processing uses the defined rules (refer to Section 3) to generate the solutions according to the user inputs. The implementations are based on the rules and solutions documented in Appendix A1 but may vary in detail.

The solution produced is in essence a collection of selected/sized objects (boilers, pumps, pipework, etc) with defined locations. This can potentially be output in a number of forms as appropriate for different parts of the construction and operating process:

- space allowance
- 2D, 3D layouts
- schematics
- specifications
- quantities
- prefabrication data
- installation data
- maintenance data.

The project focussed on traditional outputs suitable for integration into the existing design process, primarily drawings and specifications. However, the data could be output in other forms to benefit parallel design and downstream construction activities. One format used by the project for storing the solutions is a spreadsheet – see Figure 7. The spreadsheet is split into worksheets, each of which store data for a particular plant type, eg ductwork. The spreadsheet format has a suitable structure for storing data and is also a useful format for making the data available for a number of other purposes. These could include further calculations by design engineers, measurement of quantities by QSs, required lengths of ducts etc for prefabrication, or installation locations for the site construction processes.

In addition, facility has been provided to enable the solutions to be modified once generated. The solutions act as templates that can be modified by designers to suit different applications. This extends the range of applications and was found to be necessary in some cases for the benchmarking process (see below).

The following sections focus on the results and implementation issues specific to plant rooms, ceiling voids and risers, plus the subsequent integration of the individual solutions into a whole building solution.

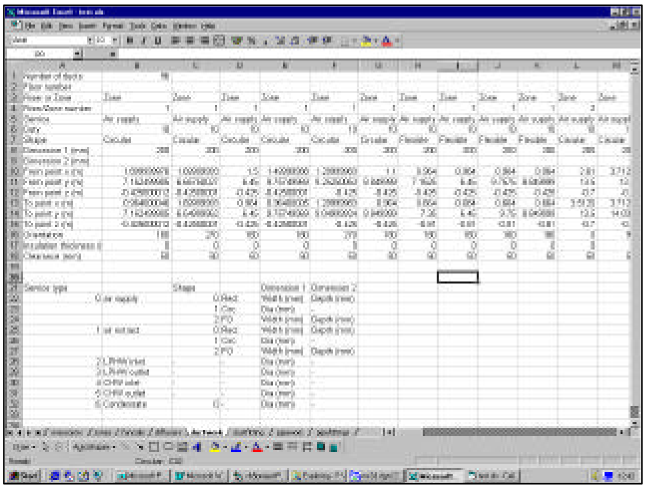


Figure 7: Spreadsheet format

4.1 Plant Rooms

The heating system solution is a gas fired closed system with sectional boilers. An example 2D layout generated for a heating plant room is included in Figure 8. The system configuration selected to meet the requirements specified is based on boilers with shunt pumps plus a primary/secondary pumping system. A pressurisation unit, distribution board, motor control centre and other ancilliary equipment are also included. Access is at either end of the plant room. The plant room is naturally ventilated via vents in the wall. Chilled water pumps can also be included to serve air cooled chillers.

The layout is generated by initially defining the access corridor according to the location of the main and escape doors and then locating plant in sequence. The plant location sequence is approximately ordered from the most to the least geometrically constrained. The boilers (plus shunt pumps) are located first as these are constrained to be as close to the flue outlet as possible.

The pipework is sized on the basis of the input heat load requirements and configured according to the appropriate defined schematic arrangement. Pipework and tray are routed after the main plant items have been located. If the external connection points are specified then it is possible for the standard solutions to route directly to these points. However, it was found to be preferable to limit the standard solutions to routing between plant items and to defined connection points within the plant room. Routes out of the plant room from these connection points can then be added by the user subsequent to generation of the solution. This was found to be a more flexible approach than requiring external connection points to be pre-defined and using standard rules for routing to them. The internal connection points are located in the services zone above the central access corridor.

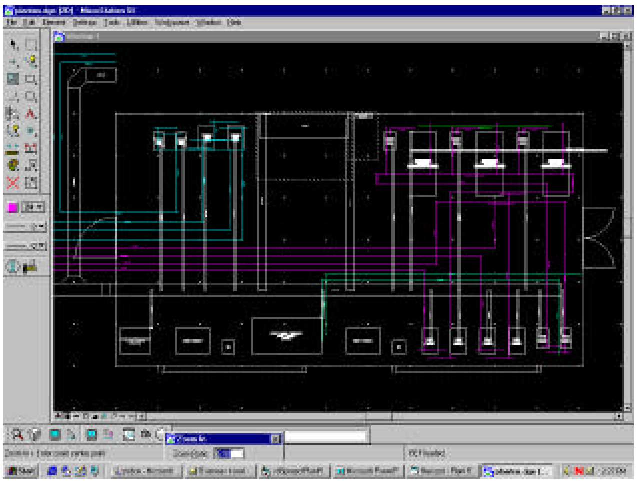


Figure 8: 2D heating plant room

Figure 9 shows the 3D output of the solution. These types of output were useful for checking implementation of rules and for enabling others to quickly understand and comment on the solutions. They could be valuable in practice as a means of informing the downstream construction process.

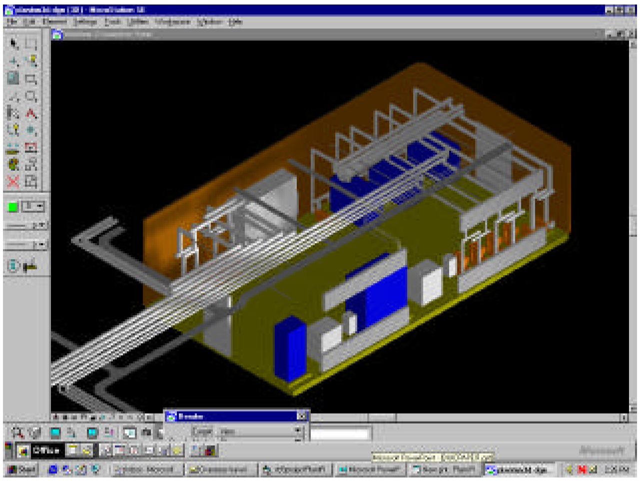


Figure 9: 3D heating plant room

Solutions have also been implemented for air handling plant room and air cooled chiller solutions. 2D and 3D outputs for the air handling unit solution are shown in Figures 10 and 11. These show a decked supply and extract air handling unit located one side of an access corridor. Components to be included in the air handling unit can be selected by the user.

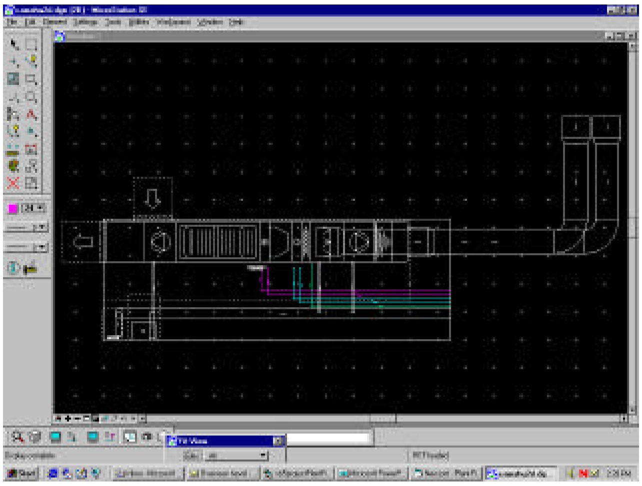


Figure 10: 2D air handling unit

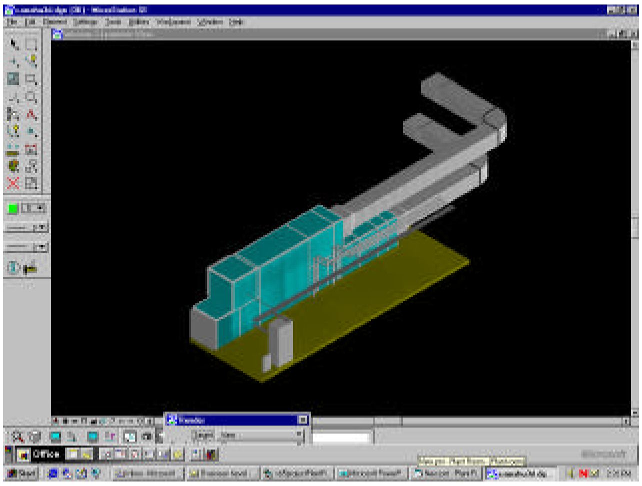


Figure 11: 3D air handling unit

Similar to the heating plant room solution, pipework, tray and ductwork routing is limited to routing between plant items and defined connections points within the plant room. Ductwork connections are provided on the air handling unit.

2D and 3D outputs for the chiller solution are shown in Figures 12 and 13. The chillers are located along one side of an access route. Pumps are assumed to be located in the heating plant room.

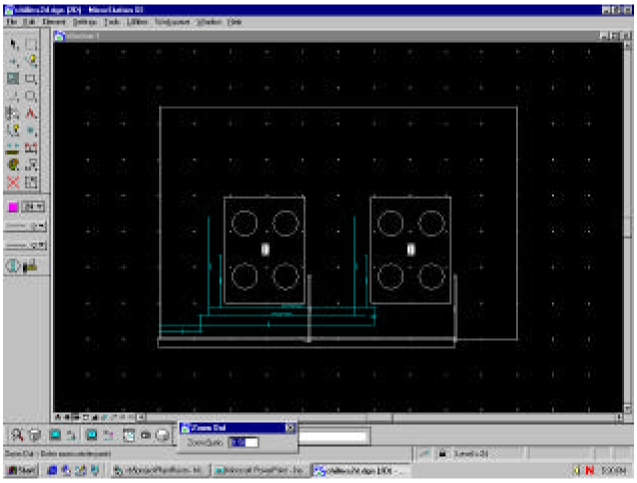


Figure 12: 2D chillers

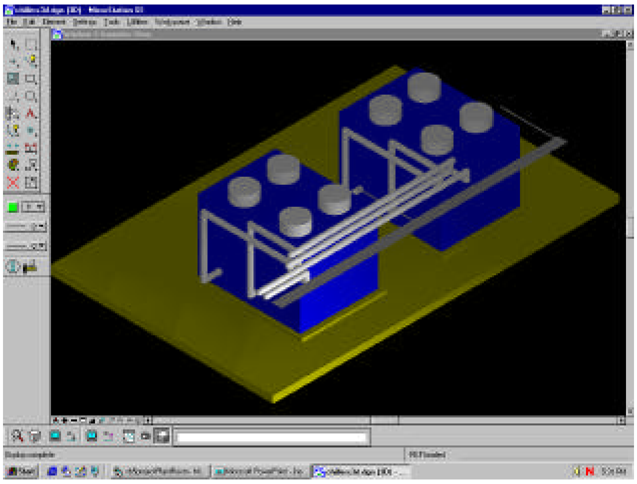


Figure 13: 3D chillers

4.2 Ceiling Voids

The ceiling void solution is based on a four pipe fan coil system. Fresh air is provided by a central air handling unit. Air supply to the space is via slot diffusers in perimeter zones and square diffusers internally. Electrical distribution is by busbars with recessed luminaires for lighting.

Whereas with plant rooms the main integration issues are between different services elements, for ceiling voids the emphasis is more on integration with non-services elements including beams, ceiling tiles and core areas. It is first necessary to define these before the services solution can be generated to suit. The following approaches have all been used:
User input when setting up the solution (for all elements)
Importing items from other programmes (for beams and columns)
Rules of thumb to make allowances or to generate layouts (for beams and columns).

Once the non-services elements have been defined, the services are located approximately in order from the most to least geometrically constrained. Luminaires are located first to integrate with the ceiling tile layout. For the structural solution illustrated (see Figures 14 and 15) - cellular beams - the distribution runs are located next as these are constrained to pass through the beam holes. These are then followed in sequence by; diffusers selected to provide the required air flow and located to integrate with the lighting; fan coils selected to meet the zone load requirements and located to ensure maintenance access from below; ductwork from fan coils to diffusers; distribution ductwork and pipework to the fan coil units (where not routed through beams); condensate runs from the fan coils to column droppers; and finally busbars and tray for power distribution.

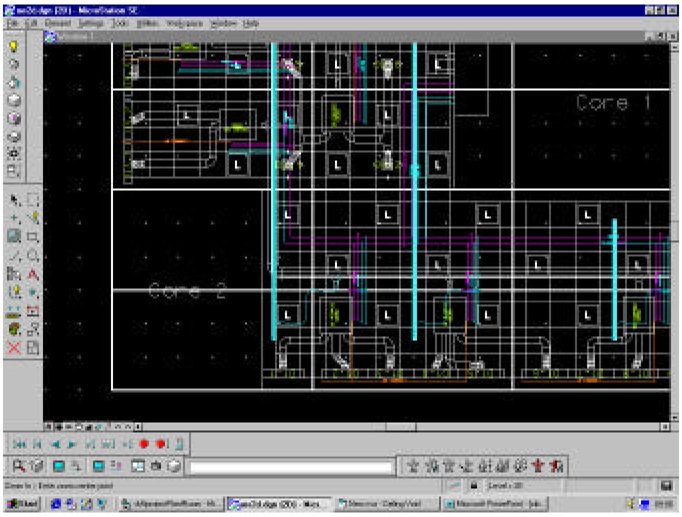


Figure 14: 2D ceiling layout

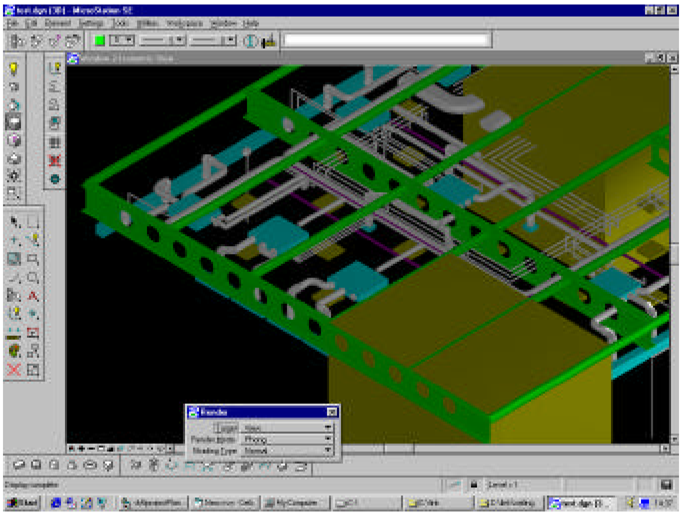


Figure 15: 3D ceiling layout

Facilities have been added to deal with more complex layouts include modification of perimeter diffuser locations to follow a non-linear façade. This was necessary for the benchmarking exercise and would be required in practice in many applications.

Another aspect in which the user input has been increased is in the distribution routing from the risers to the fan coils. The number of possible configurations of risers relative to fan coils meant that it was not practical to write standard rules. Some rules were developed for simplistic layouts but these were not able to cope with layouts encountered in the benchmarking. Routing is therefore done by the user, although selection and sizing is still according to standard rules.

4.3 Risers

Separate mechanical and electrical riser solutions have been implemented. The services to be included, their capacity and order of location in the riser are input by the user. The input screens have lists of services that can be selected for inclusion in the solutions (see Figures 16 and 18). These were found to be useful by acting a prompts or check lists to reduce the risk of error by omission.

The equipment available for selection in the mechanical riser is based on the HVAC solution to be served, ie a fan coil system. The riser geometry can be stretched or squashed to suit spatial constraints with the ductwork being resized to suit (subject to velocity and aspect ratio constraints). The 2D layout generated (Figure 16) is based on sizing to meet the overall capacity input by the user for each of the services. To generate floor by floor solutions and a 3D layout (Figure 17), it is necessary to define connections to and from the riser at each building level. Sizing of the vertical elements and horizontal take-offs is then determined by the connection flow rates.

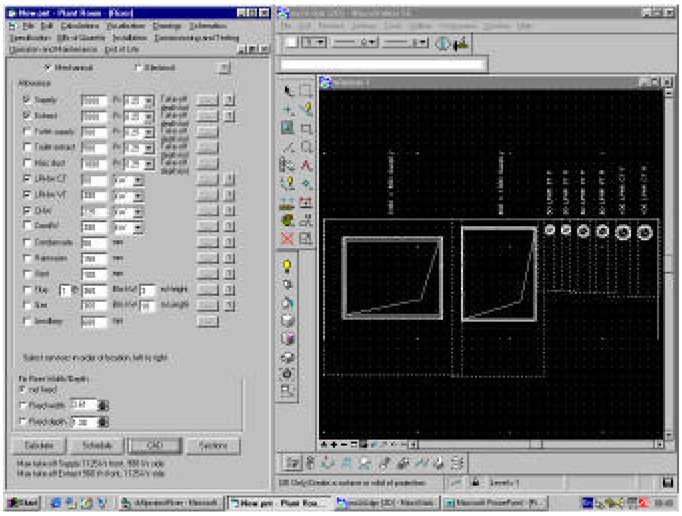


Figure 16: Mechanical riser input + 2D layout

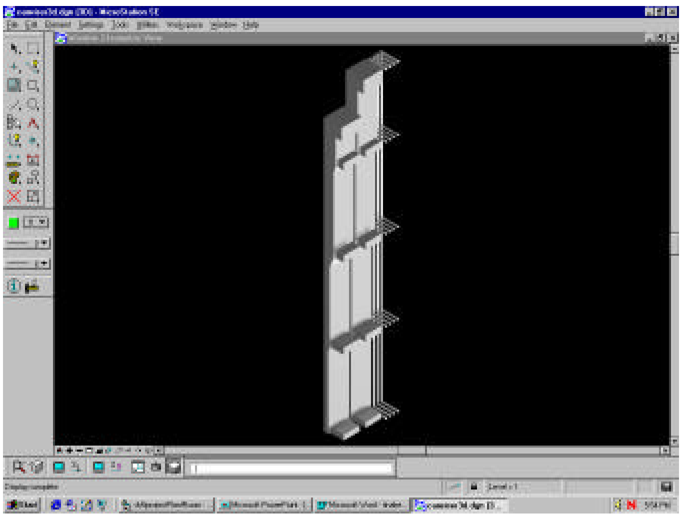


Figure 17: 3D mechanical riser

For the electrical riser the default solution is a rising busbar with distribution boards at each level. The basic 2D layout (Figure 18) will not generally vary from floor to floor. A 3D solution is shown in Figure 19).

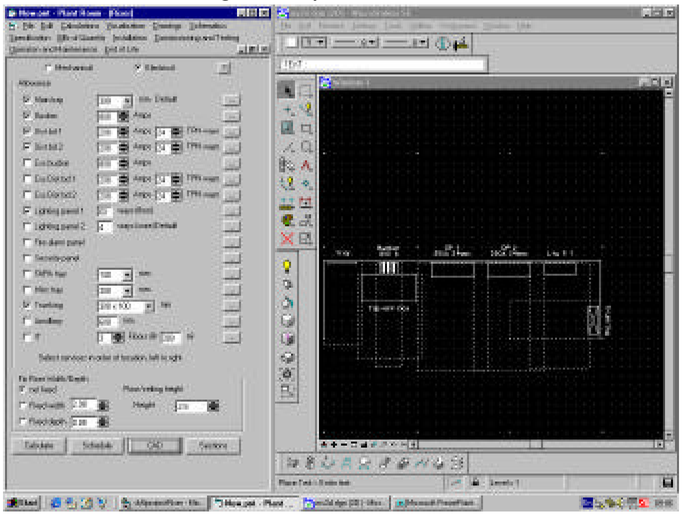


Figure 18: Electrical riser input + 2D layout

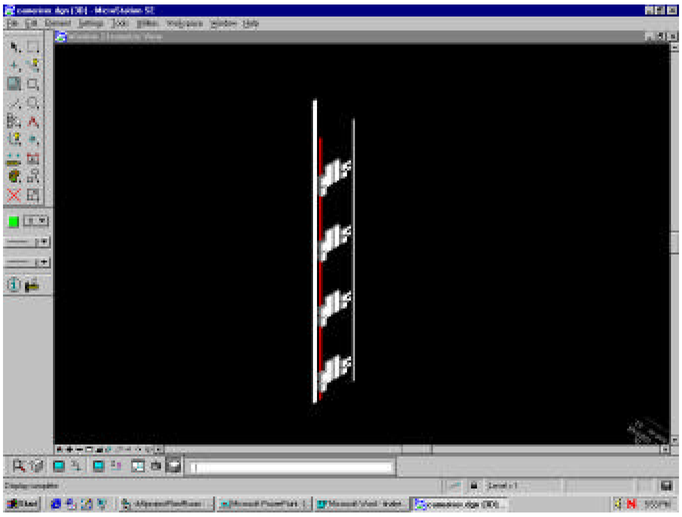


Figure 19: 3D electrical riser

4.4 Integrated Solution

The implementation work was extended to include integration of the individual solutions to produce a whole building solution and demonstrate the full potential of the approach (see Figures 20 and 21). This was achieved by adding interconnecting pipework, ductwork and tray routes. As described under 4.5, the plant room solutions have defined connection points from which services can be run, normally either to a riser or to another plant room. The target connection points can be read in from the other solutions.

When connecting a plant room distribution route to a riser, the horizontal location of the connection is taken from the riser solution, and the size and vertical location set by the plant room solution.

Connecting the ceiling void solutions to the riser solutions is done in a similar manner, with the horizontal location of the connection being taken from the riser solution and the size and vertical location set by the ceiling void solution.

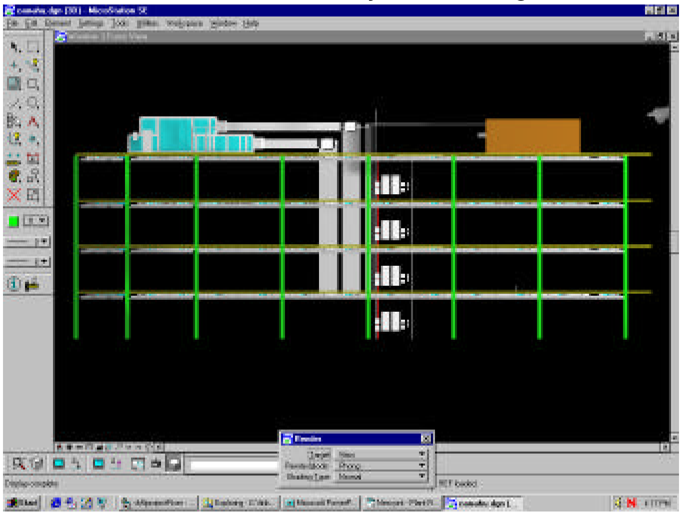


Figure 20: 3D integrated solution – front view

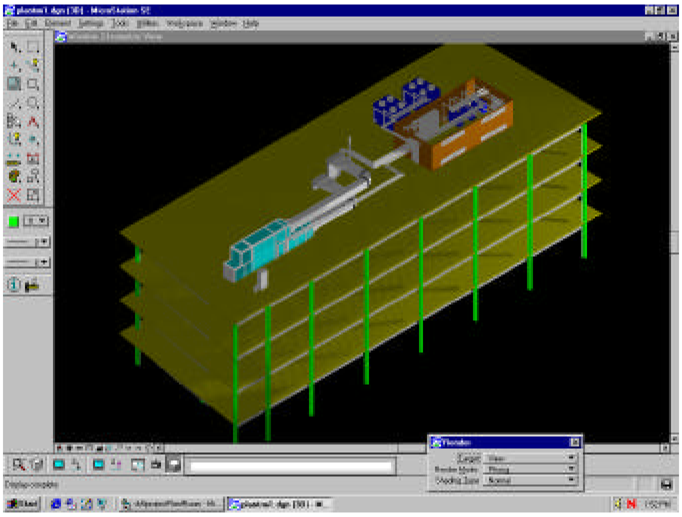


Figure 21: 3D integrated solution - isometric

5 Benchmarking of Standard Solutions

The final stage of the work was to benchmark the implemented standard solutions against current practice. Benchmarking focussed on the space requirements of the solutions. The following documents were identified as relevant sources of published sources of data for benchmarking purposes:

- Architects Journal "AJ Guide to Space for Services" [2].
- MOD Defence Works Functional Standard Design & Maintenance Guide 08 "Space requirements for plant access, operation and maintenance" [3].
- BSRIA TN 9/92 "Space and weight allowances for building services plant" [4].

Results for each of the solutions are presented below over-marked on the published data. The benchmarking showed that the implemented solutions were in close agreement published data and current design practice. The solutions were also comparable to current designs in terms of equipment selection and sizing.

5.1 Plant rooms

In each case the most appropriate sources of space allowance data have been selected for comparison – not all sources contained suitable data for each type of plant room.

Heating plant room

- AJ Guide: This source gives a range of areas against heating load. Solutions were generated at different heating loads for both the simplest (single pump set) and most complex (primary/secondary pumping) arrangements. This produced a range of results in a similar fashion to and close agreement with the published source (see Figure 22).
- MOD Guide 08: The data given is not suitable for comparison as it includes boilers only.
- BSRIA TN 9/92: Solutions were generated for two boilers and the simplest pumping arrangement (single pump set) consistent with the BSRIA assumptions. Dimensions for the standard solutions are comparable but higher than those given by BSRIA (see Figure 23). This can be attributed to the standard solution having an access route through the plant room, whereas the BSRIA solution has only one door with a more compact cupboard type arrangement.

Figure 22: Heating plant room comparison – extracted from AJ Guide [2]

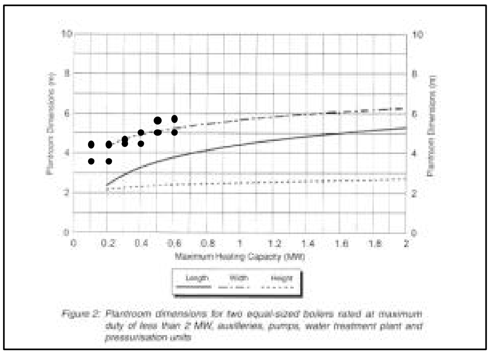


Figure 23: Heating plant room comparison – extracted from BSRIA TN 9/92 [4]

Air handling unit

- AJ Guide: Good agreement (see Figure 24).
- MOD Guide 08: Good agreement (see Figure 25).
- BSRIA TN 9/92: Solutions were generated consistent with BSRIA assumptions. Dimensions are in reasonable agreement with the data source (see Figure 26).

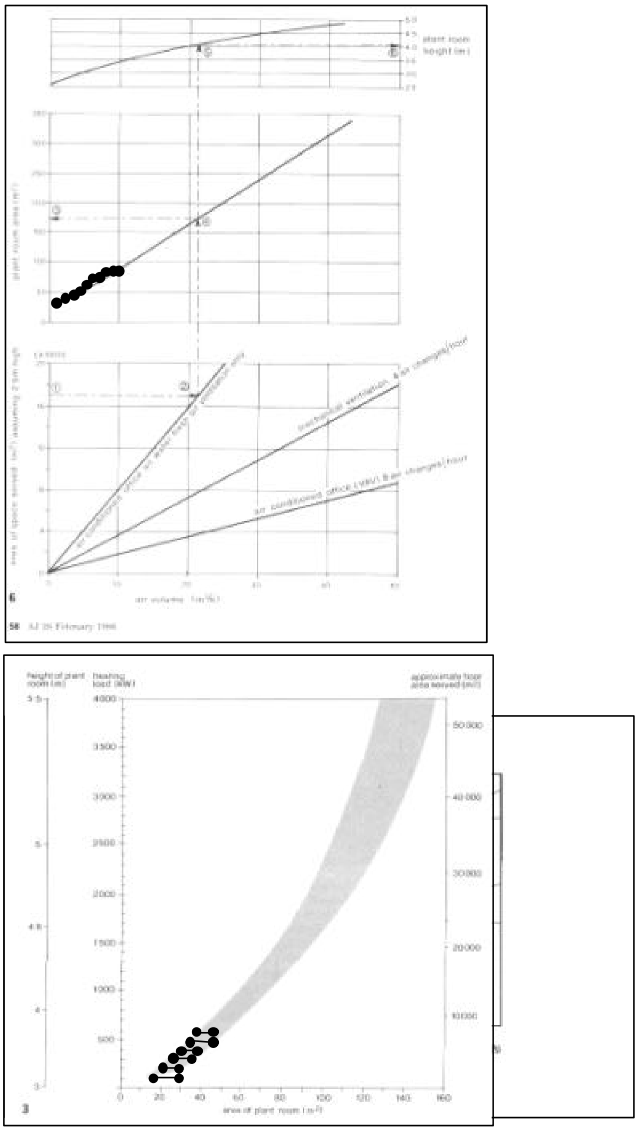


Figure 24: AHU comparison – extracted from AJ Guide [2]

Figure 25: AHU comparison – extracted from MOD Guide [3]

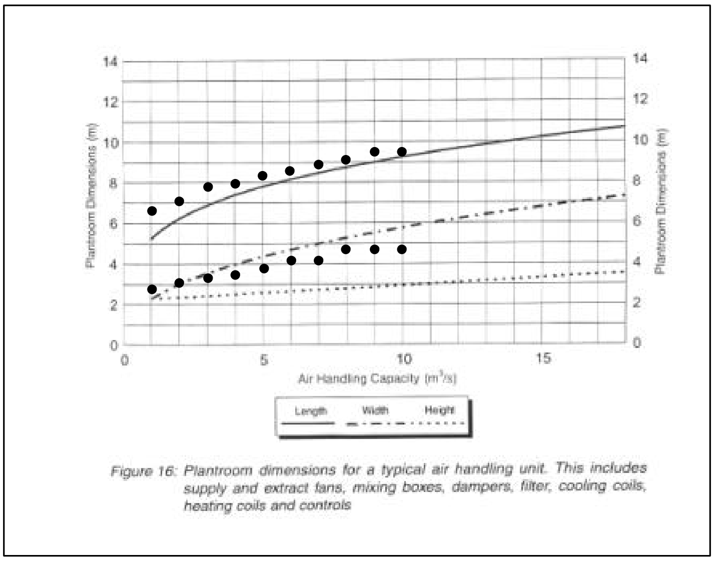


Figure 26: AHU comparison – extracted from BSRIA TN 9/92 [4]

Air cooled chillers

- AJ Guide: No comparative data.
- MOD Guide 08: Good agreement (see Figure 27) – one unit assumed below 550 kW, 2 above.
- BSRIA TN 9/92: Good agreement (see Figure 28) – one unit assumed below 550 kW, 2 above.

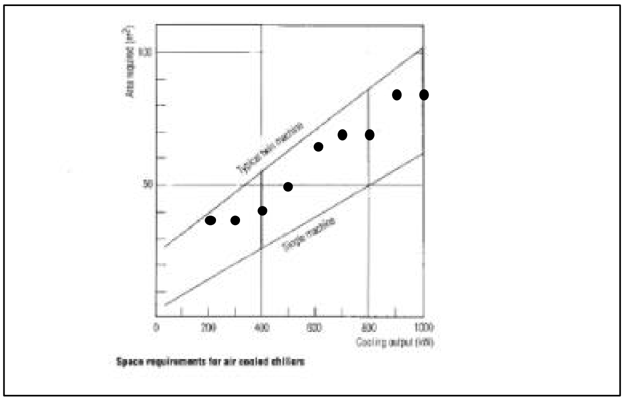


Figure 27: Chiller comparison – extracted from MOD Guide [3]

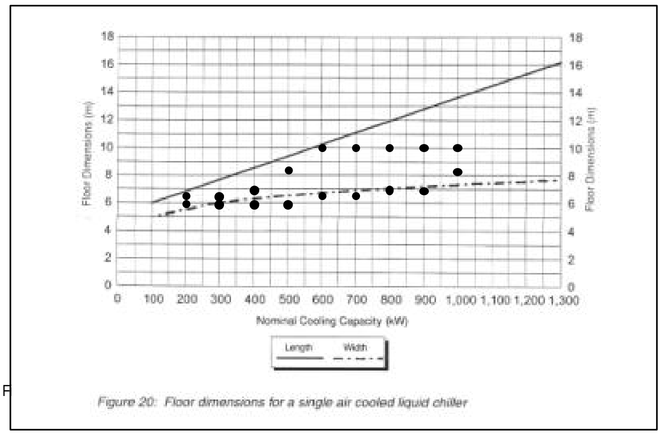


Figure 28: Chiller comparison – extracted from BSRIA TN9/92 [4]

5.2 Ceiling void

A ceiling void solution has been generated for a speculative office (see Figure 29). The standard solution has a 450 mm clear void – the same as is recommended in BSRIA TN 17/95 "Rules of Thumb" [5]. The design solution has a clear void depth of 500 mm – this is partly due to restrictions on condensate dropper locations.

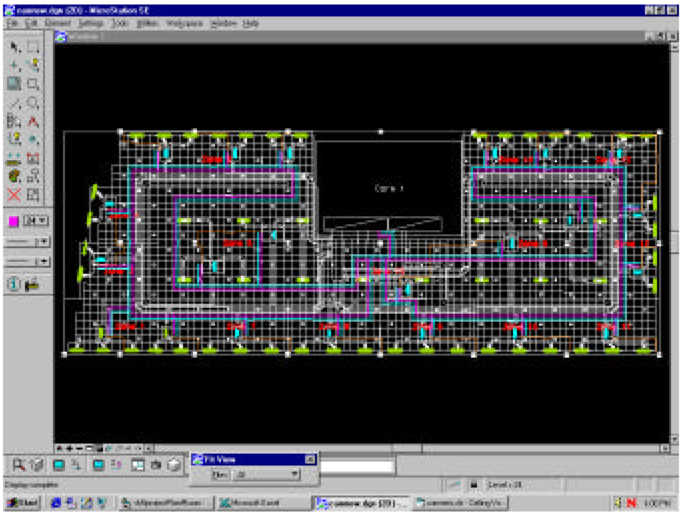


Figure 29: Ceiling void comparison – 2D layout

The standard solution is comparable to the design solution in terms of the number of fan coils and diffusers. Distribution routes are slightly longer than those for the design solution due to them being loop based (for flexibility).

5.3 Risers

Riser areas were also generated for the speculative office. The areas showed reasonable agreement with those for the design solution. The risers represent approximately 0.6% M & 0.4% E of the floor area respectively (for four storeys).

In terms of benchmarking areas against published sources, BSRIA TN 17/95 "Rules of Thumb" [5] gives values of about 1.2% M and 0.4% E. The electrical value is in agreement with the standard solution whereas the mechanical value is a lot higher. The difference in the mechanical area is to be expected as it will vary both as a function of the number of floors served and the type of system (all air systems will require a significantly greater area than fan coil systems).

6 Martin Centre Work

The work described in the preceding three sections of this report concentrated on generating solutions for relatively simple geometric layouts. These are appropriate for many applications, but ultimately it would be better to be able to deal with more complex geometries. One option is to do this by manually modifying the simple geometric solution in the CAD environment. However, it would be preferable to be able to directly generate solutions for complex geometries.

Work on this aspect was undertaken by the Martin Centre who have considerable expertise in this area. The work built on the industrial partners rules for selection and sizing boiler plant room equipment (Section 3) by using constraint modelling to generate solutions for complex room geometries. A full account of the work is given in the Martin Centre Final Report to EPSRC “Building Services Standard Solutions”. This report and the resulting Java demonstration tool are available via the project web site.

The tool requires the plant room geometry (an orthogonal polygon with known obstructions, openings and external walls) to be defined by the user in addition to the heating load. Having selected and sized the equipment on the basis of the heating load, a compatible optimising 3D variational solution is generated, using Constraint Logic Programming and in particular arc-consistency on integers. To do this the permissible topological solutions are firstly enumerated, and then refined to form compatible geometrical solutions. Heuristics are used to restrict the search to promising areas of the solution space. The final step generates pipe routes, using branch and bound optimisation to minimise the length of pipes and the number of bends.

Constraints are applied implicitly by the system and can be classified as:

- Topological constraints:
  - non-overlapping constraint between the plant room components.
  - adjacency constraint, eg between the panel board and plant room walls.
  - inclusion constraint, eg all the objects are inside the plant room.
- Dimensional constraints on the geometrical parameters of objects, eg setting a minimal or a maximal domain value.

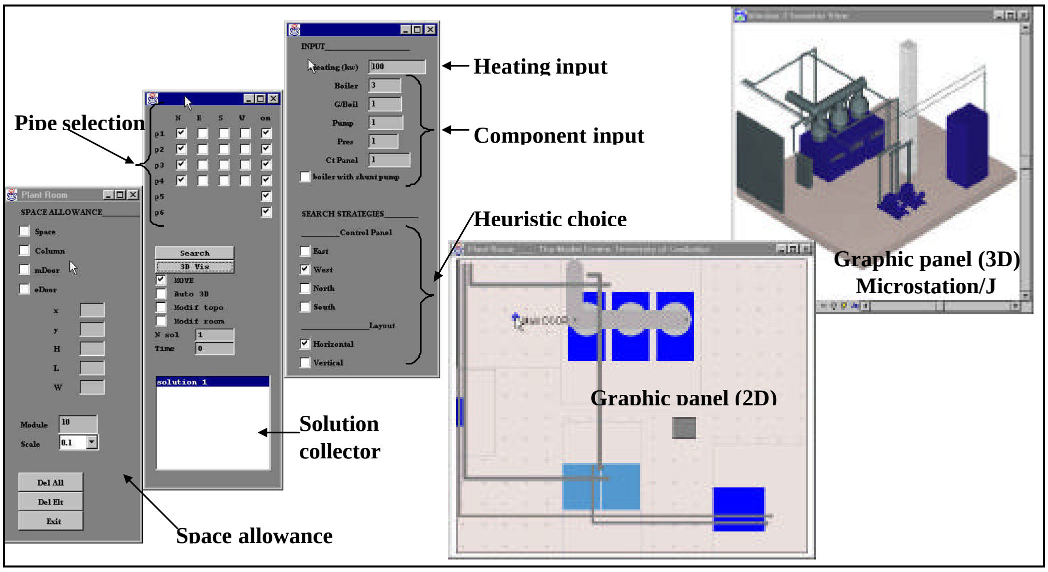


Figure 30: Demonstration tool

The resulting software (see Figure 30) is highly interactive. Modifying the topology of the solution is done directly through the graphic interface by dragging; the system automatically updates the 3D model (including the pipe-routing) while maintaining all the constraints.

The application is developed in JMDL (Java Modelling Language) as embedded in Station/J, and ECLiPSe (a trademark of IC-PARC at Imperial College, London) the constraint logic programming system. JNI (Java Native Interface - a trademark of Sun Microsystems, Inc) is used as the programming interface between ECLiPSe and JMDL. MicroStation/J (a trademark of Bentley Systems) is used to hold the object model and for the 3D rendering.

7 Conclusions

This Section discusses conclusions that may be drawn from the project and issues raised by the work.

- The use of standard solutions in conjunction with IT has the potential to significantly reduce design costs, improve quality and produce additional benefits elsewhere in the supply chain.

  The outputs from the implemented tools and the benchmarking exercise have demonstrated that it is possible to produce reasonable designs using standard solutions. The main quantifiable benefit is the reduction in design time which it is estimated to be typically in the region of 10-20%. This is based on design activities replaced by the automated generation of the standard solutions. For simple building geometries the figure could be significantly higher. Estimated direct costs associated with developing and implementing the solutions are £10ks (tens of thousands of pounds), suggesting a large nett benefit.

  Some of the tools present the user with lists of plant or options from which to select. These act as prompts and check lists. The solutions also automatically include required ancillary plant. These features inherently reduce the risk of error by omission.

  Outputs from the solutions such as 3D visualisation and quantities may be beneficial to other parties in the supply chain. Prefabrication rules could also be introduced. These benefits have not been considered in depth by the project and represent a possible area for future investigation.

- IT implementation of the solutions performs a critical role in maximising productivity improvement by automating generation of the design.

  Standardisation is widely used in design at present, particularly for selection and sizing of plant. However, the processes are invariably manual in nature. Implementation of standard solutions in IT automates many of these processes. Drawing and schedule production can also be automated. IT implementation therefore performs a critical role in maximising productivity improvements.

- Applications most suited to standardisation are characterised by:
  - a high degree of repetition between jobs
  - a limited number of practical variations
  - minimal interaction with other disciplines and services.

  Plant rooms and risers are good examples of suitable applications.

  A high degree of repetition is desirable. If a solution is only used on an occasional basis then the benefits may not be sufficient to outweigh the development, implementation and update costs.

  The number of practical variations that need to be included in the solutions will impact on the development, implementation and update costs. Rationalisation may be desirable to reduce costs. For example, the number of possible heating system configurations was restricted to four. In some cases however, this may not be possible and the number of variations may make the definition of rules impractical. This was found to be the case for distribution routing in the ceiling void which was done manually.

Interaction with other disciplines and services requires user definition of these constraints before a solution can be generated. For example, the ceiling void solution requires the definition of slabs, columns, beams, cores, ceiling tiles etc. This may become laborious and negate some of the benefits of the standard solutions approach (unless input can be imported from another software package or database or generated using rules-of-thumb).

- Partially standardised solutions can be of significant benefit.

  In some cases it may not be practical to standardise all elements or facets of a solution. Distribution routing in the ceiling void is an example of this due to the number of possible variations and configurations. However, much of the solution can still be standardised such as zone fan coil and diffuser arrangements. Using a partially standardised solution to generate these elements can still bring significant benefits. Distribution routing can then be subsequently defined by the user. (NB Selection and sizing of the routes could still be according to standard rules with only the location user-defined.)

- Reducing the scope of a solution may increase suitability for standardisation.

  For the plant room solution it was found to be preferable to limit pipework, ductwork and tray routing to interconnections between plant and connection points within the plant room. Extending the standard solution to external connection points reduced flexibility by requiring user-definition of the points and by using standard rules for routing. Reducing the scope of the solution reduced the number of interactions and variations, increasing the suitability for standardisation (consistent with the comments above).

- The standard solutions should act as templates that can subsequently be modified to suit an increased range of applications.

  The standard solutions generated according to the defined rule set and user inputs are unlikely to be wholly correct for more than a small percentage of applications. However, the bulk of the solutions are likely to be appropriate for a much larger range of applications, requiring modification of only a small part to produce a suitable solution. An example of this is the generation of a ceiling void solution that subsequently requires manual modification of diffuser locations to follow a profiled perimeter. By using the standard solution in this manner as a template, the range of applications can be greatly increased.

- A significant barrier to the widespread implementation is the current lack of manufacturers equipment data in a suitable electronic format.

The standard solutions are underpinned by the plant object database from which selections are made. Due to the lack of manufacturers data in a suitable electronic format, development and population of a database was undertaken by the project participants. The database developed is suitable for research demonstration purposes, but is limited in terms of the number of manufacturers and equipment ranges. For use of the solutions in practice, the database should include more manufacturers and a greater range of equipment. To produce such a database would require a considerable effort and remains a barrier to the widespread uptake of this and other similar IT based developments. This may be overcome by the development of an industry standard format for object definition and subsequent population a databases. Work is ongoing in this area by the IAI (International Alliance for Interoperability) [1] and others.

- Standard solutions should be seen as tools for aiding progress by way of propagating good practice and releasing resources for innovation.

  Concerns were raised during the project over whether standardisation would present a barrier to progress and innovation. To ensure that standard solutions have a positive effect in this respect, it is considered important that the solutions are continually updated to keep up with and to help propagate good practice. In addition, resources released by the use of standard solutions could be redirected on those areas of design requiring novel solutions thereby increasing innovation.

Appendix A1 Documented Rules and Solutions

This Appendix documents the rules and solutions collated for the three areas considered by the project; plant rooms, ceiling voids and risers. The rules and solutions relate to the selection, sizing and location of equipment, and are approximately split into these categories for each item of plant and equipment.

The rules and solutions have been collated for the purposes of this research project to meet the stated objectives and so are not necessarily complete. They are generic in nature and are not intended to be suitable for all applications. The implementations are based on the documented rules and solutions but may vary in detail.

A1.1 Plant Room

The rules and solutions documented are for three types of plant room:

- Heating based on a gas fired closed system with sectional boilers
- Air handling
- Chiller.

Plant	Type	Rules/Standardisation
General	Location	Boiler room usually separate space (must be separate from chillers). All other areas can be merged. Compartmentation dictated by Building Regs (escape route distances). Minimum 500 mm between any item of plant and wall. Minimum 100 mm between surface and uninsulated service. Minimum 250mm between surface and insulated service. All equipment in plant room on plinth 100 mm high. Plinths generally rectangular and overlap plant floor print by 100 mm. Large item of plant (dimensions over 1500 mm) may have profiled plinth. Ductwork is easier to set up and down, therefore pipework has horizontal priority. Access routes through plant areas 2000 mm wide, ideally not smaller than 1500 mm wide. Preferable for primary route through plantroom to double as service space with services above primary route. Double doors into plantroom preferable minimum 1½ doors open straight onto primary route through room. Single door for emergency escape on opposite side of plantroom to main doors. If plantroom on raised floor slab, provide all rotating equipment with AV mount. Provide pumps (>20 KW) with inertia base. Ground bearing plantrooms can have pumps on raised AV plinth (300 plinth layer, 50 resilient layer and 150 plinth layer). Preferred general arrangements are illustrated in Figures A1.1, A1.2 and A1.3.

Plant	Type	Rules/Standardisation
General	Location (cont)	The equipment location sequence for a heating plant room is generally as follows: • Access routes • Boilers + flues / AHU /chillers • Pumps • Pressurisation units • Panel boards • Pipework • Ductwork • Electrical distribution.
Boilers	Selection	Atmospheric gas fired sectional boilers. Heating system configurations selected on the basis of size and type of load given in Figures A1.4, A1.5, A1.6 and A1.7.

	Sizing	Number of modules:
		    <50 KW, use 1 boiler
		    >50<, use 2 boilers at 60% of total requirement
		    >100 KW, use 3 boilers, 2 @ 50% plus 1 standby or 3 @ 35% plus 1 standby.

	Location	Refer to General Location.
		
		Determined by location of flue stack for atmospheric boilers.
		
		Burner to front of unit into central corridor. If flue connection is on rear of boiler, can use space under horizontal flue as header for pipe headers.
		
		Ancillary Equipment – allow for the following usual equipment that is often located in a boiler room:
		    Side stream filter
		    Dosing Pot
		    Automatic dosing unit

Flues	Selection	Natural draft preferred solution. Use fan dilution where a vertical route through from boiler room to roof is not available. Allow for a twin wall vertical stack generally.

Plant	Type	Rules/Standardisation
	Sizing	Flue sizing depends on: type of appliance (atmospheric or FD) size of appliance (kW output will relate to flue gas volume) vertical stack height. Sizing depends greatly on each manufacture's fitting resistances. For atmospheric boilers use manufacturers look-up which gives flue size based on size and vertical stack height (assuming a maximum horizontal run from header of 6 m and two horizontal bends). Use manufacturers standard system where fan dilution selected.
	Location	Refer to General Location. For atmospheric boilers stack location determined by maximum horizontal run from boiler header and numbers of fittings as noted under Flues Sizing. Usually combine flues into vertical stack. Number of stacks depends on vertical space available in shaft i.e. 2 @ 350 diameter or 1 @ 450 diameter. Horizontal head in plant room laid to fall for condensation draining.
Ventilation	Selection	Normal vent purposes require air for aspiration and ventilation. For smoke extract purposes require 10 AC/h. Natural ventilation preferred solution if on roof or access to outside. May provide mechanical vent for smoke extract. Two speed if also used for normal vent.
	Sizing	As graphs in CIBSE Guide B13 [6] for boiler room. In summer not all boilers running (assume a max of 20% as default). The summer load is related to DHW load and kW may be able to be estimated from the building population and type.
	Location	Vents located on same external wall. Supply at low level. Extract at high level.

Plant	Type	Rules/Standardisation
Gas Booster/ System	Selection	Booster not generally required with atmospheric boilers located at low level. Provide when: Forced draught boiler used Need to supply a large kitchen (commercial) Boilers are (say 5m)above datum.
	Sizing	Gas pipework sized on the basis of total pressure drop, pipe length and fittings allowance using CIBSE Guide C4 [7].
	Location	Refer to General Location. Gas routing: • When in unventilated shafts or voids, needs to be enclosed in a pipe (say two sizes larger). • Both ends of sleeve open to ventilated spaces. • Pipe in pipe difficult to construct, therefore always run as straight and direct as possible. • Gas shut off button at exit of each room with gas appliance (booster, boilers). • Gas pipework should not be run at high level in boiler room.
Chillers	Selection	Cooling system configurations selected on the basis of size and type of load given in Figures A1.8 and A1.9. Air cooled if located outside eg on roof. Water cooled if located inside.
	Sizing	Size chillers to meet load: • 2/3 chillers up to 1 MW • 3 or more chillers above 1 MW.
	Location	Not in Basement for critical installations. Roof for air cooled chillers.
Pressurisation Units	Selection	For use with LPHW and chilled water sealed systems (preferred because of reduced air and therefore corrosion in the systems).

Plant	Type	Rules/Standardisation
	Sizing	As Pullen Booklet 0821 (Pressurisation Technical Data) [8] calculation method. Information required: Datum for equipment Static Head Min fill pressure (0.7 bar min) KW of system Capacity F & R Temp Duty of pump. Antifreeze content changes the expansion coefficient of water. Rough rule of thumb for system capacity assessment: 12 l/kW heating 9 l/kW cooling. Iterate back when actual content is known.
	Location	Refer to General Location. Vessels can be located close to back wall, but need to be removable for maintenance.
Pumps	Selection	Use close coupled end suction for energy efficiency where head predictable (shunt pumps). Use belt drive with motor above for flexibility where head less predictable (system pumps).
	Sizing	Always use impeller housing one size up to allow for future expansion of the system. Select at 75% of maximum flow for efficiency from pump curves. LPHW flow rates based on loads and flow/return temperatures of 82/71°C. CHW flow rates based on loads and flow/return temperatures of 6/12°C. Allowance for shunt pump head 100 kPa. Allowance for system pump head 250 kPa.

Plant	Type	Rules/Standardisation
	Location	Refer to General Location. Arrange duty/standby pump sets in pairs. Locate shunt pump next to boiler. Arrange so pump sets on same systems are close together. Allow for an "A" frame gantry to roll over the pump for maintenance. Allow for "stool" piece so that motor can be removed with impeller housing in place.
Air Handling Units	Selection	Most common components (for A/C building): Inlet section, Frost Coil, Filter, Reheat Coil, Access, Humidifier, Cooling Coil, Eliminator (optional), Fan: If using run round coil, place after filter Frost coil protects filters only Use combined bag/panel filter 'Steam' humidifier is the preferred solution Access section min 600mm wide. Blank sections may be required where located adjacent to a column. Use backward curved fans on supply to withstand variations in pressure due to eg filters clogging.
	Sizing	Square is most effective generally (space requirement increases with width and cost with height). For preliminary sizing, base on 2.0 m/s on cross sectional area (allows for minimal carry over and a small margin for coil frame). Aspects can be altered although not more than 1.5:1. Unless lots of length (space) available adopt a top discharge unit. Allowance for external system pressure drop 300 Pa.

Plant	Type	Rules/Standardisation
	Location	Refer to General Location. Intake (in City centre environments) should be at 4th floor level or above, preferably on roof. Discharge anywhere but not near intake. Minimum separation (draft ASHRAE standard 62, 1996 [9]) given by: $S \geq 0.04 * \sqrt{Q} * (\sqrt{D} - v/2)$ where: S is separation (m) Q is the air flow rate (l/s) D is the dilution factor (10 for office type applications) V is the discharge air velocity (m/s) Need to allow approximate same width for coil withdrawal which can be a problem on squat units. Can use double coils if access both sides. If using air heat recovery (wheels, X plate exchange) exhaust must return near to intake. Run round costs have no flexibility restriction.
Extract	Selection	Use forward curved fans or axials for smaller equipement.
	Sizing	Allowance for extract system pressure drop 250 Pa.
	Location	Refer to General Location. Refer to Air Handling Units Location where air heat recovery.
Pipework	Selection	Ancillary Pipe Equipment - place IV's either side of all equipment (# 50 mm ball valve, > 50 mm butterfly). Use fittings as defined by BSRIA Standard Details project.
	Sizing	Use CIBSE Guide C [7] "steel pipe" (bigger and higher k factors). Base sizing generally on 200 Pa/m and never exceed 250 Pa/m.

Plant	Type	Rules/Standardisation
	Location	Refer to General Location. Try to run in pairs (side by side) for flow & return but not essential. Preferable to hang from ceiling (cheaper than wall mounting). Pipework headers over corridor if space allows. This facilitates access to valves etc.
Ductwork	Selection	Use rectangular ductwork to minimise spacial requirements, unless plant room has pitched roof with space for running circular ducts. Use standard ISO/DW144 range [10]. Use fittings as defined by BSRIA Standard Details project.
	Sizing	Use CIBSE Guide [7]. 7 m/s maximum velocity limit for ductwork in plant room. Maximum aspect ratio 4:1. No transitions > 45^{o}. If fire rated allow for 100 mm additional all round. Generally wide and flat preferred to tall and thin although side wall hung route are the exception.
	Location	Refer to General Location. Ducts without service connection can go at the top of a stack of services. Preferable to hang from ceiling (cheaper than wall mounting). Cost effective to run side by side to share support.
Distribution Boards	Selection	Use MCB distribution boards as default, MCCB panel boards as required for larger loads. Configuration of electrical distribution system with distribution board and Motor Control Centre (MCC) as per Figure A1.10. (Alternative to use individual starters + control panel to replace MCC)

Plant	Type	Rules/Standardisation
	Sizing	Size board to based on incomer amps and number of ways required. Use BS 7671 [11] including all amendments. Use BSRIA TN 9/92 [4] for load allowances. Electrical load information for the mechanical plant selected will be available from their defined attributes (NB pumps, fans etc served by MCC). External electrical loads to be fed from the panel board need to be added to these, as well as rule of thumb W/m^2 data for the lighting and small power requirements within the plant space. Once the total has been finalised a further 25% spare capacity should be added to determine the number of ways required for panel selection. Individual circuit loads to be used initially to obtain preliminary cable sizes. Protective devices to be sized on the load and taken to the nearest larger size. This allows cable sizes to be generated and the cable tray sized.
	Location	Use Electricity at Work Regulations 1989 including all Appendices. Refer to General Location. Bottom of Panel to be located 1100 mm above floor. Minimum maintenance access 1m at the front of the board. Panel board (or header busbar) should ideally be located centrally to the load therefore reducing the final cable length and distribution losses. Locate away from louvres (possible source of moisture).
Motor Control Centre (MCC)	Selection	MCC to contain starters for equipment normally supplied without integral control (eg pumps and fans) + control panel. Starters: Fuses or circuit breakers for motors below 0.37 kW Direct On Line starters 0.37 – 7.5 kW Star-delta starters 7.5 – 30 kW Soft start 30 – 400 kW Inverter where speed control required.

Plant	Type	Rules/Standardisation
	Sizing	The following rules have been used to estimate the size of a compartmented (worst case) MCC: Panel height 2200 mm Cabling compartment 300 mm wide full height Direct On Line, Star-delta compartments 600 mm wide x 600 mm deep x height as noted below: Up to 11 kW 200 mm (300 mm wide if Direct On Line) 11-22 kW 300 mm 22-37 kW 400 mm 37-55 kW 600 mm 55-90 kW 1000 mm 90-160 kW 2000 mm Controls cubicle 600 mm wide x 600 mm deep x 600 mm high Fuse switch/MCCB incomers 600 mm wide x 600 mm deep x height as noted below: 63 Amp 200 mm 200 Amp 300 mm 400 Amp 400 mm 800 Amp 600 mm ACB's (1250 Amp) 600 mm wide x 800 mm deep x 2000 mm high.
	Location	Use Electricity at Work Regulations 1989 [12] including all Appendices. Refer to General Location. Locate away from louvres (possible source of moisture).

Plant	Type	Rules/Standardisation
Electrical distribution	Selection	Cable tray standard solution. Run take-off trays from main tray run below other services for access. Run ramp dropper from main run to take-offs. (Plant areas that have larger numbers of plant items may be better serviced from header busbars. Ideally the Boiler room and other plant areas should be located adjacent each other. The busbar would then replace the tray as the "central spine" distributing power throughout the plant areas (refer to Figures A1.11 and A1.12). The decision to use busbar over a panel board is related to the size of load, the number of plant items to be located in the plant area and the dimensions of the plant area. As a rough guide if the load requirement is 400A and the number of ways required / plant items is less than 15 a panel board remains the best solution. (NB this figure is not cast in stone.) Conversely if the load is greater than 400A but less than 630A and the number of items is still less than 15 a panel board still remains the best solution. This can be applied to load size of 800A. All the above is only applicable if the plant room does not exceed a wall dimension greater than 5m on its longest side. If the longest side exceeds 5m, the load is 400A and the plant items exceed 15 a header busbar should be considered.)
	Sizing	Refer to Panel Boards Sizing. Cable trays to be sized on the basis of cable outside diameters as given in Figure A1.13. All MCCs with inverter control to have cabling with neutral of equal size to phase.

Plant	Type	Rules/Standardisation
	Location	Use Electricity at Work Regulations 1989 [12] including all Appendices. Refer to General Location (main run above access route with take-offs either side). Minimum maintenance access for cable trays and trunking 150 mm. Minimum bending radius as per IEE On-site guide to BS 7671:1992 “Requirements for Electrical Installations” Table 4E [13]. When positioning the cable tray or electrical services in a plant room they should be of secondary importance to the mechanical services. There is less benefit from pre fabricating electrical components because of the way the components bolt together. They do however require a spatial zone to be allocated to benefit from speed of installation and to allow for access to change and or reset the protective devices. Refer to Figures A1.14 and A1.15.

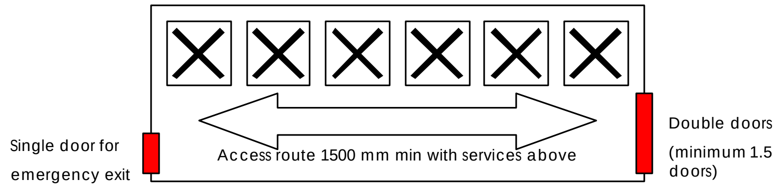


Figure A1.1 Corridor layout with plant on one side

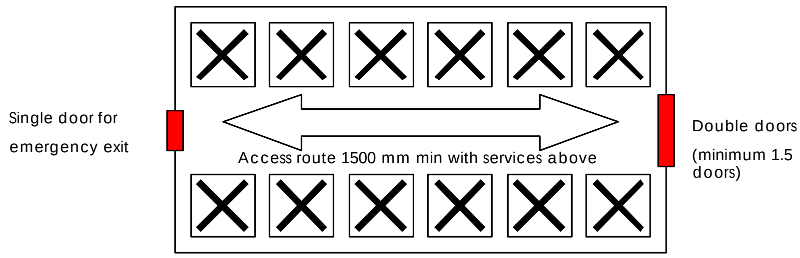


Figure A1.2 Corridor layout with plant on both sides

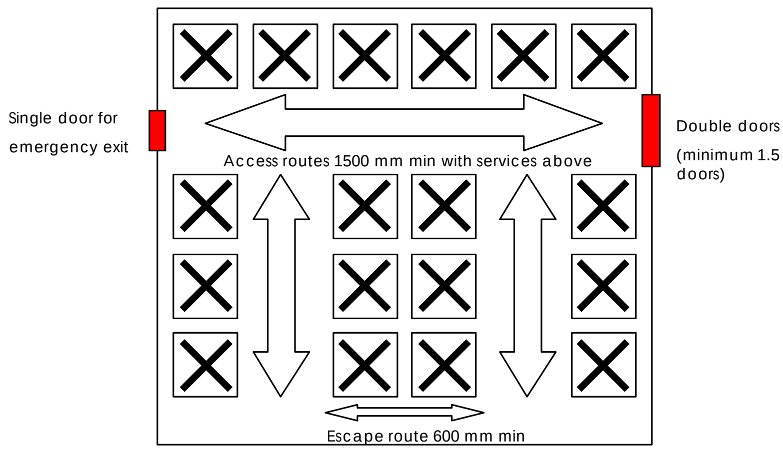


Figure A1.3 Square layout

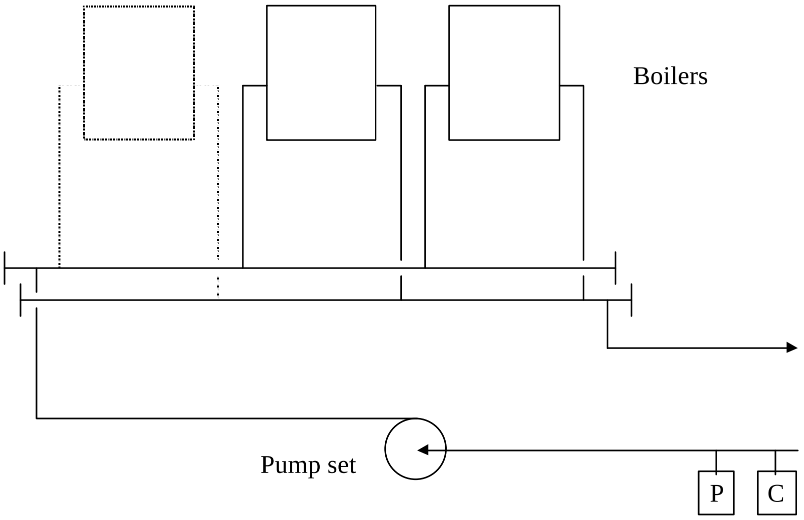


Figure A1.4 Simple heating systems up to 100 kW

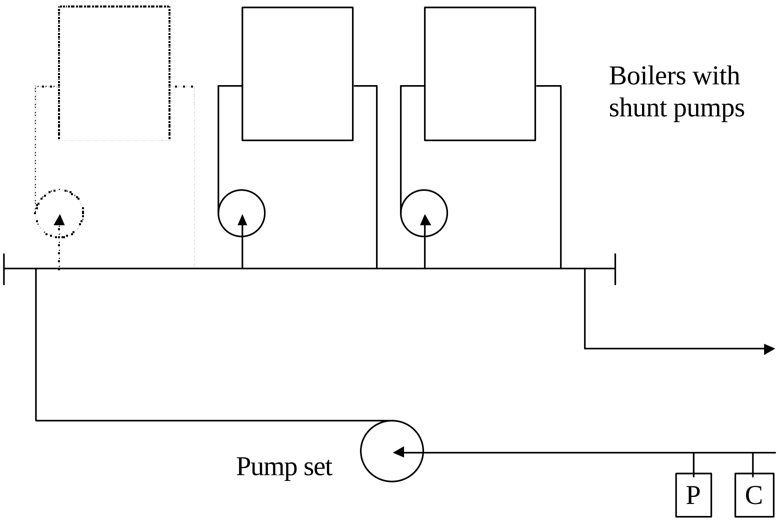


Figure A1.5 Simple heating systems of multiple boilers > 100 kW

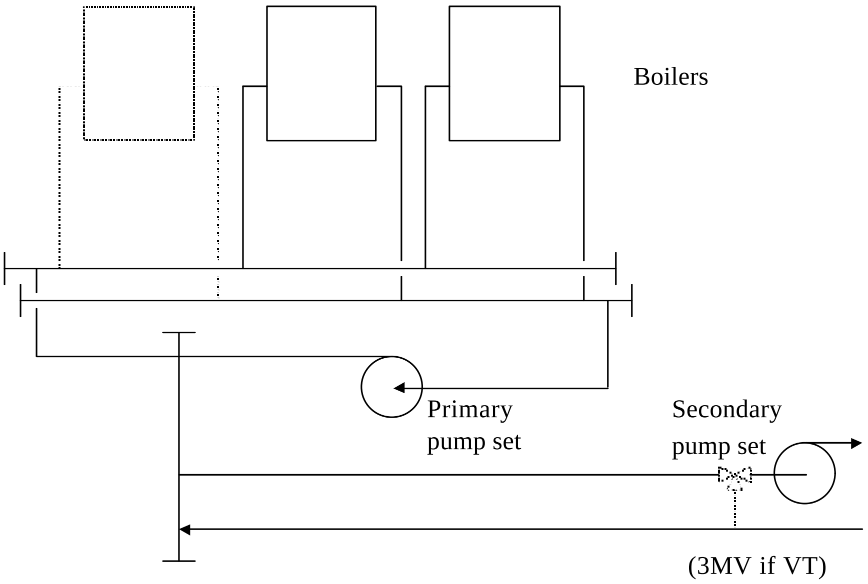


Figure A1.6 Large radiator heating system > 300 kW

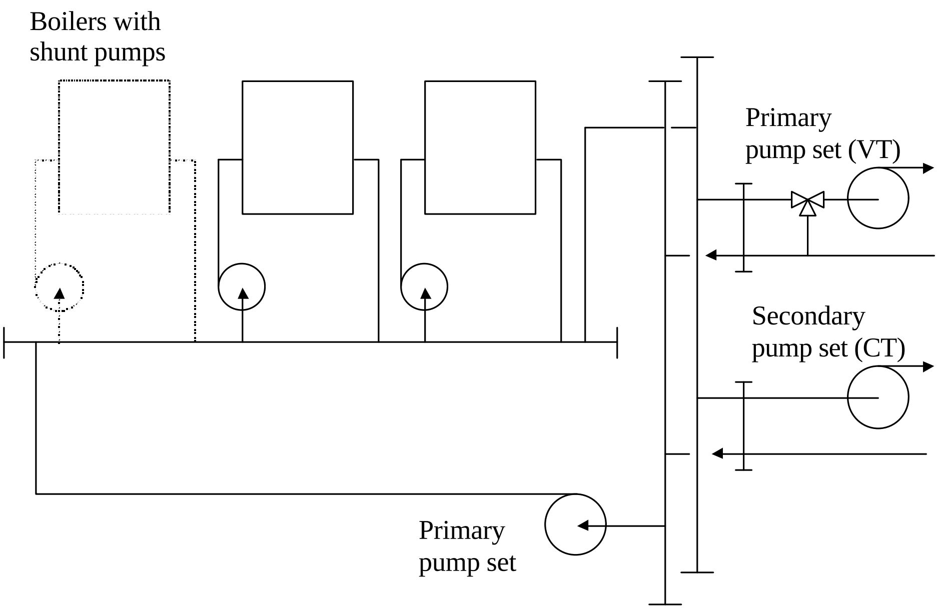


Figure A1.7 Large/multiple secondary heating systems

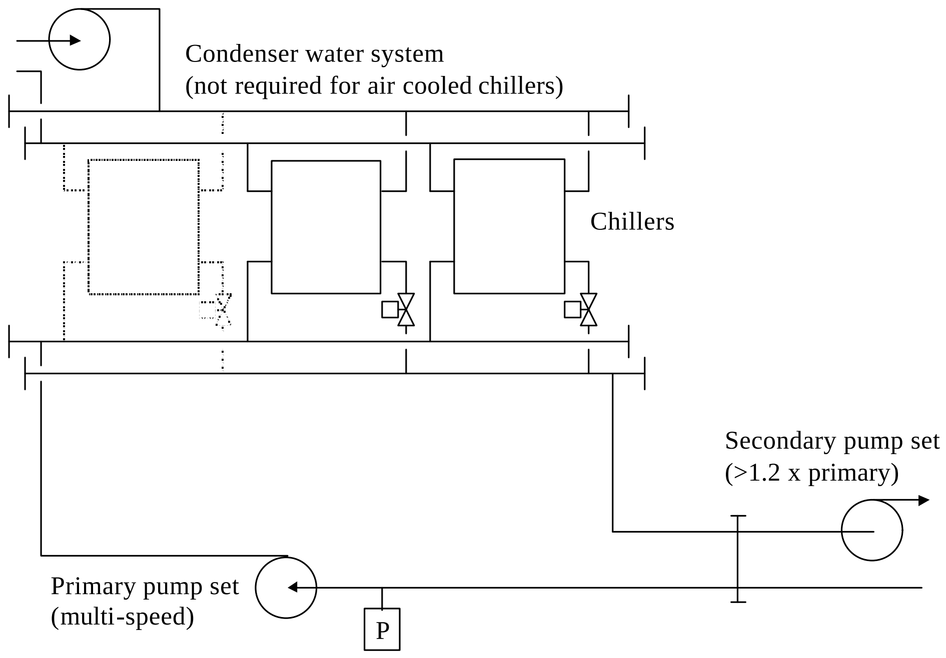


Figure A1.8 Simple cooling systems up to 1 MW (2 or 3 chillers)

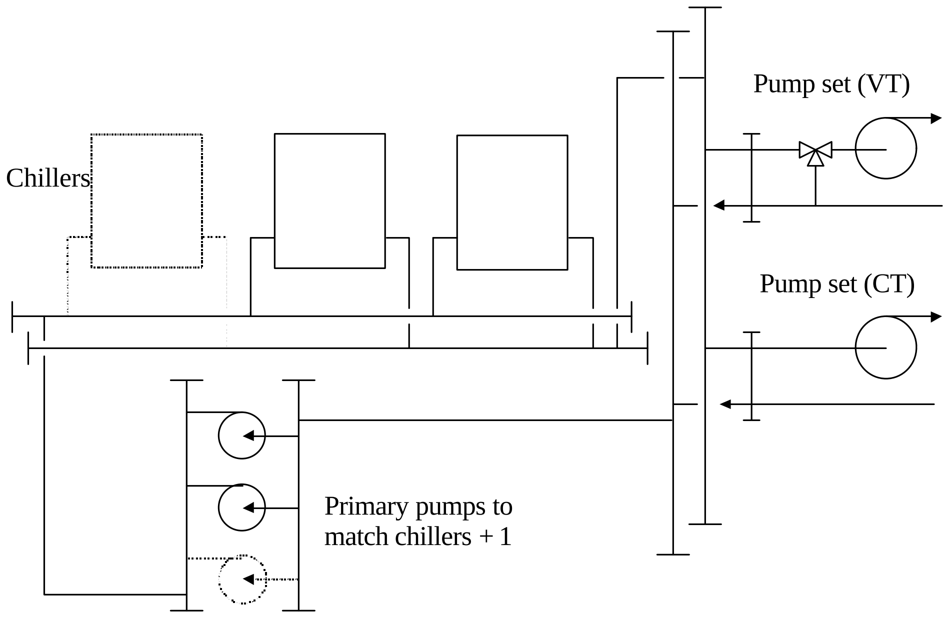


Figure A1.9 Large/multiple secondary cooling systems above 1 MW (≥3

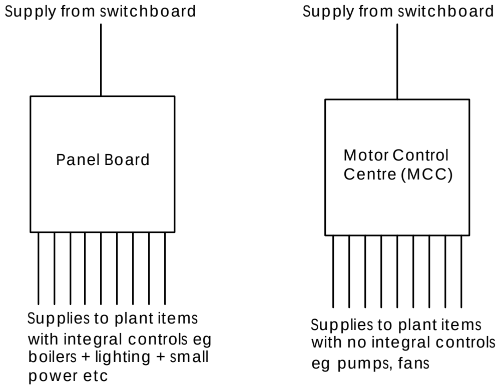


Figure A1.10 Electrical system configuration

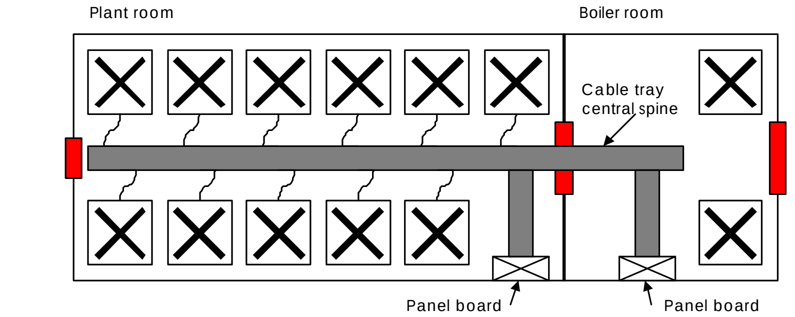


Figure A1.11 Electrical distribution (cable tray)

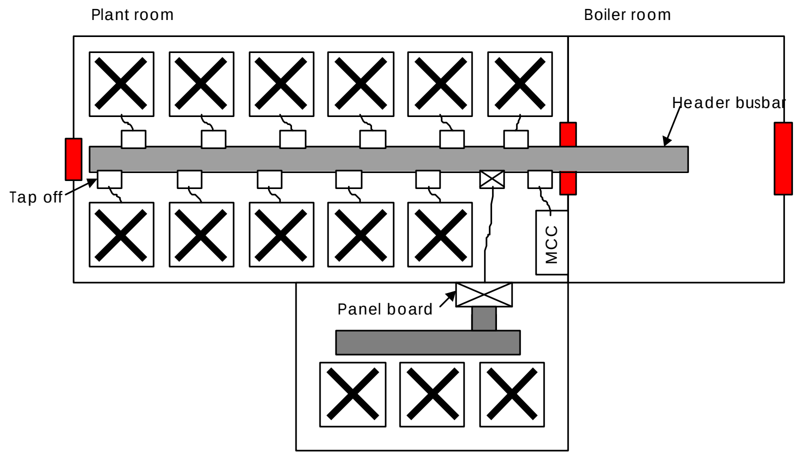


Figure A1.12 Electrical distribution (header busbar)

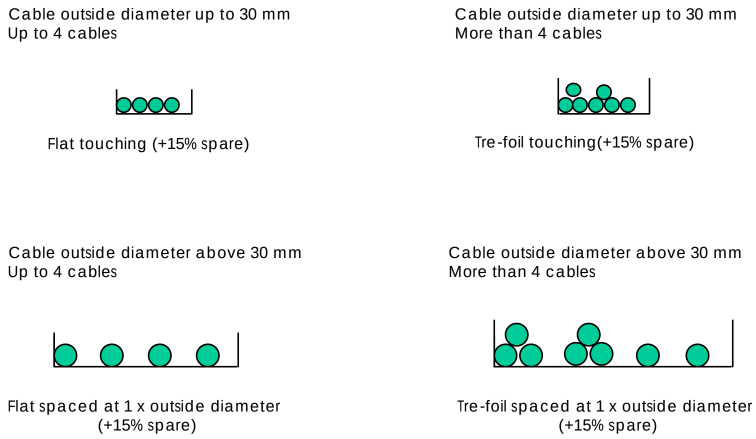


Figure A1.13 Cable tray sizing

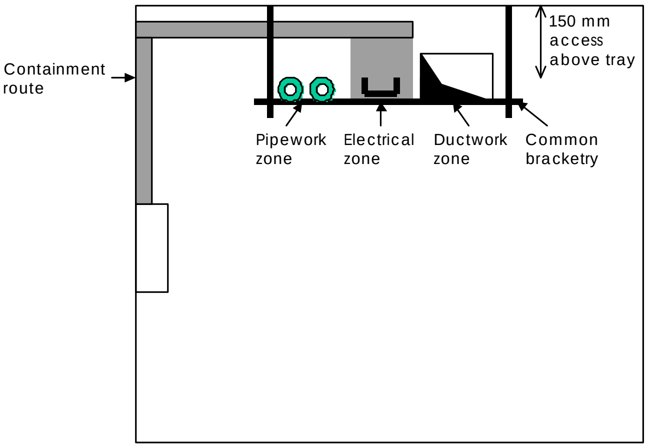


Figure A1.14 Electrical distribution (coordination)

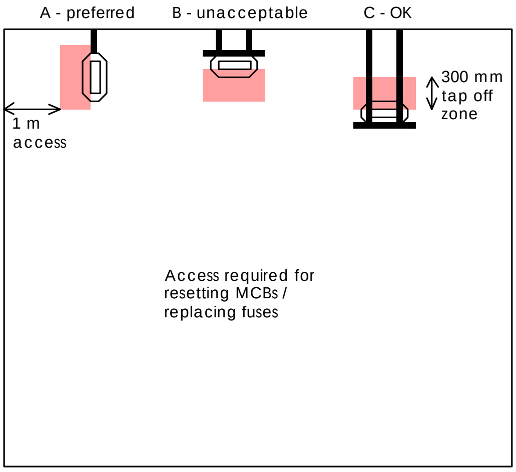


Figure A1.15 Electrical distribution (busbar mounting)

A1.2 Ceiling Void

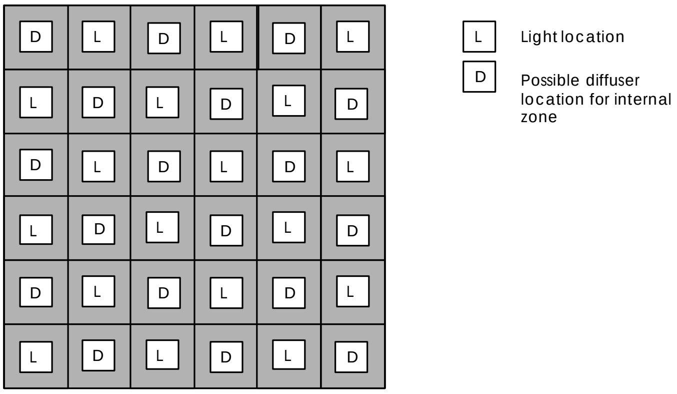
The rules and solutions documented are for a four pipe ceiling mounted fan coil system as the HVAC standard solution. Electrical distribution is by busbars with recessed luminaires for lighting.

Plant	Type	Rules/Standardisation
General	Locations	The equipment location sequence is generally as follows: • Luminaires • Diffusers • Fan coil units • Pipework • Ductwork • Electrical distribution. Equipment (eg diffusers and lights) should not be located in adjacent tiles unless there is a reasonable margin around equipment (eg diffuser dimension #450 mm for a 600 mm ceiling tile).
Lighting	Selection	Square recessed modular luminaires selected as the default – linear option as possible alternative.
	Sizing	Lumen Method CIBSE TN5 [14] to calculate maximum separation of luminaires to meet light level required.
	Location	Integration with ceiling tile layout selected to meet minimum separation requirement (refer to Figures A1.16, A1.17, A1.18 and A1.19). No luminaires on perimeter row of ceiling tiles.
Fan Coil Units	Selection	Units selected from manufacturers standard range using chilled water for cooling and LPHW for heating as required. Standard spigot plenum connections used for supply - blanked if not all required. Valve arrangement as defined by BSRIA Standard Details project.

Plant	Type	Rules/Standardisation
	Sizing	Following variables defined for selecting size of fan coil units (volumes and loads could initially be allowances based /m^2 values): Total air volume Fresh air volume Cooling required Heating required External pressure drop Noise level. If largest unit not big enough to serve zone, then treat with 2 of the same type, then 3 of the same type, and so on.
	Location	Heating and cooling pipework connections staggered to assist coordination. Locate fan coils on riser side of zone to minimise condensate and other pipework runs and air flow direction changes from the risers through unit to the diffusers (see Figure A1.20). Locate 50-100 mm below slab to allow for slab inconsistencies and slope towards drain exit. Limit distance to diffusers to keep pressure drop down. Avoid grouping intakes as this can cause acoustic problems through reinforcement.
Diffusers	Selection	Perimeter zones - slot diffusers selected from manufacturers standard range. Internal zones - square diffusers selected from manufacturers standard range.
	Sizing	Use manufacturers sizing algorithms to meet throw, pressure drop and noise requirements.
	Location	Located square diffusers to nearest possible location to suit lighting layout – refer to Figures A1.16, A1.17, A1.18 and A1.19. Locate slot diffusers along perimeter.

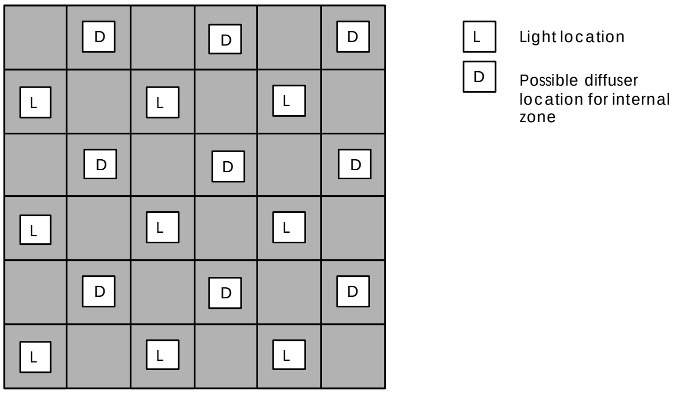
Plant	Type	Rules/Standardisation
Ductwork	Selection	Local ductwork from fan coils to diffusers circular. Distribution ductwork circular up to 200 mm, flat oval above to limit depth requirement. Use standard ISO/DW144 ranges [10]. Use fittings as defined by BSRIA Standard Details project.
	Sizing	Use CIBSE Guide [7]. Local ductwork from fan coils to diffusers sized as plenum spigot connection subject to a maximum velocity of 3 m/s. 5 m/s maximum velocity limit for ductwork distribution to fan coils.
	Location	Run duct and pipework headers out from riser and tap off to fan coil units. Run fresh air to 200 mm behind fan coil – better diffusion of air supply into fan coil and avoids balancing problem with fresh air supply. Duct bends should, where possible, be located away from fan coils and diffusers. Route ductwork through cellular beams if possible, otherwise run below beams. Route ductwork down centre of area to be served. Branch supply ductwork local to risers to facilitate crossovers. Terminate extract stub duct with attenuator as "bellmouth".
Pipework	Selection	Use fittings as defined by BSRIA Standard Details project.
	Sizing	For LPHW and CHW pipework use CIBSE Guide C [7] "steel pipe" (bigger and higher k factors). Base sizing on 200 Pa/m and never exceed 250 Pa/m. Size condensate at 20 mm from units, 40 mm for 2 or more units, 50 mm in risers.

Plant	Type	Rules/Standardisation
	Location	Try to run in pairs (side by side) for F & R but not essential. Reverse return arrangements preferred where possible. Share commissioning sets if adjacent units similar (cost and commissioning benefits) running pipework with a self-balancing “T”. Route through cellular beams if possible, otherwise run below beams. Run condensate lines @ 1:100 gradient to column droppers.
Electical Distribution	Selection	Standard solution small power busbars. Busbars served by cables run on tray from electrical risers.
	Sizing	Select 8 pole busbar to suit loading.
	Location	Number and location of busbars determined by the distance from the load type to the busbar. As a rule the load should not be more than 3m from the busbar. This rule should be applied primarily in the width direction. The busbar length should be determined by the load requirements placed upon it (with the limiting factor being the Amp rating). Refer to Figure A1.21.



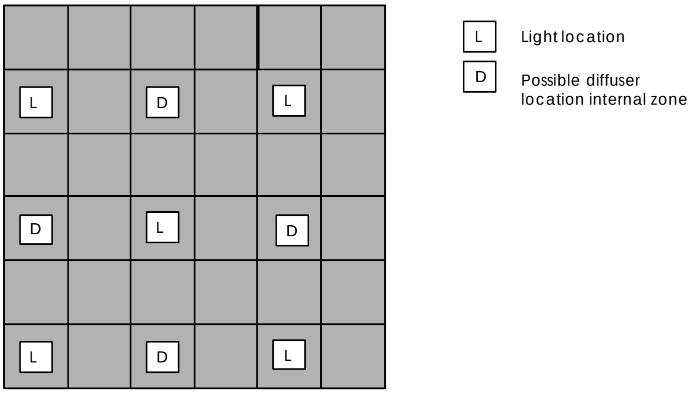
Spacing √2 * tile dimension

Figure A1.16 Ceiling void layouts – lighting and diffusers 1



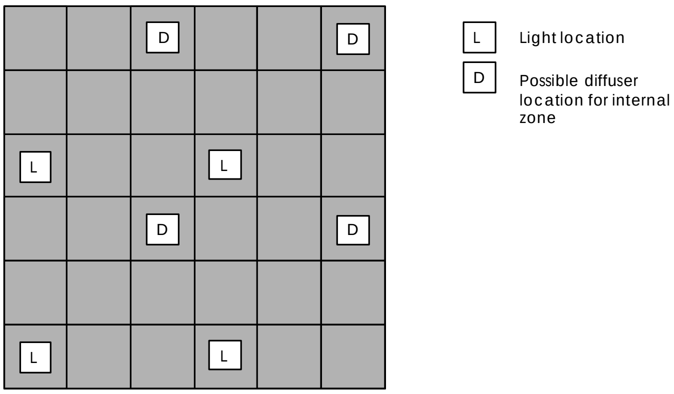
Spacing 2 * tile dimension

Figure A1.17 Ceiling void layouts – lighting and diffusers 2



Spacing 2√2 * tile dimension

Figure A1.18 Ceiling void layouts – lighting and diffusers 3



Spacing 3 * tile dimension

Figure A1.19 Ceiling void layouts – lighting and diffusers 4

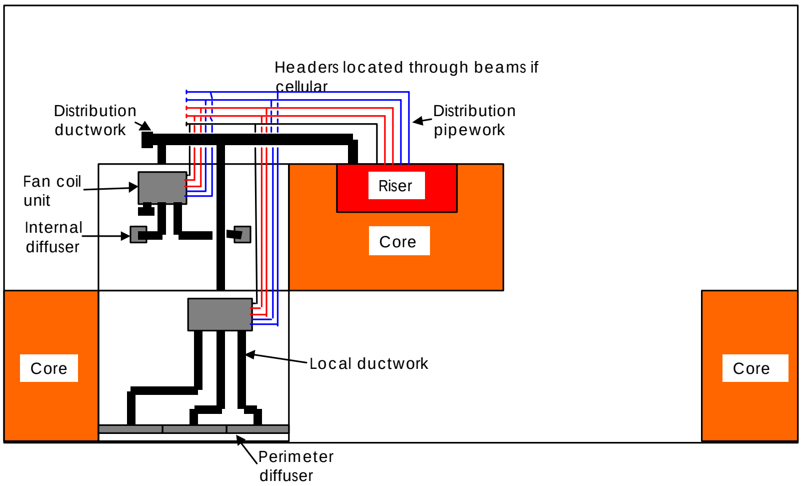


Figure A1.20 Ceiling void layouts – fan coils

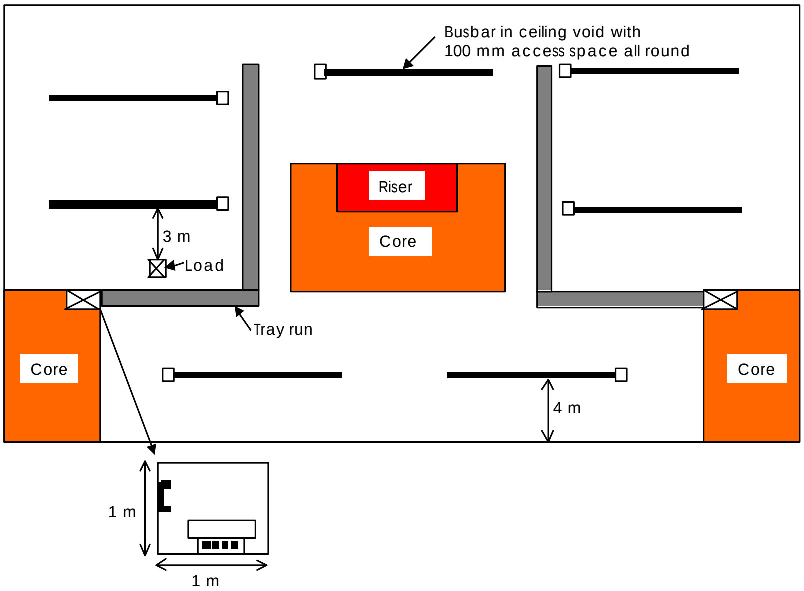


Figure A1.21 Ceiling void layouts – electrical

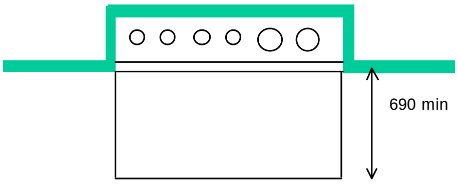
A1.3 Risers

The mechanical and electrical risers are defined separately. (Data/comms is not included in the electrical riser.) The selection of equipment for the mechanical riser is based on the HVAC solution to be served, ie a fan coil system. For the electrical riser the preferred solution is a rising busbar with panel boards distributing to the floors.

Plant	Type	Rules/Standardisation
General	Selection	Mechanical and electrical risers separate. Selection of mechanical services to suit system, ie fan coil. The number of risers and their location will be related to plant room locations and building form – see Reference [2]. Floor space served by a riser is approx. 15-23 m radius - BSRIA rules of thumb TN 17/95 [5]. Ceiling depth and the maximum size of duct take-off connections is often a key driver in determining the number of risers required. There is no formal procedure for selecting the number and position of electrical risers. A rule of thumb is that risers be spaced no more than 60m apart i.e. they have a radius of 30m. This is driven by the need to comply with the BS7671 Voltage Drop regulations and the Earth Fault Loop Impedance limits (Zs) [11].
	Sizing	Risers should maintain a straight and constant cross-section. Minimum size required at each floor level determined by connections which fix flow rates, loads etc.
	Location	Refer to General Selection. Layout of mechanical riser as Figures A1.22, A1.23 and A1.24 (in order of preference as decreasing space efficiency), selected subject to riser dimension constraints. Layout of electrical riser as Figure A1.25. (NB access space in front of panel within riser could be reduced if clear access available from outside.)
Ductwork	Selection	Use rectangular ductwork to minimise space requirement. Use fittings as defined by BSRIA Standard Details project.

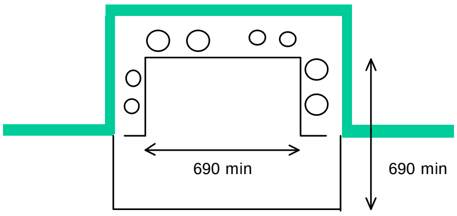
Plant	Type	Rules/Standardisation
	Sizing	Use CIBSE Guide [7]. Use standard ISO/DW144 rectangular range [10] to minimise space requirement. 7 m/s maximum velocity in riser. 5 m/s maximum velocity in take-offs. Maximum aspect ratio 4:1, preferably not > 2:1. No transitions > 45°.
	Location	Fire dampers through slab/riser wall to suit fire compartmentation strategy. See Figures A1.26 and A1.27 for space allowances (based on Ref [3]) with reduced clearances between services. If fire rated allow for 100 mm additional all round.
Pipework	Selection	Use fittings as defined by BSRIA Standard Details project. Pipework selection based on fan coil system, ie supply and extract ductwork, LPHW pipework, chilled water pipework and a condensate drain.
	Sizing	Use CIBSE Guide C "steel pipe" [7] (bigger and higher k factors). Base sizing generally on 200 Pa/m and never exceed 250 Pa/m.
	Location	Try to run in pairs (side by side) for F & R but not essential. See Figures A1.28, A1.29 and A1.30 for space allowances (based on Ref [3] with pipe clearances increased by 25 mm).
Distribution Boards	Selection	Use MCB distribution boards as default, MCCB panel boards as required for larger loads.
	Sizing	Size board to based on incomer amps and number of ways required. Use BS 7671 [11] including all amendments. Use BSRIA TN 9/92 [4] for load allowances.

Plant	Type	Rules/Standardisation
	Location	See Figure A1.25 for spacing allowances. Maintenance requirements assumed to be 1m from the front of the face of the Distribution board and or Tap off unit.
Distribution	Selection	Rising busbar serving panel boards. Allow for cable tray route for plant remote from LV distribution. Allow for cable tray route for eg fire alarm, PA.
	Sizing	Size busbar with spare capacity of 25%. Cable tray to plant remote from LV distribution 300 mm if main plant rooms remote, 100 mm if only ancilliary items remote. Cable tray route for eg fire alarm, PA 100 mm with space for expansion.
	Location	Refer to Figure A1.25. Cable tray space requirements as BSRIA TN 10/92 Part C [4]. In addition to these there should be an allowance of 850mm in front of the tray for installation of future cabling. Allow 50mm clearance either side.



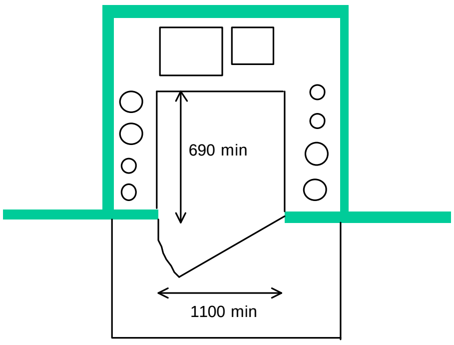
Based on Reference [1]

Figure A1.22 Simple mechanical riser layout



Based on Reference [1]

Figure A1.23 Sided mechanical riser layout



Based on Reference [1]

Figure A1.24 Walk-in mechanical riser layout

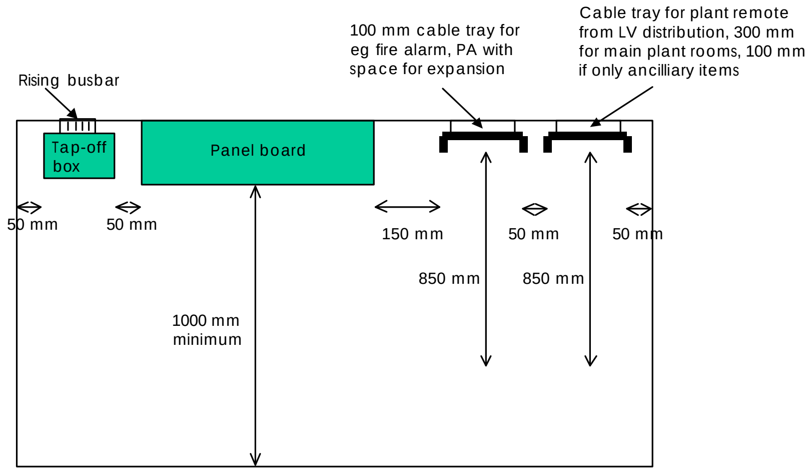
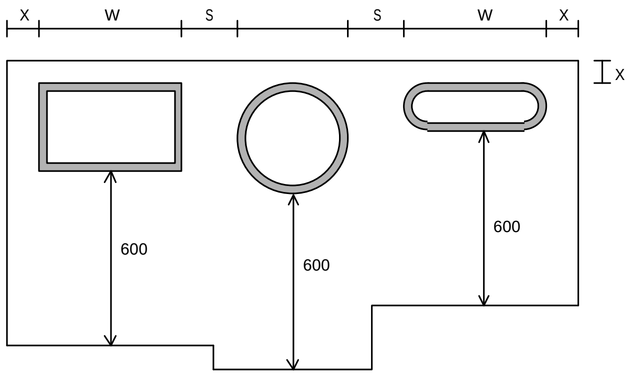


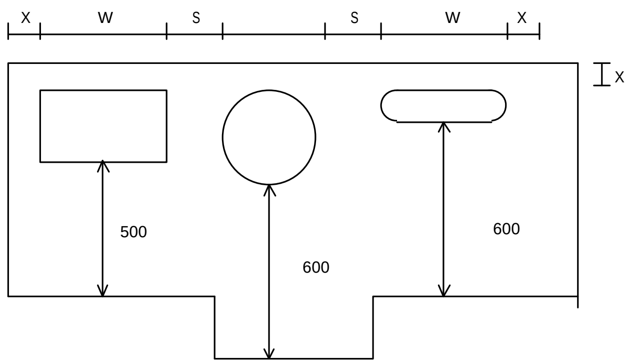
Figure A1.25 Electrical riser layout



For W ≤ 1000 mm X = 200 mm S = 400 mm
For W > 1000 mm X = 400 mm S = 600 mm

Based on Reference [1]

Figure A1.26 Insulated ducts



For W ≤ 1000 mm X = 100 mm S = 300 mm
For W > 1000 mm X = 300 mm S = 400 mm

Based on Reference [1]

Figure A1.27 Uninsulated ducts

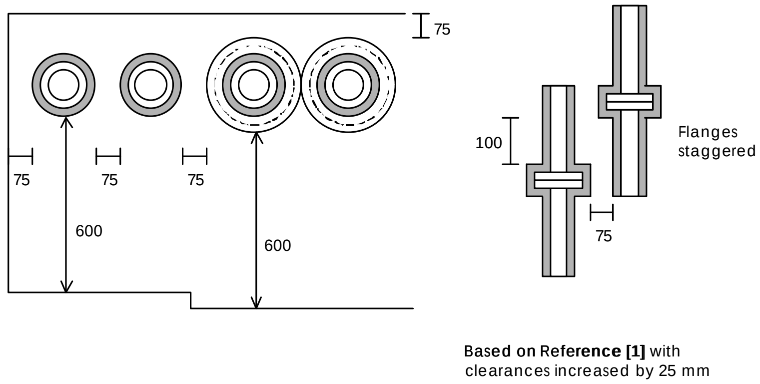


Figure A1.28 Insulated pipework

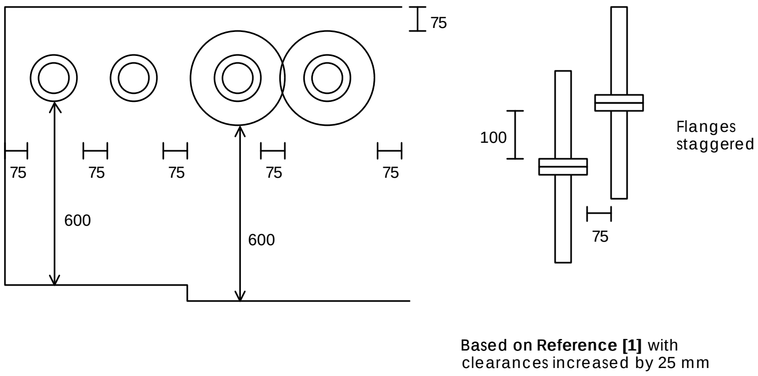


Figure A1.29 Uninsulated pipework

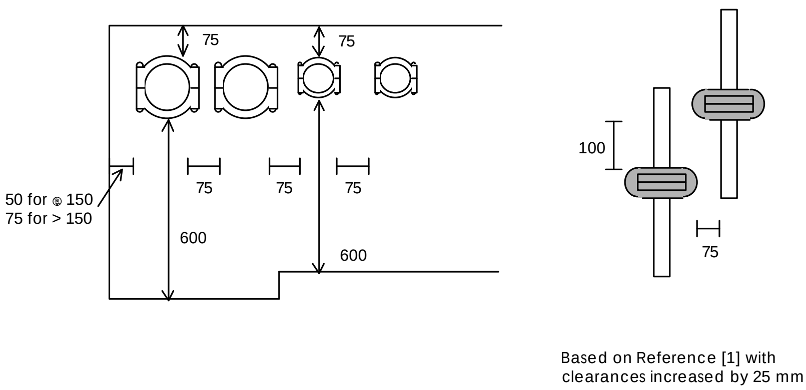


Figure A1.30 Mechanically grooved end joints - uninsulated

Appendix A2 Equipment Object Definitions

Plant data including performance, physical size and connection details are required to underpin the selection, sizing and location process. Blank data sheets for defining equipment as objects with attributes are included in this Appendix. These definitions will feed into and take account of work being undertaken by the IAI on object definitions.

The following data sheets (boiler, pump, pressurisation unit, panel board, fan, fan coil unit, diffuser) have been evolved on the basis of what is required to meet the selection, sizing and location process for this project. Liaison is being undertaken with the IAI to ensure documenting is consistent with IAI definitions where available and to feed in data from the project to the IAI where no definitions are currently available. This will help to ensure the data sets produced will be usable not just for this project but also for other future purposes where the IAI definitions are adopted.

General spatial definition is rectilinear from front right hand corner – refer to Figure A2.1.

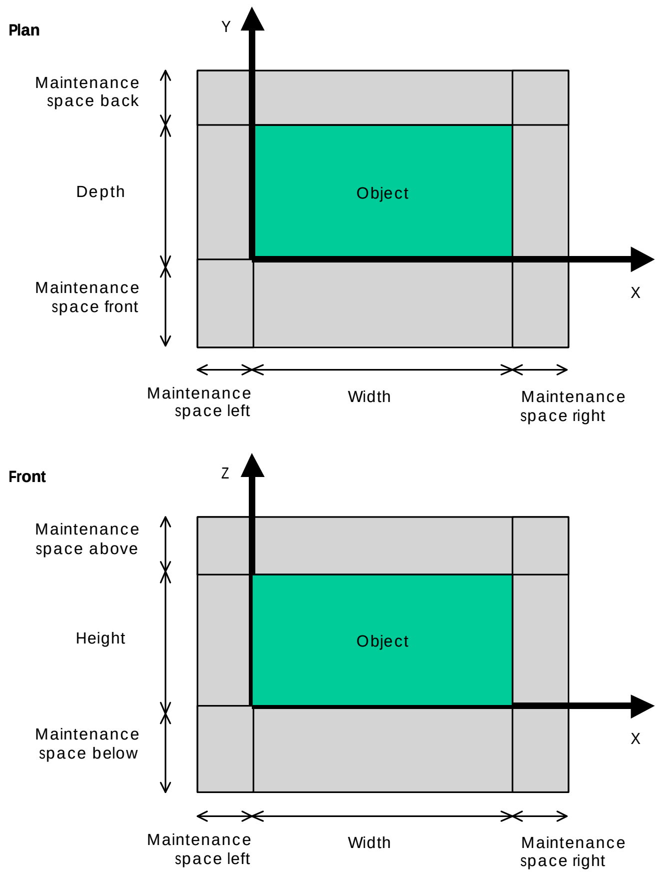


Figure A2.1 Definition of object geometry

Boiler

Description
Manufacturer
ModelRef
Width (mm)
Depth (mm)
Height (mm)
Maintenance space left (mm)
Maintenance space right (mm)
Maintenance space front (mm)
Maintenance space back (mm)
Maintenance space above (mm)
Maintenance space below (mm)
Access width (mm)
Access height (mm)
Output (kW)
Gas input rate (m3/h)
Minimum gas inlet pressure (mbar)
Maximum gas inlet pressure (mbar)
Gas setting pressure (mbar)
Water content (l)
Water flow rate (l/s)
Minimum water flow rate (l/s)
Pressure drop (kPa)
Maximum water pressure (bar)
Minimum water pressure (bar)
Flue gas volume (m3/h)
Flue gas temperature (oC)
Gas connection size (mm)
Gas connection location x
Gas connection location y
Gas connection location z
Gas connection direction x
Gas connection direction y
Gas connection direction z
LPHW inlet connection size (mm)
LPHW inlet connection location x
LPHW inlet connection location y
LPHW inlet connection location z
LPHW inlet connection direction
LPHW inlet connection direction
LPHW inlet connection direction
LPHW outlet connection size (mm)
LPHW outlet connection location x
LPHW outlet connection location y
LPHW outlet connection location z
LPHW outlet connection direction x
LPHW outlet connection direction y
LPHW outlet connection direction z
Flue connection size (mm)
Flue connection location x
Flue connection location y
Flue connection location z

Flue connection direction x
Flue connection direction y
Flue connection direction z
Electrical connection size (mm)
Electrical connection location x
Electrical connection location y
Electrical connection location z
Electrical connection direction x
Electrical connection direction y
Electrical connection direction z
Running Current (Amps)
Starting Current (Amps)
Phases
Weight (kg)
Web address

Chiller

Description
Manufacturer
ModelRef
Width (mm)
Depth (mm)
Height (mm)
Maintenance space left (mm)
Maintenance space right (mm)
Maintenance space front (mm)
Maintenance space back (mm)
Maintenance space above (mm)
Maintenance space below (mm)
Access width (mm)
Access height (mm)
Refrigerant
Output (kW) - 6 LWT, 30 AT
Glycol (%)
Water content (l)
Water flow rate (l/s)
Minimum water flow (l/s)
Pressure drop (kPa)
Maximum water pressure (kPa)
Minimum water pressure (bar)
CHW inlet connection size (mm)
CHW inlet connection location x
CHW inlet connection location y
CHW inlet connection location z
CHW inlet connection direction x
CHW inlet connection direction y
CHW inlet connection direction z
CHW outlet connection size (mm)
CHW outlet connection location x
CHW outlet connection location y
CHW outlet connection location z
CHW outlet connection direction x
CHW outlet connection direction y
CHW outlet connection direction z
Electrical connection size 1 (mm)
Electrical connection 1 location x
Electrical connection 1 location y
Electrical connection 1 location z
Electrical connection 1 direction x
Electrical connection 1direction y
Electrical connection 1 direction z
Power 1 (kW)
Running Current 1 (Amps)
Starting Current 1 (Amps)
Electrical connection size 2 (mm)
Electrical connection 2 location x
Electrical connection 2 location y
Electrical connection 2 location z
Electrical connection 2 direction x

Electrical connection 2 direction y
Electrical connection 2 direction z
Power 2 (kW)
Running Current 2 (Amps)
Starting Current 2 (Amps)
Phases
No of fans
Sound power (dBA)
Weight (kg)
Web address

Pump

Description
Manufacturer
ModelRef
Width (mm)
Depth (mm)
Height (mm)
Maintenance space left (mm)
Maintenance space right (mm)
Maintenance space front (mm)
Maintenance space back (mm)
Maintenance space above (mm)
Maintenance space below (mm)
Access width (mm)
Access height (mm)
Motor rating (kW)
Power 1
Power 2
Power 3
Power 4
Power 5
Power 6
Power 7
Power 8
Power 9
Power 10
Flow 1
Flow 2
Flow 3
Flow 4
Flow 5
Flow 6
Flow 7
Flow 8
Flow 9
Flow 10
Pressure 1
Pressure 2
Pressure 3
Pressure 4
Pressure 5
Pressure 6
Pressure 7
Pressure 8
Pressure 9
Pressure 10
LPHW inlet connection size (mm)
LPHW inlet connection location x
LPHW inlet connection location y
LPHW inlet connection location z
LPHW inlet connection direction X
LPHW inlet connection direction Y
LPHW inlet connection direction Z

LPHW outlet connection size (mm)
LPHW outlet connection location x
LPHW outlet connection location y
LPHW outlet connection location z
LPHW outlet connection direction x
LPHW outlet connection direction y
LPHW outlet connection direction z
Electrical connection size (mm)
Electrical connection location x
Electrical connection location y
Electrical connection location z
Electrical connection direction x
Electrical connection direction y
Electrical connection direction z
Running Current (Amps)
Starting Current (Amps)
Phases
Weight (kg)
Costs
Web address

Pressurisation unit

Description
Manufacturer
Model Ref.
Pressurisation Unit width (mm)
Pressurisation Unit depth (mm)
Pressurisation Unit height (mm)
Pressurisation Unit maintenance space left (mm)
Pressurisation Unit maintenance space right (mm)
Pressurisation Unit maintenance space front (mm)
Pressurisation Unit maintenance space back (mm)
Pressurisation Unit maintenance space above (mm)
Pressurisation Unit maintenance space below (mm)
Access width (mm)
Access height (mm)
System Volume (l)
System Temperature (°C)
Vessel Volume (l)
Fill Pressure (bar)
Static head (bar)
Antifreeze percentage (%)
Maximum Temperature (°C)
Mains supply connection size (mm)
Mains supply location x
Mains supply location y
Mains supply location z
Mains supply direction x
Mains supply direction y
Mains supply direction z
System fill connection size (mm)
System fill connection location x
System fill connection location y
System fill connection location z
System fill connection direction x
System fill connection direction y
System fill connection direction z
Electrical connection size (mm)
Electrical connection location x
Electrical connection location y
Electrical connection location z
Electrical connection direction x
Electrical connection direction y
Electrical connection direction z
Motor Size (kW)
Running Current (Amps)
Starting Current (Amps)
Phases
Weight (kg)
Web address

Water booster

Description
Manufacturer
ModelRef
Width (mm)
Depth (mm)
Height (mm)
Maintenance space left (mm)
Maintenance space right (mm)
Maintenance space front (mm)
Maintenance space back (mm)
Maintenance space above (mm)
Maintenance space below (mm)
Access width (mm)
Access height (mm)
Motor rating (kW)
Power (kW)
Flow (l/s)
Head (m)
Water inlet connection size (mm)
Water inlet connection location x
Water inlet connection location y
Water inlet connection location z
Water inlet connection direction X
Water inlet connection direction Y
Water inlet connection direction Z
Water outlet connection size (mm)
Water outlet connection location x
Water outlet connection location y
Water outlet connection location z
Water outlet connection direction x
Water outlet connection direction y
Water outlet connection direction z
Electrical connection size (mm)
Electrical connection location x
Electrical connection location y
Electrical connection location z
Electrical connection direction x
Electrical connection direction y
Electrical connection direction z
Running Current (Amps)
Starting Current (Amps)
Phases
Weight (kg)
Costs
Web address

Distribution/Panel board

Description
Manufacturer
Model Ref.
Panel Board width (mm)
Panel Board depth (mm)
Panel Board height (mm)
Panel Board maintenance space left (mm)
Panel Board maintenance space right (mm)
Panel Board maintenance space front (mm)
Panel Board maintenance space back (mm)
Panel Board maintenance space above (mm)
Panel Board maintenance space below (mm)
Access width (mm)
Access height (mm)
Incomer Size (No)
Outgoing Ways (No)
Incoming Cable Tray connection size (mm)
Incoming Cable Tray connection location x
Incoming Cable Tray connection location y
Incoming Cable Tray connection location z
Incoming Cable Tray connection direction x
Incoming Cable Tray connection direction y
Incoming Cable Tray connection direction z
Outgoing Cable Tray connection size (mm)
Outgoing Cable Tray connection location x
Outgoing Cable Tray connection location y
Outgoing Cable Tray connection location z
Outgoing Cable Tray connection direction x
Outgoing Cable Tray connection direction y
Outgoing Cable Tray connection direction z
Weight (kg)
Web address

Fan

Description
Manufacturer
Model Ref.
Fan width (mm)
Fan depth (mm)
Fan height (mm)
Fan maintenance space left (mm)
Fan maintenance space right (mm)
Fan maintenance space front (mm)
Fan maintenance space back (mm)
Fan maintenance space above (mm)
Fan maintenance space below (mm)
Fan access width (mm)
Fan access height (mm)
Motor rating (kW)
AirFlowRate (m3/s)
Pressure drop (Pa)
Sound Power (dB)
Inlet connection size (mm)
Inlet connection location x
Inlet connection location y
Inlet connection location z
Inlet connection direction x
Inlet connection direction y
Inlet connection direction z
Outlet connection size (mm)
Outlet connection location x
Outlet connection location y
Outlet connection location z
Outlet connection direction x
Outlet connection direction y
Outlet connection direction z
Electrical connection size (mm)
Electrical connection location x
Electrical connection location y
Electrical connection location z
Electrical connection direction x
Electrical connection direction y
Electrical connection direction z
Running Current (Amps)
Starting Current (Amps)
Phases
Weight (kg)
Web address

Luminaire

Description
Manufacturer
Model Ref.
Width (mm)
Depth (mm)
Height (mm)
Maintenance space left (mm)
Maintenance space right (mm)
Maintenance space front (mm)
Maintenance space back (mm)
Maintenance space above (mm)
Maintenance space below (mm)
Access width (mm)
Access height (mm)
Number of Lamps
Lumen Output
Room Index 075
Room Index 1
Room Index 125
Room Index 15
Room Index 2
Room Index 25
Room Index 3
Room Index 4
Room Index 5
Spacing to height ratio
Electrical size (mm)
Electrical connection location x
Electrical connection location y
Electrical connection location z
Electrical connection direction x
Electrical connection direction y
Electrical connection direction z
Running Current (Amps)
Starting Current (Amps)
Circuit Power (Watts)
Phases
Weight (kg)
Web address

Fan coil unit

Description
Manufacturer
Model Ref.
Width (mm)
Depth (mm)
Height (mm)
Maintenance space left (mm)
Maintenance space right (mm)
Maintenance space front (mm)
Maintenance space back (mm)
Maintenance space above (mm)
Maintenance space below (mm)
Access width (mm)
Access height (mm)
Outlet duct connection size (mm)
Outlet duct connection location x
Outlet duct connection location y
Outlet duct connection location z
Outlet duct connection direction x
Outlet duct connection direction y
Outlet duct connection direction z
Outlet duct spigot number
Outlet duct spigot pitch
Intlet duct connection size (mm)
Inlet duct connection location x
Inlet duct connection location y
Inlet duct connection location z
Inlet duct connection direction x
Inlet duct connection direction y
Inlet duct connection direction z
Inlet duct spigot number
Inlet duct spigot pitch
Cooling output (kW) (total, med spd, 30 Pa)
Cooling coil water content (l)
Cooling coil water flow rate (l/s)
Cooling coil pressure drop (kPa)
Maximum CHW pressure (bar)
CHW inlet size (mm)
CHW inlet connection location x
CHW inlet connection location y
CHW inlet connection location z
CHW inlet connection direction x
CHW inlet connection direction y
CHW inlet connection direction z
CHW outlet size (mm)
CHW outlet connection location x
CHW outlet connection location y
CHW outlet connection location z
CHW outlet connection direction x
CHW outlet connection direction y
CHW outlet connection direction z
Condensate size (mm)

Condensate connection location x
Condensate connection location y
Condensate connection location z
Condensate connection direction x
Condensate connection direction y
Condensate connection direction z
Heating output (kW) (med spd, 30 Pa)
Heating coil water content (l)
Heating coil water flow rate (l/s)
Heating coil pressure drop (kPa)
Maximum LPHW pressure (bar)
LPHW inlet size (mm)
LPHW inlet connection location x
LPHW inlet connection location y
LPHW inlet connection location z
LPHW inlet connection direction x
LPHW inlet connection direction y
LPHW inlet connection direction z
LPHW outlet size (mm)
LPHW outlet connection location x
LPHW outlet connection location y
LPHW outlet connection location z
LPHW outlet connection direction x
LPHW outlet connection direction y
LPHW outlet connection direction z
Filter EU rating
Fan power (kW)
AirFlowRate (m3/s) (total, med spd, 30 Pa)
Fan pressure drop (Pa)
Sound power (dBA)
Electrical size (mm)
Electrical connection location x
Electrical connection location y
Electrical connection location z
Electrical connection direction x
Electrical connection direction y
Electrical connection direction z
Running Current (Amps)
Starting Current (Amps)
Phases
Weight (kg)
Web address

Square diffuser

Description
Manufacturer
Model Ref.
Width (mm)
Depth (mm)
Height (mm)
Maintenance space left (mm)
Maintenance space right (mm)
Maintenance space front (mm)
Maintenance space back (mm)
Maintenance space above (mm)
Maintenance space below (mm)
Access width (mm)
Access height (mm)
Duct Connection Type
Duct Diameter
Duct Connection location x
Duct Connection location y
Duct Connection location z
Duct Connection direction x
Duct Connection direction y
Duct Connection direction z
Effective Area (m2/s)
AirFlowRate (m3/s)
Pressure Drop (kPa)
Noise Criteria (dB)
Weight (kg)
Plenum height (mm)
Web address

Slot diffuser

Description
Manufacturer
Model Ref.
Width (mm)
Depth (mm)
Height (mm)
Maintenance space left (mm)
Maintenance space right (mm)
Maintenance space front (mm)
Maintenance space back (mm)
Maintenance space above (mm)
Maintenance space below (mm)
Access width (mm)
Access height (mm)
Duct Connection Type
Duct Diameter
Duct Connection location x
Duct Connection location y
Duct Connection location z
Duct Connection direction x
Duct Connection direction y
Duct Connection direction z
Effective Opening (m)
AirFlowRate (m3/s)
Pressure Drop (kPa)
Noise Criteria (dB)
Weight (kg)
Web address

Busbar

Description
Manufacturer
Model Ref.
Width (mm)
Depth (mm)
Height (mm)
Maintenance space left (mm)
Maintenance space right (mm)
Maintenance space front (mm)
Maintenance space back (mm)
Maintenance space above (mm)
Maintenance space below (mm)
Access width (mm)
Access height (mm)
Rating (Amps)
Tap-off rating (Amps)
Tap-off spacing (mm)
Weight (kg/m)
Web address

Tap-off box

Description
Manufacturer
Model Ref.
Width (mm)
Depth (mm)
Height (mm)
Maintenance space left (mm)
Maintenance space right (mm)
Maintenance space front (mm)
Maintenance space back (mm)
Maintenance space above (mm)
Maintenance space below (mm)
Access width (mm)
Access height (mm)
Busbar min rating (Amps)
Busbar max rating (Amps)
Tap-off rating (Amps)
Weight (kg)
Web address

Lighting panel

Description
Manufacturer
Model Ref.
Panel Board width (mm)
Panel Board depth (mm)
Panel Board height (mm)
Panel Board maintenance space left (mm)
Panel Board maintenance space right (mm)
Panel Board maintenance space front (mm)
Panel Board maintenance space back (mm)
Panel Board maintenance space above (mm)
Panel Board maintenance space below (mm)
Access width (mm)
Access height (mm)
Spare data
Outgoing Ways (No)
Incoming Cable Tray connection size (mm)
Incoming Cable Tray connection location x
Incoming Cable Tray connection location y
Incoming Cable Tray connection location z
Incoming Cable Tray connection direction x
Incoming Cable Tray connection direction y
Incoming Cable Tray connection direction z
Outgoing Cable Tray connection size (mm)
Outgoing Cable Tray connection location x
Outgoing Cable Tray connection location y
Outgoing Cable Tray connection location z
Outgoing Cable Tray connection direction x
Outgoing Cable Tray connection direction y
Outgoing Cable Tray connection direction z
Weight (kg)
Web address

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