# Simplified Sizing and Selection of HVAC Systems

By Ivan Ox

Submitted for partial fulfilment of the requirement for the degree Magister in Engineering (Mechanical) in the The Department of Mechanical and Aeronautical Engineering at the University of Pretoria, Pretoria.

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## Abstract


Several problems are still experienced in the design of energy efficient buildings. Two major problems are the overspecification of HVAC systems, and the specification of an inappropriate system.

The purpose of this thesis is the design of an expert system that will help engineers and architects to size and select HVAC systems in the preliminary and brief design stages. At this stage of a project there is very little technical data and engineers usually use their experience to quote loads and to select a system. A simplified cooling load calculation module was designed to give a reasonable answer while using sketchy input data. An expert system was then designed to make the selection process easier.

Both systems are easy and fast to use. The selection module gives usable and realistic answers. The cooling load calculation module unfortunately did not achieve the desired accuracy and should be redesigned.


## Samevatting


Daar is steeds verskeie probleme in die ontwerp van energie-effektiewe geboue. Die twee hoof-probleme is die oorontwerp van 'n verkoelingstelsel, en die keuse van 'n ontoepaslike stelsel.

Die doel van hierdie verhandeling is die ontwerp van 'n deskundige stelsel wat konsultant-ingenieurs en argitekte kan help met die lasberaming en keuse van 'n verkoelingstelsel in die inleidende stadiums van 'n ontwerp. Die konsultant maak gebruik van sy ondervinding om lasberamings te doen en stelsels te selekteer omdat daar min tegniese data is. 'n Vereenvoudigde lasberekeningsmodule is ontwerp om redelike antwoorde te gee maar wat min insette gebruik. 'n Deskundige stelsel is ontwerp om die seleksieproses te vereenvoudig.

Beide modules is eenvoudig en maklik om te gebruik. Die seleksiemodule gee realistiese en bruikbare antwoorde. Ongelukkig is die antwoorde van die lasberekeningsmodule minder akkuraat as wat vereis word, en moet verkieslik herontwerp word.

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# Prologue

## 1.1 Introduction

We are entering a new decade where the environment and pollution are some of our biggest concerns, but we are still burning a dwindling amount of irreplaceable fossil fuel for our energy needs (Clarke & Maver, 1991:25). Atomic energy did not live up to its expectations mostly because of its negative environmental impact and 'Green' politics. The search for an economically viable source of environmentally friendly energy has not produced any likely candidates. Therefore, there must be more awareness of environmental issues in engineering. Unfortunately economic and technical issues are still the major factor behind most engineering decisions (Beck, 1993:10). There is however, potential to reduce energy consumption in buildings (Clarke & Maver, 1991:25).

## 1.2 Potential Impact and Trends

Buildings have been identified as one of the largest users of energy. Buildings account for approximately 40% of the energy used in developed countries. Of this approximately 50% is used for air-conditioning. From these figures one can make an assumption that approximately 10% of the global energy supply is used to air condition buildings. This makes the efficiency of air-conditioning systems a global concern (Rousseau & Mathews, 1993:439).

Energy savings of around 30% is said to be possible with better designing of buildings, air-conditioning and control systems (Rousseau & Mathews, 1993:439). UK Department of Energy suggested that better designed new buildings can reduce energy consumption by 50% and that the retrofit of old buildings with better designed systems can improve their energy consumption by 25% (Clarke & Maver, 1991:25). A reduction of approximately 2.5% in global energy consumption can be expected if the optimistic figures in reduction in energy consumption in new and retrofitted buildings are used.

Several companies and institutes started design philosophies that reduce the energy consumption of office buildings. The US-based Pacific Gas & Electric initiated the Advanced Customer Technology Test ($ACT^2$). With this they plan to reduce the energy consumption index from 1050 $MJ/m^2/yr$ for a base case design to 300 $MJ/m^2/yr$ for a super-efficient designed building. The Energy Edge Building is Bonneville Power Administrations program to reduce the energy consumption of buildings by 30%. They hope to achieve an energy consumption index of approximately 503 $MJ/m^2/yr$. Natural Resources, Canada's C-2000 program, used the Integrated Design Approach (IDA) to design a building with a predicted energy consumption index in the low 300 MJ/m$^2$/yr range. An energy consumption index in the low 300 MJ/m$^2$/yr range is also the target of the Energy Efficient Office of the Future (EOF) program of the Building Research Establishment (BRE) based in the UK (Todesco, 1997: 43).

Integrated Design Approach (IDA) is a system designed to reduce the cooling load and equipment size by using high insulation level, equipment with the highest efficiency and the extensive use of day lighting. Emphasis is also placed on the commissioning of the building to ensure that the equipment operates as designed. Pilot programs that used IDA have shown that reductions of 30% to 50% on energy use compared to ASHRAE Standards 90.1 is possible without difficulty or expense. The IDA process is graphically represented in Figure 1 (Todesco, 1997:45).

The cost of an HVAC system design using this approach is less or very close to that of a base case system (Todesco, 1997:45). This is due to the interaction between all the elements in the design. The positive effect of higher cost of the insulation and lighting is a lower cooling load. This in turn leads to a smaller cooling system that in turn costs less (Todesco, 1997:53). In light of global environmental concern, this type of design philosophy should be the way of the future.

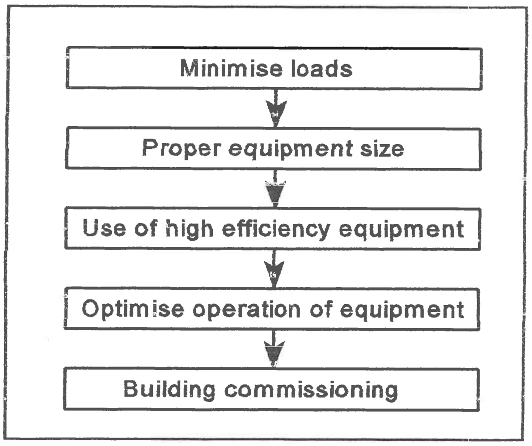


**Figure 1** Process flow of IDA

Sustainable design is used in the building industry as a method to design buildings that reduce the environmental impact of a building (Beck, 1993:10). A key point of the sustainable design approach is IDA (Beck, 1993:11). The emphasis of the design is also on reducing the energy and water use. The use of nontoxic and environmentally friendly materials are also advised. Although there is a growing awareness of environmental issues, most decisions are still made on economic bases. Fortunately a design that reduces energy and water also reduces energy cost and sometimes life-cycle costs. Beck (1993:10-11) states that environmental friendly designs first costs may be higher but also agree with Todesco (1997:53) that this is not always the case.

There is also a move to integration of building systems via Integrated Building Management Systems (IBMS or BMS) (Clark & Metha, 1997:481 ). The BMS can manage the building automation, information processing and communication (Arkin & Paciuk, 1997:471). BMS could react quickly to changes in the building and adjust energy consumption accordingly. BMS can also minimise the energy cost of a building in controlling the maximum electricity demand by selectively reducing lighting levels in perimeter zones, reducing HVAC loads, reducing lift speeds or even stopping a number of lifts (Clark & Metha, 1997:485). It should also be possible to alter the HVAC load by either predicting occupancy or monitoring the building access control system (Clark & Metha, 1997:481 ). Integrated management systems could also be used to prevent sick building syndrome (Arkin & Paciuk, 1997:471).

Sick building syndrome is the worst case aftermath of a building designed for aesthetic reasons with a disregard for the energy efficiency of the HVAC system. The end result is a building that has high energy costs and a high level of tenant complaints (Blaine, 1993:29).

## 1.3 Definition of the Problem

Even though IDA and BMS show potential to reduce energy consumption, HVAC systems have been shown in studies to be the one factor mostly mentioned by tenants as the reason why they have relocated. Owners are realising that the HVAC system is one of the important elements that govern the renting and resell value of their buildings (Linford, 1997:77).

There are unfortunately still some problems experienced in the design of energy-efficient green buildings. One of these is that the performance of an HVAC system cannot easily be described because of the complex interaction of all the components (Rousseau & Mathews, 1993:441; Clarke & Maver, 1993:25). This leads to the designer overdesigning the HVAC system. This system then runs at a less efficient setpoint which increases the energy usage (Rousseau & Matthews, 1993:440).

The design of an HVAC system is complex (Rousseau & Mathews, 1993:442; Tseng, Harmon & Edwards, 1993:959). It requires time which most HVAC system designers usually don't have a lot off because in practice they are often forced to work on a number of projects simultaneously. There is then little time to optimise the design to reduce energy consumption (Rousseau & Mathews, 1993:442). The complexity of the design process poses another problem. Engineering and construction experience is needed to make an intelligent analysis of a building and HVAC system. Linford (1997:79) also states that a recently graduated mechanical engineer will not clearly understand the complex nature of an HVAC system and how each of its components interacts. Linford's (1997:79) experience showed that three to five years of experience needs to be acquired. This is then followed with a lifetime of acquiring experience that adds to the engineer's knowledge base (Linford, 1997:79).

One of the key items of the IDA design philosophy is correct sizing of the equipment to design better and more efficient buildings (Todesco, 1997:45). One method to achieve this is by using a computerised load simulation program. These programs can calculate the necessary loads and can show if a system is applicable for a building. The program can also calculate the yearly energy use which can be used to make design changes to a building to reduce its energy consumption (Barat, 1991:100). Load calculation programs are already in their third to fourth generation (Clark & Maver, 1991:26). Programs like New Quick (TEMMI) are easy to use because they have a good human computer interface. It is a design tool that simulates the building, air-conditioning system and the control system as a unit ((Mathews, Van Heerden & Arndt, 1999:429-449). This integration of a design tool is also advised by Rousseau and Mathews (1993:449).

Unfortunately most energy models need large amounts of input data of which some are difficult to obtain and for which some technical HVAC background is needed (Clark & Maver, 1991:31) (Barat, 1991:100). Most of these inputs are not available in the brief and preliminary stages of the design (Clark & Maver, 1991:26). There are also time constraints usually involved in the brief and preliminary design stages.

The selection of an HVAC system also requires experience that makes it difficult for persons with limited technical experience to select a system (Linford, 1997:79). A selected HVAC system is needed to calculate the life-cycle and energy cost.

Another problem is that HVAC engineers are not included in the early stages of the design of the building when the customer/developer and the architect meet. The engineers can give valuable insets for the architect on how his design affects the energy needs of the building and what materials to use to improve the efficiency of the building. Information about space requirements and aesthetics of a selected cooling system can also be given (Beck, 1993:11). This information includes the space requirement of ducts, plant rooms, cooling towers or wall-mounted units (Gupta, 1997:55). The developer can then also see what effects each design has on initial cost and life-cycle cost of the building. Nothing in the design of the building must be done that does not make economical sense, although saving energy is morally and politically correct (Linford, 1997:78-79).

## 1.4 Aim

A simplified simulation program for use in the brief and preliminary stages may be of help to consultant engineers, sales representatives, and architects to overcome some of the problems mentioned above. Such a program will have to give a reasonable answer while using sketchy input data. It will also have to give an idea of the cooling load, help with system selection and must give preliminary values for life-cycle cost, energy cost and space needed for a selected cooling system.

The purpose of this thesis is to lay a foundation for the creation of an expert system that will help consultant engineers, sales representatives and architects to size, select and budget HVAC systems in the preliminary and brief design stages. The first step in creating the program is to define an ideal program. This is done by analysing the needs of the users and the inputs that are available. Once this is done several characteristics can be defined which give a general feeling of how the interface will look. Some characteristics are unobtainable and in other cases certain trade-offs have to be made between them. This makes it important to set priorities between characteristics.

The ideal program consists of three modules. The modules are the load calculation module, the system selection module and the cost calculation module. All the modules should be able to work on their own and should also form a unit where each module result is used as the next module input. The interaction of the modules is shown in figure 2.

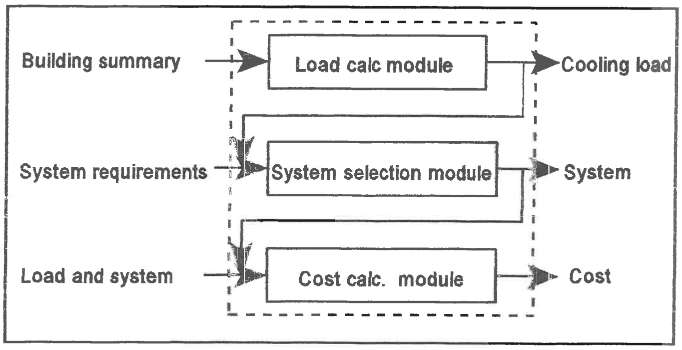


**Figure 2** Module set-up and interaction

The program must be fast because of the time constraints, very simple to use, very user friendly and should be able to operate on a laptop computer. The interface of the program should make it possible to use the program in a meeting between the consultant engineer, architect and the developer or while the engineer is in contact with the developer over the phone. The needs of the developer and architect should real-time (in a meeting) be converted into realistic maximum cooling load, selected cooling system, life cycle cost, energy cost and space needed for the cooling system.

Another specification is that a person with a limited HVAC background (for example: sales representative) should be able to use this program. The program should give reasonable results from sketchy inputs and must assume more technical input from inputs that the person has entered. The selection module must be able to deduct the design specifications from the answers of several questions that the program asked. The cost module must be able to translate the calculated load and selected system into life-cycle and energy cost.

*In Summary*

- *The ideal package consists of the following:*
  - *Cooling load calculation module:*
    - *Inputs:* *Summary of the building*
    - *Output:* *Cooling loads required*
  - *System selection module:*
    - *Inputs:* *System requirements*
    - *Output:* *Selected system*
  - *Cost Calculation module:*
    - *Inputs:* *Cooling loads required*
    - *Selected system*
  - *Output:* *Costs of system:* *Initial cost*
    - *Running cost*
    - *Energy cost*
- *Characteristics of the ideal program:*
  - *All the modules must be very easy and fast to use.*
  - *The modules input must limit technical inputs.*
  - *The modules must be able to interact with each other.*
  - *The program must be fast enough to be used in a meeting.*
  - *The load calculations must be reasonably accurate.*

The development of the load calculation and system selection modules of this design tool for the brief and preliminary design stages are discussed in the next chapters. The aim of development was to get the modules as close to the ideal package as possible.

# 2

# Expert System Development Method

## 2.1. Introduction

Computer programs make it possible to design better systems more effectively (Ahart, 1995:154). Computers have become affordable, more powerful and large inexpensive storage space plus CD ROM's make it easier to store large volumes of information (Ahart, 1995, p 154). This and the use of MS Windows 3.1 and MS Windows 95 have helped in the creation of a number of user-friendly HVAC design software (Smith, 1996:83). A system to develop an expert system will be discussed in this chapter. This system can be used for the development of most software (Wolfgram, Dear & Galbraith, 1987:16).

## 2.2. Stages of Development

The simplified cooling load calculation and selection modules were designed and implemented using a system for the development of expert system software (Wolfgram, Dear & Galbraith, 1987:141). The development system consists of a number of stages with different goals that have to be achieved.

### Stage 1: Identification and Definition

This stage has to do with the identification and evaluation of the problem. This includes determining the problem domain, scope, potential users and the appropriateness of the application. The hardware and software needs must also be determined. The benefits and costs of the system are also determined. Project effort, which include things like duration of the project, time and cost, must also be evaluated. Knowledge discovery is the next stage after the problem has been defined. (Wolfgram, Dear & Galbraith, 1987:142-149).

### Stage 2: Development of a Prototype

Knowledge discovery is the main aim of the second stage. The knowledge can be obtained from two primary sources, domain independent and domain dependent information. Domain independent information is usually public archival information in the form of books, journals, pamphlets, and articles. This information is used to become familiar with the problem. Domain dependent information consists of a report from internal research and development projects and information from the expert. This information is already more specified and mostly applicable to only a small domain. The information that the expert gives is important because it can contain situational data, relationships of problems, tendencies, starting point for trouble shooting, what to look for and procedural rules.

The knowledge acquisition process begins by familiarising oneself with the problem and with the jargon used by the expert. It is important to understand what the expert is saying. The next part of the process is to interview the expert about the problem and to find out how the expert typically solves the problem. It may happen that an expert omits information. This sometimes happens because the expert considers certain information as common knowledge. Other experts must then be interviewed to clarify the issue if there are discrepancies in the information that was obtained. In the last part of this stage the information must be analysed, validated and then coded.

The development of the prototype can start once all the information has been gathered and verified. A good understanding of the problem and the information is also essential in this stage. Microcomputers are usually used as a development platform of the prototype. A developed inference engine and knowledge base must be written from scratch if no development tools are used. A number of things must be considered when designing the prototype. This includes the amount, reliability, consistency, relationship of the data and methods of maintaining the data. It is preferable if the expert system can be shown in a descriptive visual model that clearly indicates the problem solving process. Hypotheses and procedural rules must also be considered. The construction of the system can now start after the prototype has been completed. (Wolfgram, Dear & Galbraith, 1987:150-152).

## Stage 3: Construction

The prototype is completed in the construction stage by completing all the rules and interfaces of the expert system. Detailed "personal" and "private" knowledge of expert must be accurate at this stage of the project. The system must also be evaluated to determine if it is worth going on with the project. The full cost of the system must therefore be defined. The cost can typically be divided into software, hardware, and development. This will influence the decision to proceed with the project or not. The testing and evaluation stage of the system is used to determine the progress of the project. (Wolfgram, Dear & Galbraith, 1987:152-156).

## Stage 4: Testing and Evaluation

The performance of the expert system is usually evaluated against a standard. This can be problematic if no clear standards are available. Objectivity is another problem in the evaluation of the systems because the analysis is subjected to personal interpretation. It is therefore very important to stay objective in this stage. The main evaluation criteria is user acceptance of the system. Performance, completeness and accuracy of the system must be evaluated. The effect and value adding benefits of the system must also be determined. It is important to consider the liabilities and the risk involved because of the use of the expert system.

Feedback in the development stage must be incorporated. Evaluation can be divided into formal and informal evaluations. Formal evaluations take the form of planned milestones while informal evaluation generally in the form of a general review. The user would typically like a system that is simplistic in the amount of computer expertise needed. Systems advice must be useful and it must be able to explain and justify its answer if problems arise. Response time is important because the user wants "natural" conversation without pauses of several minutes.

Critical performance and valuation check is done by executing several test scenarios for which the expert has solved or checked for correct answers and reasoning. Test for completeness and consistency is done by static testing while dynamic testing tests the reasoning of the system by using audit trails. Accuracy of 90% - 95% should be aimed at.

The results of the test must be evaluated against the time and money that the expert system cost. In short does the system improve productivity and is it effective? The liability risk of the expert is a very important consideration. It is critical to know what effect/cost an error of the expert system has.

It is preferable to have reasonable milestone evaluations during stages two and three to improve the chances of developing a successful expert system. It has been shown that long prototype and testing periods are preferable because it is easier to test working prototypes than prototypes on paper. It also makes it possible to test realistic problems. This type of development has the added advantage that it improves the moral of the development team. (Wolfgram, Dear & Galbraith, 1987:157-160).

### Stage 5: Integration and Implementation

The expert system can be released after it has been successfully evaluated and tested. This stage also includes the training of users, completion of user guides and software documentation. It is also sometimes necessary to port the system to other hardware and software platforms. The system must also be promoted in the organisation. Its acceptance will depend on its ability to offer the organisation productivity gains. (Wolfgram, Dear & Galbraith, 1987:160-161).

### Stage 6: Maintenance

This stage of the project is usually not done by the developer of the system. It is necessary to do maintenance on the system because no environment stays static. New knowledge that is discovered can enhance the domain and improve the heuristics of the system. Debugging to improve the code is also necessary and the user interface may also have to be improved. Changes in hardware and software may entail major changes to the system. Any problems must be located and new information must be evaluated and added to the knowledge base. (Wolfgram, Dear & Galbraith, 1987:161).

## 2.3. Implementation

The development of the cooling load calculation and selection module will be discussed in the next four chapters. It will follow the outline of the development method discussed in the previous section. Only the first four stages are applicable on the modules. The first three stages of the development of the simplified cooling load calculation method are in Chapter Three. The results of this module are then discussed in Chapter Four. Chapter Five similarly contains the first three stages of the development of the selection module while the results of the selection module are discussed in Chapter Six.

# 3

# Simplified Load Calculation Module

## 3.1 Introduction

One of the key items of the IDA design philosophy, as discussed in the prologue, is the correct sizing of HVAC equipment (Todesco, 1997:45). The development of the first module, the load calculation, will be discussed in this chapter. The simplified cooling load calculation module was designed and implemented using the system discussed in the previous chapter (Wolfgram, Dear & Galbraith, 1987:141). The development system was simplified because the cooling calculation module on its own is not an expert system.

## 3.2 Stage 1: Identification and Definition

The problem has been discussed in detail in section 1.3 of the prologue. The aim of the program, as discussed in section 1.4 of the prologue, is to create a simplified cooling load calculation program for the brief and preliminary stages of HVAC design.

The cooling load calculation module on its own is not an expert system. It is simply a coded calculation method. In the selection of a cooling load calculation method, some of the simplifications and assumption however need some expert knowledge. The cooling load calculation method is a useful and integral add-on to the system selection module which will be discussed in Chapter Five.

The expert system development method was still followed because it gives a structured approach to the design of software. The potential users of the module, as highlighted in section 1.4 of the prologue, are consultants, architects, and sales representatives. People with limited technical knowledge must also be able to use the cooling load calculation module. The load calculation module must therefore be easy to use and must not require many inputs. The input must make use of easily understood multiple options. This will limits the user's inputs.

Consultant engineers must be able to guarantee the quality and reliability of the work done in a design (Marther, Mazzuchetti & Watson, 1994:18). The accuracy of the load calculation unit should therefore be in certain allowable tolerances. A tolerance of ± 10% was set as the aim for the simplified load calculation module in respect of electrical analogy model(Mathews, 1986:35-39; van Heerden & Mathews, 1996:223-228).

The hardware and software requirements were determined with the target group of users in mind. Microcomputers, better known as desktop computers, personal computers or PC, are widely used, mostly running Windows 3.11, 95 or 98 as their operating system. These operating systems offer a graphical, mouse-driven environment for which it is easy to write user-friendly programs. It is also relatively easy to produce a professional-looking product. Borland Turbo Pascal for Windows was selected as the development language because it was the language used by the research group in which this study was done. Pascal supports window programming and is an easy language to learn although window programming can get complicated and tedious. Rapid development language, like Delphi and Visual Basic, may have been a better option. The development of the prototype will be discussed in the next section.

## 3.3 Stage 2: Development of a Prototype

The development of a prototype starts with knowledge discovery. The knowledge used for this module comes mainly from domain independent sources like textbooks and articles. The basic components that affect the cooling load will be discussed next.

The heat transfer into and out of the building is affected by the materials used; the geometric factors such as size, shape, and orientation, by internal loads; and climatic factors. Thermal storage also affects the cooling load requirement. The main function of heat-loss and heat-gain calculations is to estimate the heating /cooling capacity required of the heating and air-conditioning components. The loads calculated can be divided into the following four categories:

- *Transmission.* Heat loss or heat gain due to a temperature difference across a surface.
- *Solar.* Heat gain due to transmission of solar energy through transparent surfaces.
- *Infiltration.* Heat loss or gain due to the infiltration of outside air.
- *Internal.* This is heat gain due to lights, people and equipment (Stoecker, W.F. & Jones, J.W.1982:63-64).

The next step is to consider a number of cooling load calculation methods to determine which will be the most appropriate for this application. First generation load calculation methods are very simple, well established and are reasonablely accurate although mistakes of up to 25% have been recorded. These textbook-based load calculation methods use empirical data from tables to calculate the heat transfer. The electrical analogy-type load-calculated method is ideally suited for integrated building simulations but is more complex and needs more technical input.

In the brief and preliminary design stages the inputs are mostly very sketchy or non existing. This makes it possible to consider the use of a textbook-based cooling load calculation method. An advantage of this type of method is that it uses tables to calculate the cooling load. This has the effect that the load calculation is very fast. This is becoming less of an advantage as the speed of computers increases. Tables also make it possible to limit very technical inputs to only one table option.

The users therefore do not have to worry about the specific thermal resistance of a sandwich material which is several layers of different material next to each other that form a boundary. The module can use the value in the table for the sandwich material that the user has chosen graphically. The use of a textbook-type method will limit the use of the module to the brief and preliminary design stage because it can only calculate the passive building load.

Five cooling load calculation methods were considered for the simplified load calculation module. Only textbook-based load calculations and thumb rule type of calculation methods were considered. Thumb rules are generally crude and fast methods to get approximate values fast.

**CARRIER Cooling Load Calculation Method**

The CARRIER method is a well-established table-based calculation method. The method is simple and fast to use. The large number of tables used can slow the calculation process down. CARRIER takes wall, floors, window, roof area and type into account. It also has a large number of insulation types for each of the above. Thermal storage is also taken into account. It also incorporates the effect of internal loads and people. The method further has typical bypass and fresh air volume for a number of building types. The method also clearly shows how to convert northern hemisphere tables to southern hemisphere tables. A major drawback of this method is the fact that the information is in British units. It will therefore be necessary to convert all these tables into SI units if this method is used. CARRIER method shares its negative points with other table-based methods in that it cannot calculate the passive performance of a building and outdoor and indoor set points are taken as fixed. The CARRIER method is discussed in detail in the CARRIER textbook (Carrier Air-conditioning Company, 1969:1.1-1.113).

**ASHRAE CLTD Cooling Load Calculation Method**

The ASHRAE CLTD method is another well-established table-based calculation method. The method is also simple and fast to use. Similar to the CARRIER method the large number of tables used can slow the calculation process down. An equivalent temperature difference method was developed by ASHRAE called the cooling-load temperature difference (CLTD) to incorporate the effect of thermal storage of commonly used walls and roofs. The CLTD method, like CARRIER, takes wall, floors, window, roof area, and type into account. It also has a large a number of insulation types for each of the above. It incorporates the effect of internal loads and people. The detail of the method is discussed in ASHRAE fundamentals' handbook. The CLTD has the same drawbacks as the CARRIER method in that it cannot calculate the passive performance of a building and the outdoor and indoor set points are taken as fixed (ASHRAE, 1992:66.33-66.49).

**Simplified Thumb Rule Cooling Load Calculation Method**

A thumb rule mentioned by sales representatives for window-mounted and small split units calculate the maximum cooling load by multiplying 500 - 600 BTU/hr with the floor area. This very simple calculation is popular for application where an HVAC system must meet the needs of a single office. They use their discretion to choose between the two values. They will typically use the higher value if there is more than one person in the office. The methods tend to overestimate the load but the sales representatives say that they rather over specify the unit to ensure the client is happy. This method is very simple and easy to implement but from an unknown source and accuracy.

## Panasonic Cooling Load Calculation Method

This method is a simple and fast method to calculate a cooling load. The method was designed to calculate the load for the installation of unitary systems. The method uses a table to do the calculation. The method does not take the wall, floor and roof type into account.

| Item | | Quantity | Outside design deg. °C | | | | | (Quantity x factor) BTU/HR |
|---|---|---|---|---|---|---|---|---|
| | | | 32 | 35 | 38 | 41 | 45 | |
| | | | FACTOR | | | | | |
| 1. Floor area | | m² | 24 | 32 | 52 | 76 | 100 | |
| 2. Room volume | | m² | 20 | | | | | |
| 3. Windows exposed to sun (use only the exposure with the largest result) | South latitude | | | | | | | |
| | N or E | m² | 460 | 480 | 540 | 600 | 600 | |
| | NW | m² | 840 | 880 | 920 | 980 | 1040 | |
| | W | m² | 1140 | 1200 | 1260 | 1320 | 1380 | |
| | NE or SW | m² | 620 | 660 | 700 | 760 | 820 | |
| 4. All windows (not including item 3) | | m² | 120 | 160 | 220 | 280 | 340 | |
| 5. Wall exposed to sun (use only the exposure used in item 3) | | m² | 120 | 140 | 180 | 200 | 228 | |
| 6. All exterior walls (not including item 5) | | m² | 68 | 100 | 148 | 180 | 220 | |
| 7. Partitions (all interior walls adjacent to an unconditioned space) | | m² | 32 | 44 | 68 | 84 | 100 | |
| 8.Ceiling or roof | Ceiling (with unconditioned space above) | m² | 24 | 32 | 52 | 76 | 100 | |
| | Ceiling (no insulation) | m² | 88 | 108 | 140 | 160 | 180 | |
| | Ceiling (50 mm or more insulation) | m² | 32 | 32 | 44 | 44 | 56 | |
| | Roof (no insulation) | m² | 184 | 212 | 236 | 264 | 288 | |
| 9. People (number of people) | | no. | 600 | | | | | |
| 10. Lights & electrical equipment in use | | w | 3 | | | | | |
| Total cooling load | | | | | | | **BTU/HR =** | |

**Thumb Rule Cooling Load Calculation Method**

This method consists of several empirical maximum and minimum cooling load values per floor area. There are different values for different types of buildings.

| Type | Maximum ($m^2$/KW) | Minimum ($m^2$/KW) |
|---|---|---|
| Apartment building | 9.253 | 13.219 |
| Auditorium - theatres (Seats / KW) | 5.123 | 6.261 |
| Banks | 5.816 | 6.609 |
| Barber shops | 5.287 | 6.609 |
| Beauty parlours | 5.287 | 6.609 |
| Bowling alleys (KW / alley) | 7.379 | 7.906 |
| Churches (seats / KW) | 5.123 | 7.115 |
| Cocktail lounges | 3.966 | 5.287 |
| Computer rooms | 2.115 | 3.966 |
| Dental offices | 5.287 | 6.609 |
| Department stores | 7.931 | 9.253 |
| Dormitory | 7.402 | 9.253 |
| Dress shops | 6.609 | 7.931 |
| Factories | 7.931 | 9.253 |
| High-rise office buildings | 7.402 | 8.460 |
| Hospitals - nursing homes | 6.874 | 7.931 |
| Hotels | 7.402 | 8.592 |
| Libraries | 6.609 | 7.402 |
| Medical centres | 9.253 | 10.839 |
| Motels | 7.402 | 8.460 |
| Post offices | 7.931 | 8.460 |
| Residences | 13.219 | 15.862 |
| Restaurants | 5.816 | 6.609 |
| Schools | 6.609 | 7.931 |
| Shopping centres | 7.931 | 9.253 |

The table above was converted to SI units and comes from Design and Estimating for Heating, Ventilating, and Air-conditioning by Rizzi (1980:353). This method does not take the wall, glass and roof type or area into account. It also only takes people into account for auditoriums and churches. This is an easy method to convert to a computer program.

**Selection**

The thumb rules methods were not seriously considered because of their questionable accuracy. The Panasonic method was designed for sizing of unitary systems and may not be appropriate for sizing of other systems and was therefore not selected. This left the two texts book methods that are very similar. The CARRIER method was selected because it clearly shows how to convert northern hemisphere tables into southern hemisphere tables. It, like the CLTD method, takes wall, floors, window, roof area and type into account. It however has a larger number of insulation types for each of the above. The wall, roof, window and floor tables also lend themselves to graphical selection. Like the CLTD method, thermal storage is also taken into account. So too is the effect of internal loads and people. The method further has typical bypass and fresh air volume for a number of building types. The table can easily convert from British units to SI units by a computer program. A number of simplifications were done to the method to reduce input and make some of the inputs easier. These simplifications will be discussed in the next section.

**Prototype**

The development of the prototype can be started with the cooling load calculation method selected. The prototype load was coded in Turbo Pascal for DOS running on Windows. Some simplification and assumptions were done to the basic CARRIER method to reduce the inputs that are necessary. They are:

- The whole building was taken as one zone.
- Only four walls can be specified in the north, south, east and west direction.
- Only one type of wall, thickness, and insulation can be selected for all four walls.
- Only four glass areas can be specified in the north, south, east and west direction.
- Only one type of glass and shading can be selected for all four glass areas.
- Only one floor area and type can be specified.
- Only one roof area and type can be specified.
- No indoor partitions can be specified.
- The internal load of the building must be given per footprint floor area. The floor area on the ground level is called the footprint area of the building.

The following assumptions were also made:

- It is assumed that the maximum load will be at 15h00.
- When the user selects a building type, the module uses tables to get typical values of:
    - Bypass factor.
    - Ventilation standards.
    - Heat gain from people
- The module calculates the mass of the building by using the mass of the material selected for the walls, glass, floor and the roof. This is used to select the storage factor.

This reduces the input that the program needs to:

- Building = What type of building is it
- Hemisphere = In which hemisphere is the building
- Latitude = At what latitude is the building situated
- Altitude = At what altitude is the building situated
- Month = For what month must the calculation be done
- Bypass factor = The bypass factor used. This is defined by the type of building
- People = Number of people in the building
- Input power = Internal power load in $W/m^2$ of footprint floor area
- Temperature inside = Inside design temperature (°C)
- RH inside = Inside design relative humiditie (%)
- Temperature outside= Outside temperature (°C)
- RH outside = Outside relative humiditie (%)
- Wall area (North) = Wall area of the northern side of the building ($m^2$)
- Wall area (West) = Wall area of the western side of the building ($m^2$)
- Wall area (South) = Wall area of the southern side of the building ($m^2$)
- Wall area (East) = Wall area of the eastern side of the building ($m^2$)
- Wall type = What type of wall is used
- Wall thickness = What is the thickness of the wall (mm)
- Wall insulation = What type and thickness insulation is used for the walls
- Glass area (North) = Glass area of the northern side of the building ($m^2$)
- Glass area (West) = Glass area of the western side of the building ($m^2$)
- Glass area (South) = Glass area of the southern side of the building ($m^2$)
- Glass area (East) = Glass area of the eastern side of the building ($m^2$)
- Glass type = What type of glass is used
- Shading type = What type of shading does the glass have
- Floor area = Footprint floor area of the building. This is the ground floor area ($m^2$)
- Floor type. = What type of floor is used ($m^2$)
- Floor thickness = What is the thickness of the floor (mm)
- Insulation = What type and thickness insulation is used for the floor
- Roof area = Roof area of the building ($m^2$)
- Roof type = What type of roof is used
- Roof thickness = What is the thickness of the roof (mm)
- Roof insulation = What type and thickness insulation is used for the roof

The simplified Carrier method used in the module will now be shown. The module uses the reduced inputs given above. The formulas, tables, constants and inputs used in the module will be given. First the formula will be shown after which each of the components that are not inputs will be discussed. It will typically take the form:

SF = Shading factor = f (Glass type, Shading type) see Table 16

Where the first part, for example SF, is the abbreviation that is used in the formula. The next part shows that, for example, the abbreviation SF stands for Shading factor. The last part shows that SF is a function of Glass type and Shading type and the information is in Table 16 of the CARRIER textbook. The discussion of the method will follow the general format of the " Air-Conditioning Load Estimate" form. (Carrier Air-conditioning Company, 1969:1-124)

**Solar Gain - Glass**

$q_1$ = Glass area (north) * SHG * SF * SLF (1)
$q_2$ = Glass area (west) * SHG * SF * SLF (2)
$q_3$ = Glass area (south) * SHG * SF * SLF (3)
$q_4$ = Glass area (east) * SHG * SF * SLF (4)

where
SHG = Peak solar heat gain thru.glass = f (Latitude, Month, Hemisphere) (W/m$^2$) see Table 6
SF = Shading factor = f (Glass type, Shading type) see Table 16
SLF = Storage load factor = f (Exposure, Building weight, Hemisphere, Time) see Table 10

**Solar and Transmission Gain - Walls and Roof**

$q_5$ = Wall area (north) * ETD * TC (5)
$q_6$ = Wall area (west) * ETD * TC (6)
$q_7$ = Wall area (south) * ETD * TC (7)
$q_8$ = Wall area (east) * ETD * TC (8)

where
ETD = Equivalent temperature difference = f (Wall weight, Exposure, Time, Hemisphere) (°C) see Table 19
TC = Transmission coefficient (W/m$^2$)(°C) = f (Wall type, Wall thickness, Wall insulation) see Table 21, 22, 23, 24
and
$q_9$ = Roof area (east) * ETD * TC (9)

where
ETD = Equivalent temperature difference = f (Roof weight, Time) (°C) see Table 20
TC = Transmission coefficient (W/m$^2$)(°C) = f (Roof type, Roof thickness, Roof insulation) see Table 27, 28

**Transmission Gain - Except Wall and Roof**

$q_{10}$ = Total glass area * TC (10)

where
Total glass area = Glass area (north) + Glass area (south) + Glass area (east) + Glass area (west)
TC = Transmission coefficient = f (Glass type) (W/m$^2$)(°C) see Table 33

$q_{11}$ = Floor area * TC * (Temperature outside - Temperature inside) (11)

where
TC = Transmission coefficient = f (Floor type, Floor weight, Floor insolation ) (W/m$^2$)(°C) see Table 29

### Internal Loads

$q_{12}$ = People * HG (12)

where
HG = Heat gain from people = f (Building type, Inside temperature, Type of heat gain) (W) see Table 48

$q_{13}$ = Input power * Footprint floor area (13)

### Storage

$q_{14}$ = - Footprint floor area * TS * ST (14)

where
TS = Temperature swing = f (Building type) (°C) see Table 4
ST = Storage factor = f (Building type, Building weight, Glass ratio) (W/m$^2$)(°C) see Table 13

### Sensible Heat

$q_{15}$ = People * VS * 1230 * (Temperature outside - Temperature inside) * BF (15)

where
VS = Ventilation standards = f (Building type) (m$^2$/minute) see Table 45
BF = Bypass factor = f (Building type) see Table 62

### Latent Heat

$q_{16}$ = People * HG (16)

where
HG = Heat gain from people = f (Building Type) (W) see Table 48

$q_{17}$ = People * VS * 30 000 * Difference in humidity ratio * BF (17)

where
VS = Ventilation standards = f (Building type) (m$^2$/minute) see Table 45
BF = Bypass factor = f (Building type) see Table 62

### Outdoor Air Heat

$q_{18}$ = People * VS * 30 000 * Difference in humidity ratio * (1 - BF) (18)

where
VS = Ventilation standards = f (Building type) (m$^2$/minute) see Table 45
BF = Bypass factor = f (Building type) see Table 62

$$q_{19} = \text{People} * \text{VS} * 1230 * (\text{Temperature outside} - \text{Temperature inside}) * (1 - \text{BF}) \quad (19)$$

where

| | | |
|---|---|---|
| VS = Ventilation standards | = f (Building type) ($m^2$/minute) | see Table 45 |
| BF = Bypass factor | = f (Building type) | see Table 62 |

**Total**

The total cooling load is the total of all the individual loads.

$$q_{Total} = q_1 + q_2 + \ldots + q_{18} + q_{19} \text{ (W)} \quad (20)$$

**Outputs**

The following outputs are given by the prototype after the calculation was completed:

- The total cooling load.
- The bypass factors that ware used.
- The ventilation standard that was used.
- The building weight that was calculated.

The prototype was not tested against other systems. Some very informal tests showed that the prototype answers for the cooling load were in the correct range. The completion of the module will be discussed in the next section.

## 3.4 Stage 3: Construction

The completion of the module mainly constituted the conversion from a Dos-based program to a Windows-based program. The DOS prototype needed little modification to form the load calculation section of the module. The main input and output section however still had to be coded for Window.

One of the pivotal ideas of the module is simplicity. This extends to the user's interface that should preferably use only one input window and one output window. Multiple option inputs are also preferable because this limits the type of input that is possible and speeds up the entering process. A related point is the minimisation of keyboard inputs. This and mouse-driven input selection processes improve the entering speed. Graphical selections of more technical inputs also improve entering speed. Simplified menu options are in line with the idea of simplicity.

The second key design idea is understandability. This and simplicity create an easy-to-use module. The inputs must typically be as non-technical as possible. Graphical selection mentioned above helps to achieve this requirement. A way to check this requirement is by eliminating inputs that the user will not understand. In other words, any input that the user will not understand must not be asked. The output window should give all the assumptions made. It should also give a summary of all the input to summarise at a glance what inputs were used. This feature can be used to check the program in the construction phase.

One input screen, Figure 3, and one output screen, Figure 4, were used to meet the above-mentioned specifications.

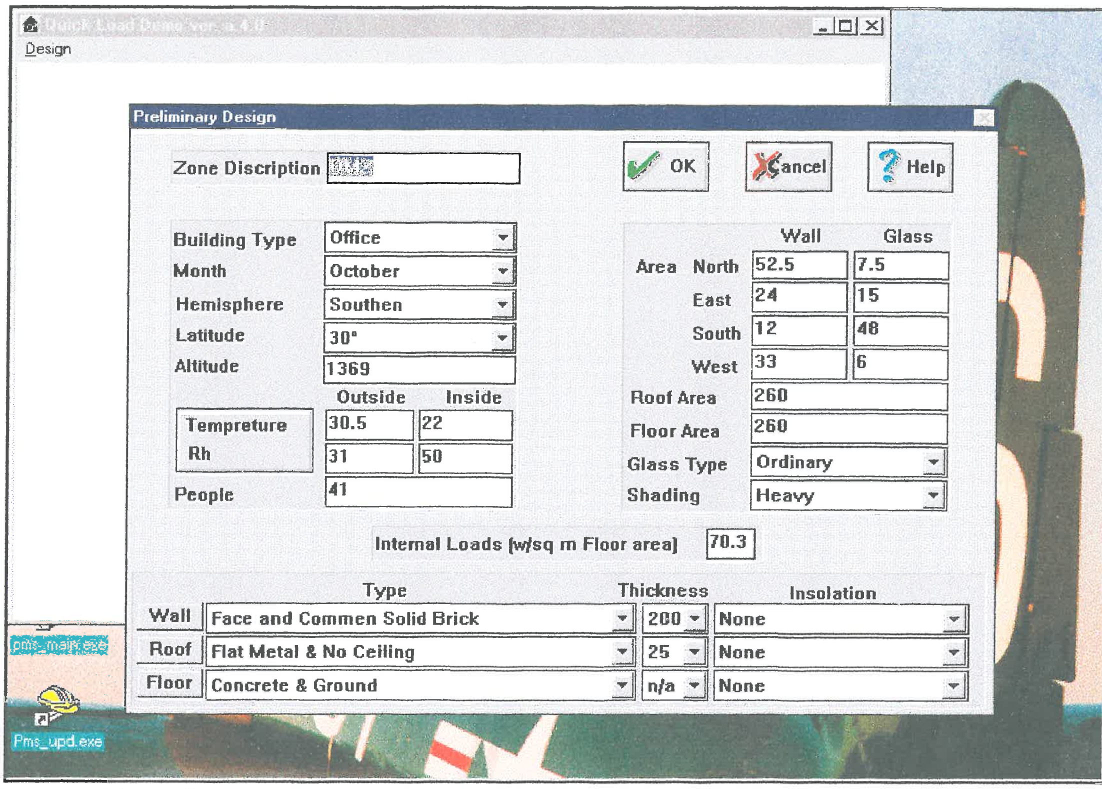


**Figure 3** Input Screen

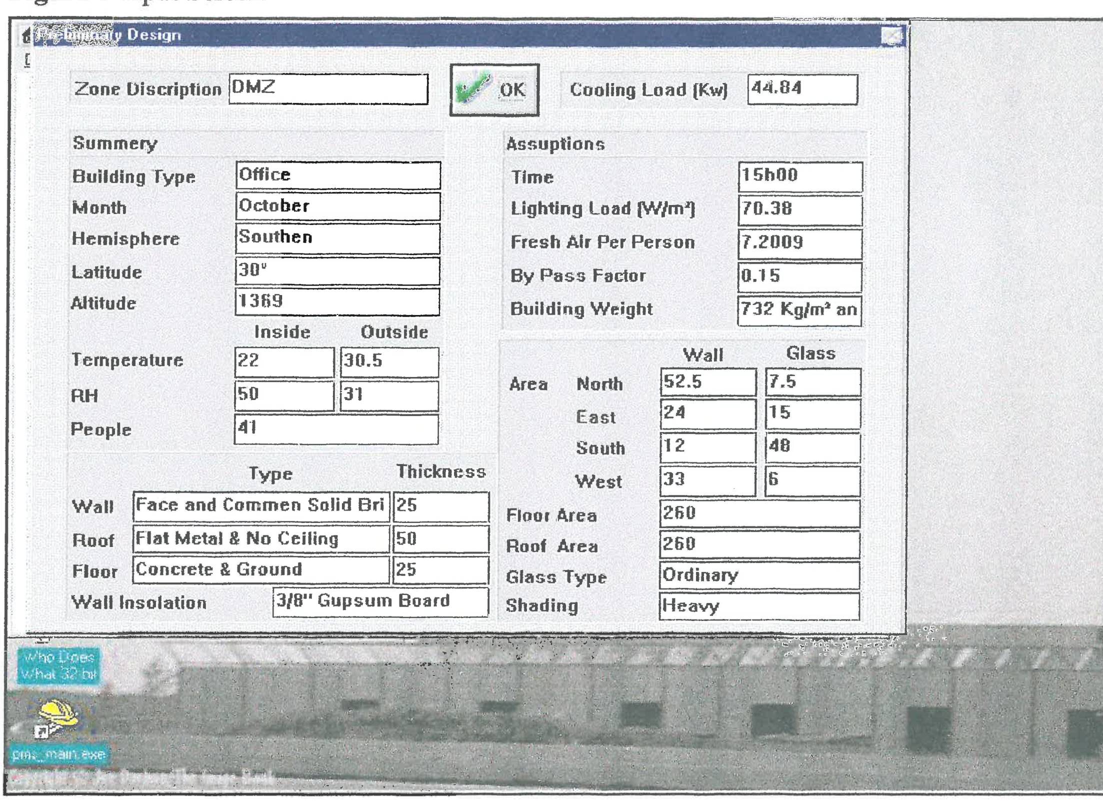


**Figure 4** Output Screen

The user's inputs were kept to a minimum by making use of combo boxes of the drop-down list type. A drop-down list combo box is an input box that expands into a list of possible options when clicked on. It is only possible to choose one option in the list of the combo box. This limits the possible inputs and increases the speed of selection. The wall, roof and floor type selection was done by combo boxes. To speed up the selection extra buttons were added which give the option to select the wall, floor and roof graphically. Figures 5-7 show examples of the graphical selection of wall, roof and floor selection.

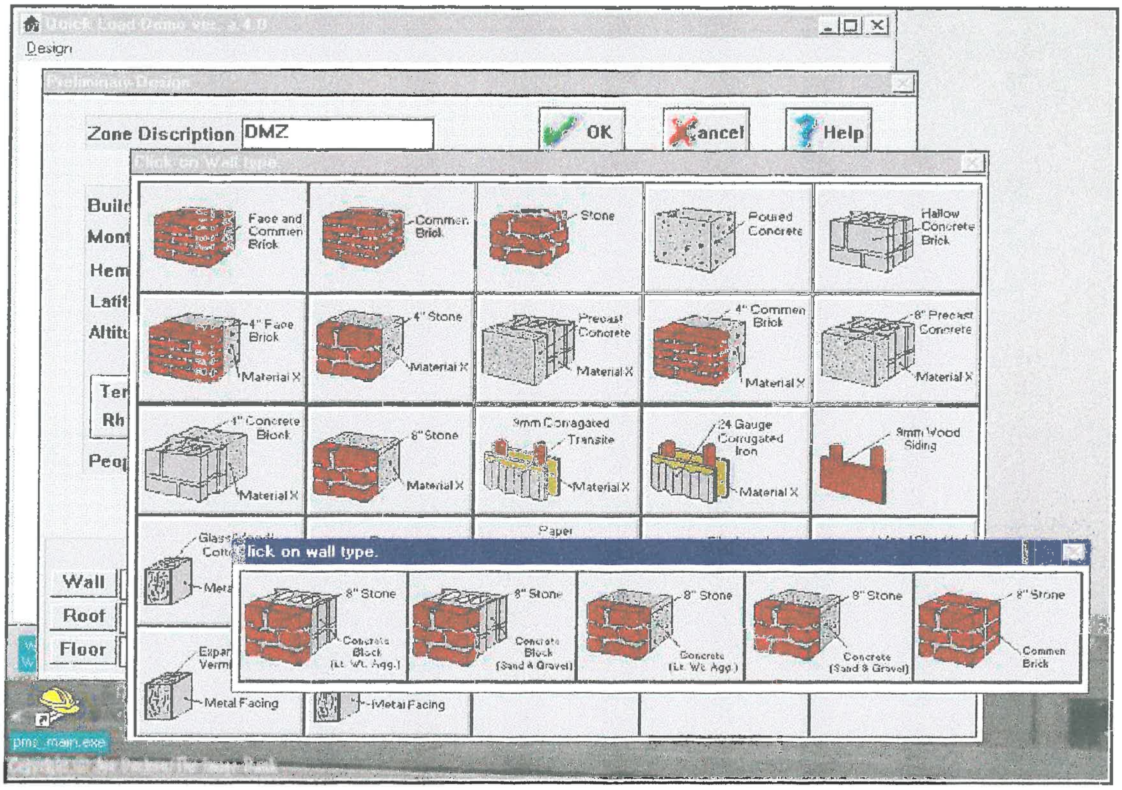


**Figure 5** Graphical selection of wall type

This is a lot faster than going through all the possible options in the combo box. The module used the building type to select values for bypass factor, air changes and heat gain from people. The module also calculates the building weight using the selected walls, roof and floor weights. This is then used to calculate the thermal storage. The result of this design process will be discussed in the next section.

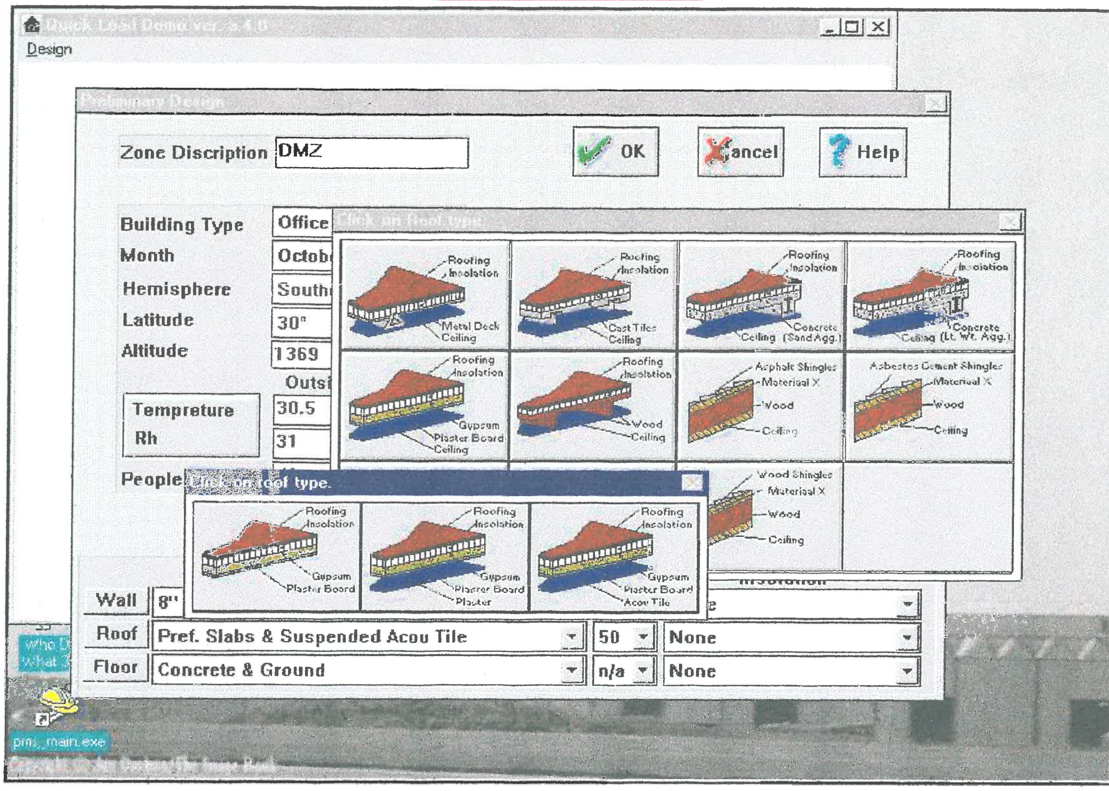


**Figure 6** Graphical selection of roof type

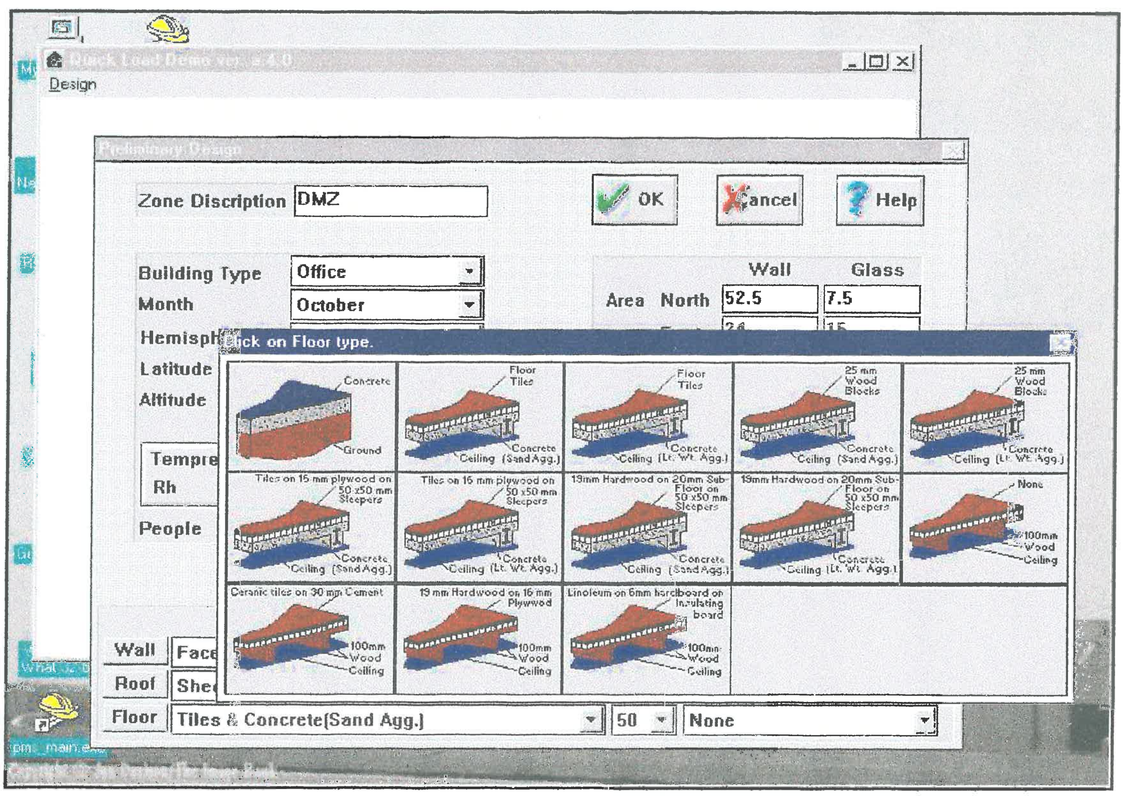


**Figure 7** Graphical selection of floor type

# 4

# Stage 4: Testing and Evaluation

## 4.1 Introduction

The end result of the simplicity/understandability design philosophy was a module that made it easy and fast to enter information and gave a cooling load, assumptions and summary of inputs. The only technical input is relative humidity. All the complex inputs like wall type, roof type and floor type can be selected graphically. The calculation takes less than a second to perform on a Pentium 120 MHz with 64 Meg Ram. The time wise bottle neck in the calculation of the cooling load is the entering of data. The speed of the program makes real-time consulting with the program feasible. The program is not hardware intensive because it works on a 386-SX 40 MHz with 4 Meg RAM and fits on a stiffy.

The evaluation of the cooling load calculation was done in three tests. Test A consisted of ten case studies of a wide variety of fictional buildings. Load calculations were done for each of these case studies using the simplified cooling load calculation program (called Quick load), ASHRAE CLTD method, New Quick (TEMMI), Panasonic method and two thumb rule methods. New Quick was used as the benchmark (Mathews,Van Heerden & Arndt, 1999:429-449). Test A was used to get a feeling of the accuracy of the different methods in real life situations. New Quick is a fourth-generation electrical analogy program. It was used as the bench-mark because it has been extensively verified(Mathews,Van Heerden & Arndt, 1999:429-449). The Panasonic method is given to companies to help them to select the right size of HVAC units. The method is intended to calculate the cooling load in small offices or homes where unitary systems are usually used. The results of the different methods were also compared to the thumb rules because they are widely used for sizing by small companies that sell small unitary systems.Test B tried to identify where the errors seen in Test A originated from. The same case studies were used but with the difference that the same wall type, roof type and floor type were used for each case. The load calculation of each case was done using Quick loads, New Quick and ASHRAE CLTD. Test C tried to pinpoint the difference between the Quick loads and New Quick. This was done by using a single case where one variable at a time is changed.

## 4.2 Test A: Global View

### Introduction

This test was done to get a global view of the accuracies of several different load calculations. The methods included New Quick, a small unit calculation sheet method, ASHRAE CLTD calculation method, Quick load and a general thumb rule type of calculation. The test was intended to see if complexity really improves the accuracy of the answer and by how much. The case studies that were used were chosen for their diversity, from a low-cost house to a high-rise building. Different wall, roof and floor types were used for each case. This made it difficult to identify the origin of the errors. Three sets of calculations were done. The Real (A.1) set used the information as specified in the case studies. In the No-load (A.2) set all internal loads where assumed to be zero. The final Empty (A.3) set of calculation assumed the building has no people or internal loads.

### Results Test A.1: Real Set

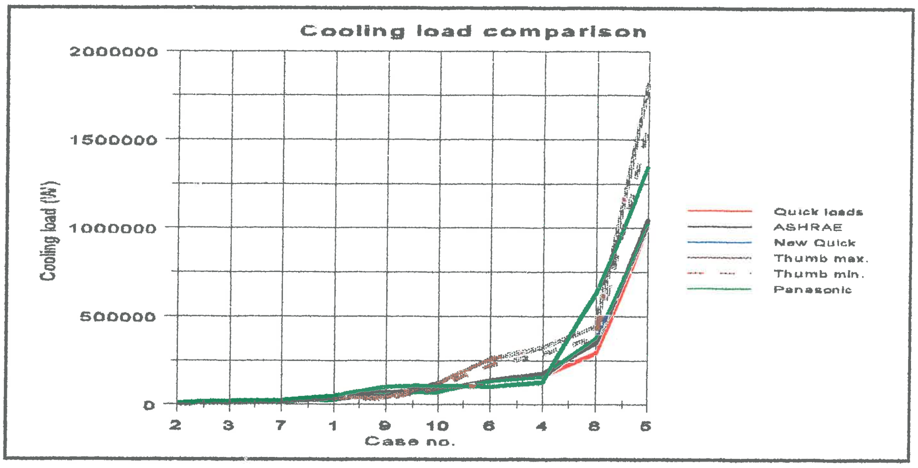


**Figure 8** Test A.1: Cooling load comparison

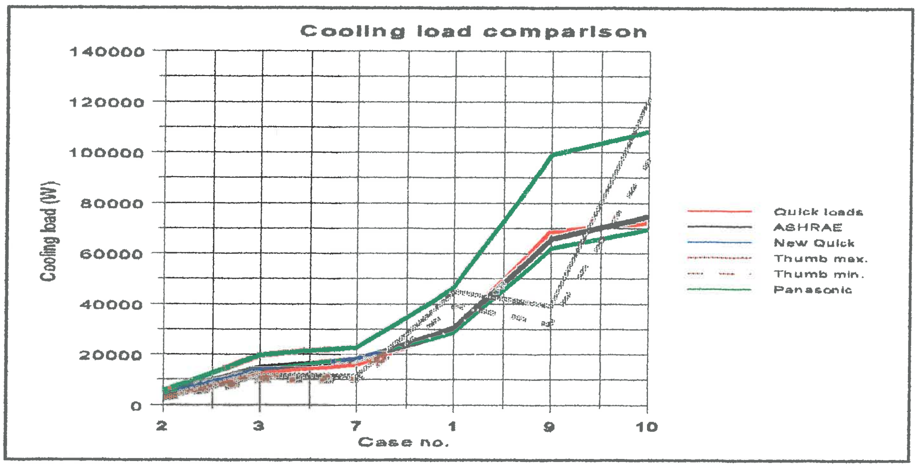


**Figure 9** Test A.1: Zoom of cooling load comparison

The previous two figures show that the added complexity does improve the accuracy in relation to New Quick. The thumb rules method and the Panasonic method showed similar trends. They were reasonablely accurate in cases that required small cooling loads. The accuracy of these methods declined drastically as the required cooling load increased. This behavior is predictable because the Panasonic method was created to calculate loads where small unitary systems are used. The Panasonic method is also a lot better than the thumb rules in that it takes a lot more things into account. Thumb rules use only floor area to calculate a maximum and minimum cooling load. This makes this type of method susceptible to mistakes when the internal loads and occupancy vary in two identical buildings. This can clearly be seen in the graph. The Panasonic overestimates the load in all but one of the cases. This is in line with the design philosophy used in the sizing of small unitary and window-mounted systems. Such systems are usually operated by the occupant of the zone. The system may be left off to save energy while the occupant is not in the zone. When the occupant returns, or realises that the zone is hot, the occupant will then switch on the air-conditioning system. The occupant usually wants instant change in the temperature. A slightly oversized system can more easily cope with such demands. The graphs also show that the decision to only consider the Quick load and CLTD methods was correct because they followed New Quick closely. The CLTD line is below the CARRIER line in Figure 8. The thumb rule and the Panasonic method were removed from the next graphs to study the differences of the remaining methods. An error graph is also drawn to show the error associated with each method in relationship with New Quick.

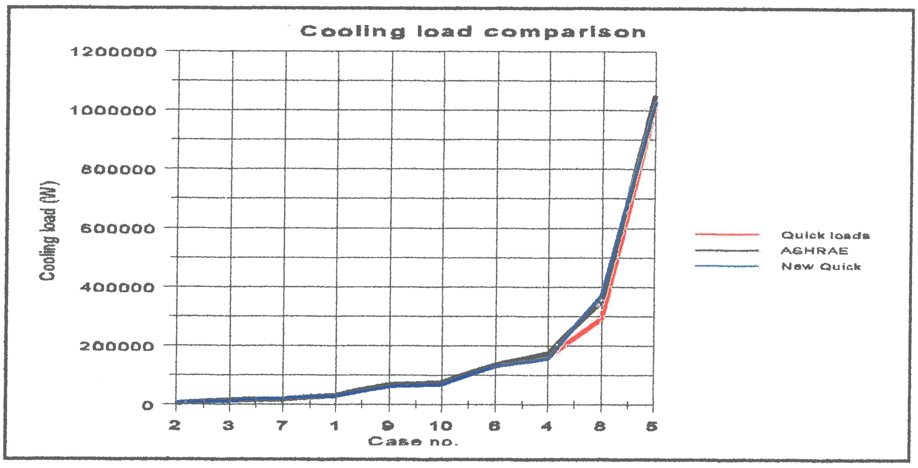


**Figure 10** Test A.1: Simplified cooling load comparison

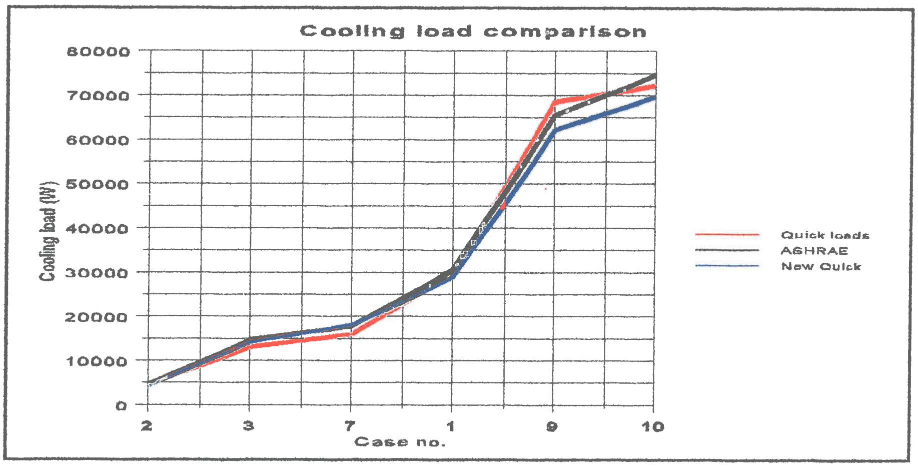


**Figure 11** Test A.1: Zoom of simplified cooling load comparison

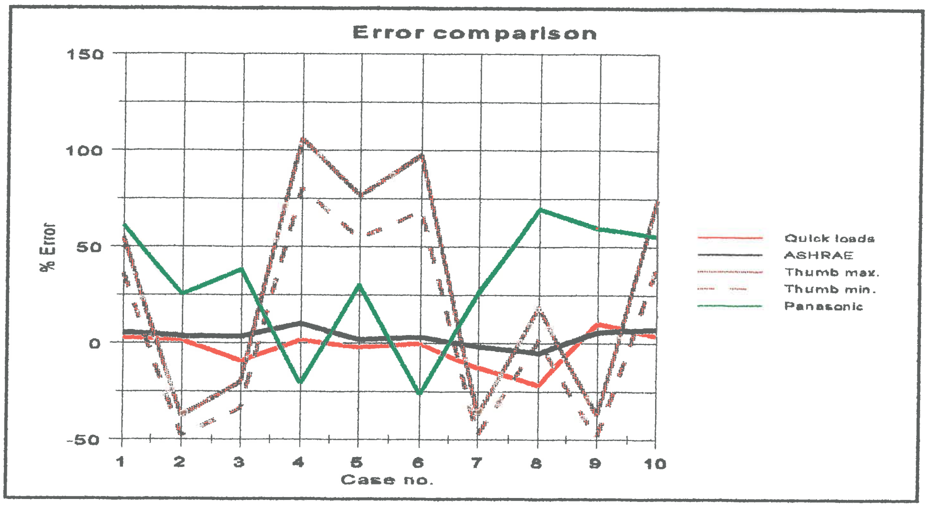


**Figure 12** Test A.1: Error comparison

The two textbook-based method results are very close to each other with the ASHRAE CLTD method giving slightly better results. The difference between the module and the CLTD method can be contributed to difference tables that the two methods use to calculate the cooling load. The errors of the two textbook-based systems with respect to New Quick were similar. The methods also gave better results than the thumb rules and the Panasonic method. Unfortunately the two textbook modules gave errors of between -8% and 22% which translate to a possible error of ± 30%. The module therefore failed to achieve the desired accuracy required. In the next two sets of tests, firstly the internal loads and then the occupants were removed to see if the errors of the two textbook systems are related to the internal load or occupancy.

## Results Test A.2: No-Loads Set

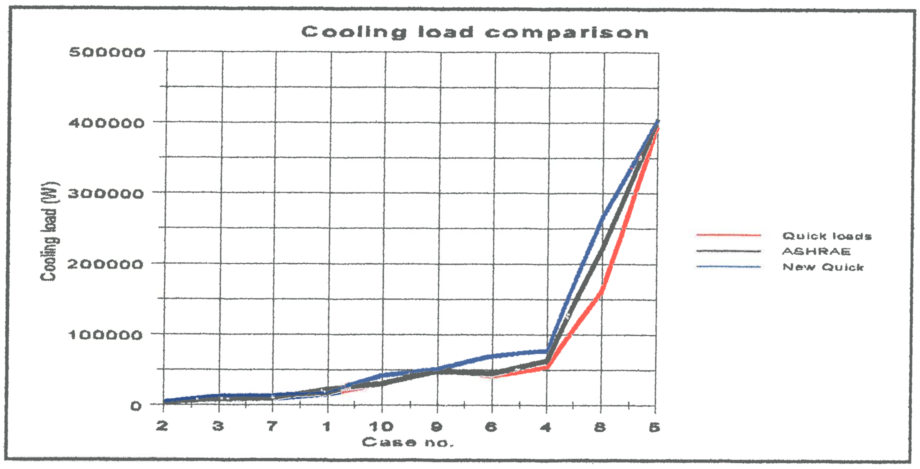


**Figure 13** Test A.2: Cooling load comparison

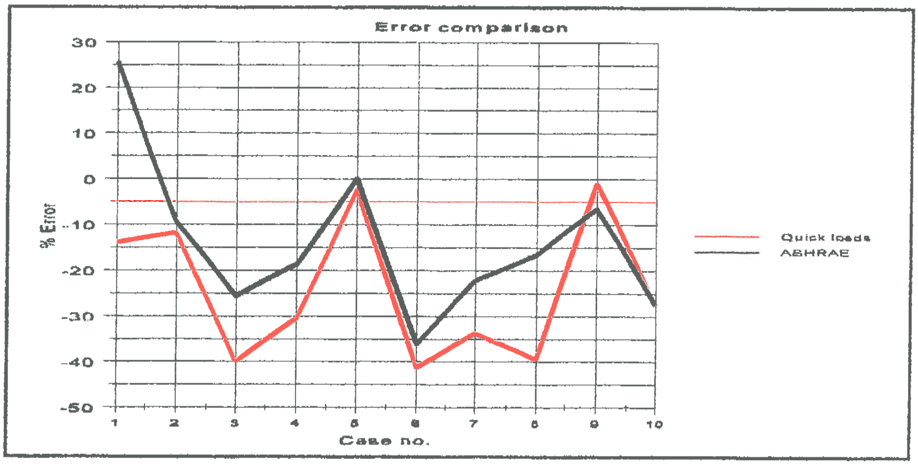


**Figure 14** Test A.2: Error comparison

The error of the two textbook methods becomes more pronounced when the internal loads are removed. Both the methods underestimate the load with the CLTD method giving better results. They show maximum errors of up to 42% in comparison with maximum errors of 22% for the Real Test. The error of the methods is therefore bigger than first thought. It seems that the internal loads are correcting some of the error caused by the building and/or the occupant. This in itself is not preferable because it in turn means that the internal load effect on the cooling load is not the same as in New Quick. The occupancy is removed in the next test to leave an empty building.

## Results Test A.3: Empty Set

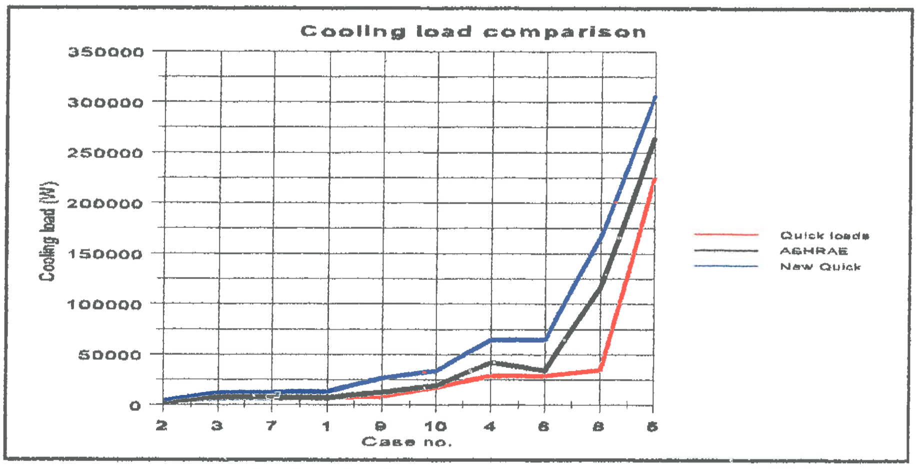


**Figure 15** Test A.3: Cooling load comparison


**Figure 16** Test A.3: Error comparison

The trend of increased error continues with this set of tests where the occupants are also removed. This leaves only an empty shell of the building to compare. The two methods again underestimate the cooling loads and the ASHRAE CLTD method again gives better results. The maximum error increases to 80% for Quick loads and 52% for the ASHRAE CLTD methods. This means that the two textbook-based methods give unusable results. The occupancy has a similar effect on the internal loads in that it corrects some of the error caused by the shell of the building. This also means that the occupancy has a bigger effect on the cooling load calculated by the two textbook methods than in New Quick. No trend was found when the error was plotted against wall, glass, floor, roof area and glass to wall ratios.

## *Discussion*

The maximum error of the different tests and methods are shown in the following Table.

| Test | Quick Load | ASHRAE CLTD | Thumb max. | Thumb min. | Panasonic |
|---|---|---|---|---|---|
| A.1 | 22% | 10% | 106% | 80% | 70% |
| A.2 | 41% | 36% | | | |
| A.3 | 80% | 52% | | | |

The ASHRAE CLTD method is the most accurate, followed by Quick load. The Panasonic method gives decent results for the simplicity of the method. The thumb rule is inadequate. The table also shows how the accuracy decreases as the building is emptied. In this set different walls, glass, roof and floor were used. This makes it difficult to identify a trend. A new set of tests, with buildings that have similar type of shell, were therefore needed to see if the source of the error could be identified.

# 4.3 Test B: Comparable View

## Introduction

This test was done to compare accuracies of three different load calculation methods. The methods included a New Quick, ASHRAE CLTD calculation method and Quick load. Several assumptions were made to make it possible to compare results and identify trends. The assumptions are listed below.

### Case studies assumptions.

- The buildings are all office buildings.
- The buildings are in the same location:
  - Hemisphere
  - The latitude
  - The altitude
  - Month
- Inside design specifications are the same:
  - Design temperature
  - Design relative humidities
- Outside climate is the same:
  - Temperature
  - Relative humidities
- The walls are the same for each building:
  - Type
  - Thickness
  - Insulation
- The glass used in all the buildings are the same:
  - Type
  - Shading
- Floors are also the same:
  - Type
  - Thickness
  - Insulation
- Roofs are the same for all the buildings:
  - Type
  - Thickness
  - Insulation

These are reasonable assumptions except in the case of the lowcost housing, residential house and the house office. These assumptions should make it possible to identify the origin of the error. New Quick was again used as the benchmark. Three sets of calculations were done. The Real (B.1) set used the information as specified in the case studies. In the No-load (B.2) set all internal loads were assumed to be zero. The final Empty (B.3) set of calculation assumed the building had no occupancy or internal loads.

## Results Test B.1: Real Set

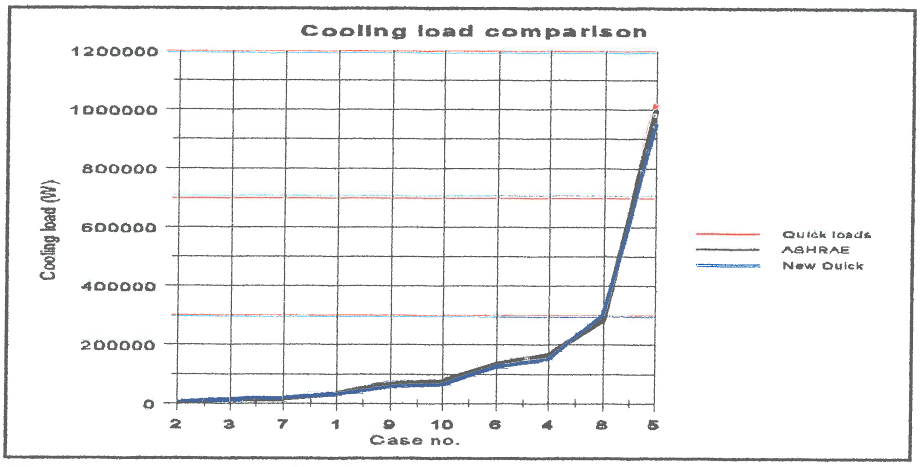


**Figure 17** Test B.1: Cooling load comparison


**Figure 18** Test B.1: Error comparison

The test shows similar results to the A.1 test with a slightly lower maximum error of 20%. In most of the cases the two textbook methods overestimate the cooling load. The CLTD again achieved a lower error than Quick loads. The fact that the error for this test differs from the A.1 test shows that the building shell material selection influences the maximum error. The next test is similar to Test A.2 in that the internal loads are removed to determine the effect of them on the cooling load.

## Results Test B.2: No-Loads Set

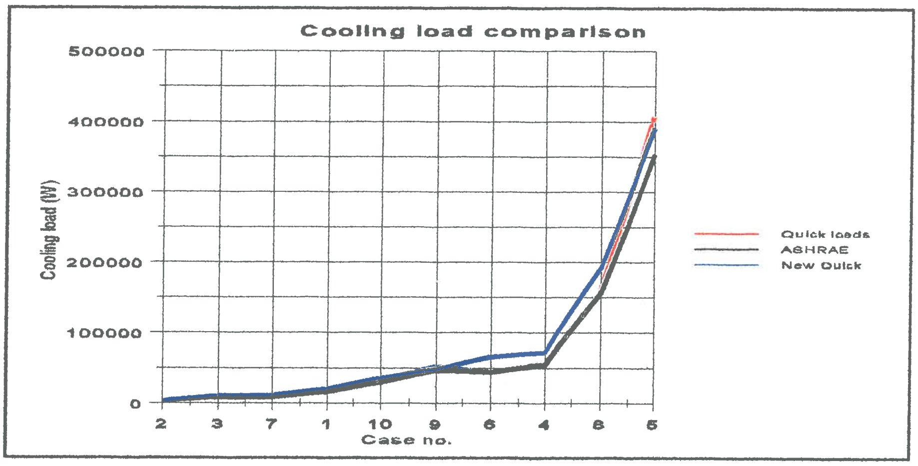


**Figure 19** Test B.2: Cooling load comparison


**Figure 20** Test B.2: Error comparison

The test shows similar results to the A.2 test with a lower maximum error of 34%. The maximum error also increases as in the A.2 test. In most of the cases the two textbook methods underestimated the cooling load. From the similarity to Test A.2 a conclusion can be reached that the internal loads correct some of the error of the building shell and/or occupancy. This again raises the problem that it means that the effect of the internal loads on the cooling load is also not correct. In the next test the occupants of the buildings are also removed.

## Results Test B.3: Empty Set

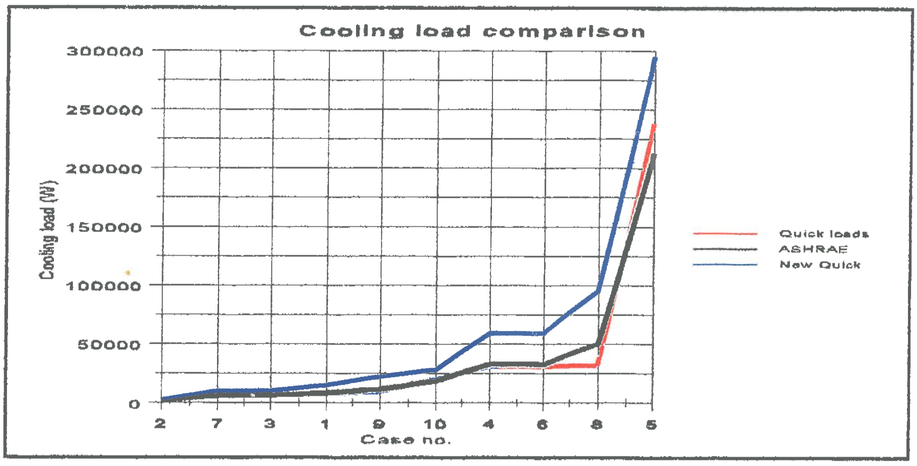


**Figure 21** Test B.3: Cooling load comparison

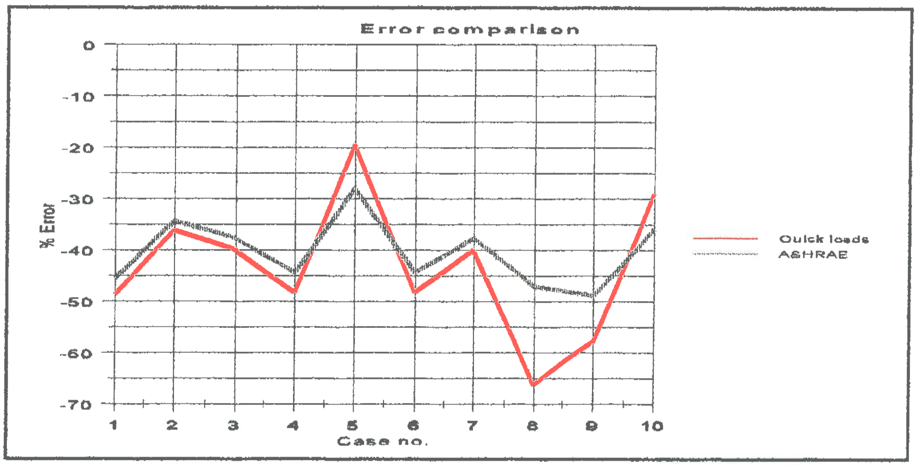


**Figure 22** Test B.3: Error comparison

The test shows similar results to the A.3 test with a lower maximum error of 66%. The maximum error also increases over the B.2 test. It can be seen in the cooling load comparison graph that the two textbook methods give similar results that underestimates the cooling load. The CLTD method returns a lower maximum error than Quick load. A similar tendency is seen that the occupancy corrects some of the error that is caused by the building shell. This also means that the effect of the occupancy on the cooling load is not correct. The error is now plotted for a number of physical dimensions of the buildings to try and identify a possible cause for the underestimation of the cooling load by the two textbook methods. These did not show any trend.

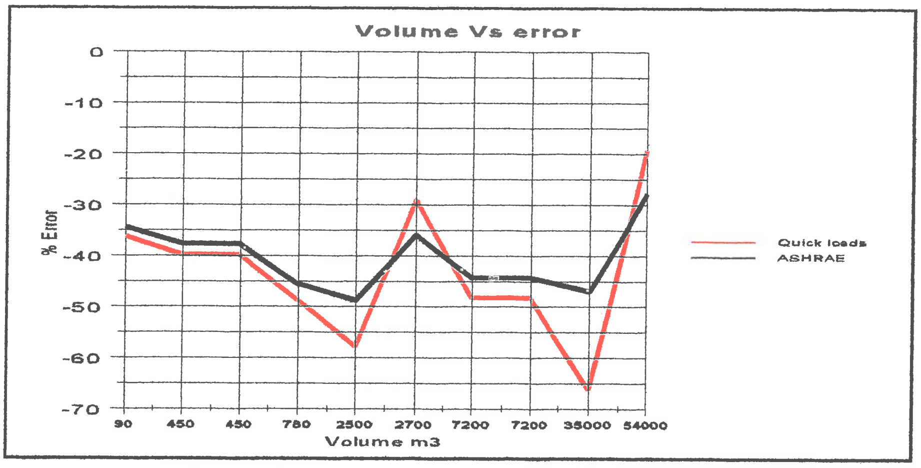


**Figure 23** Test B.3: Volume vs % error

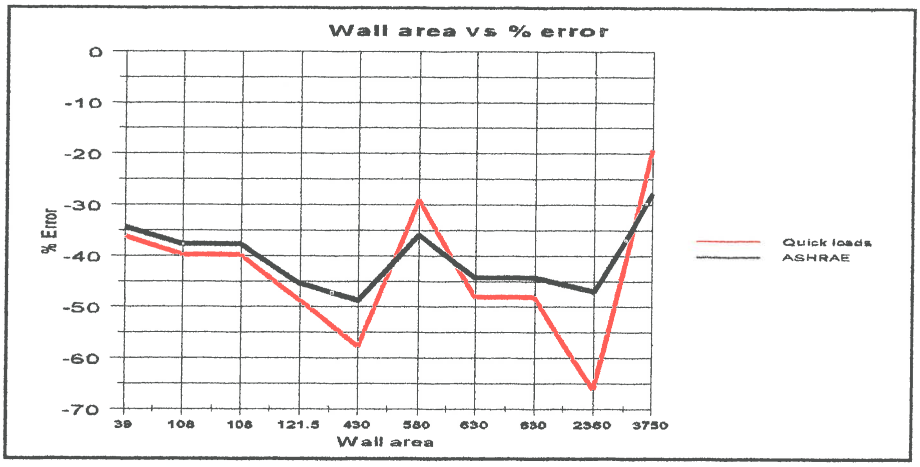


**Figure 24** Test B.3: Wall area vs % error

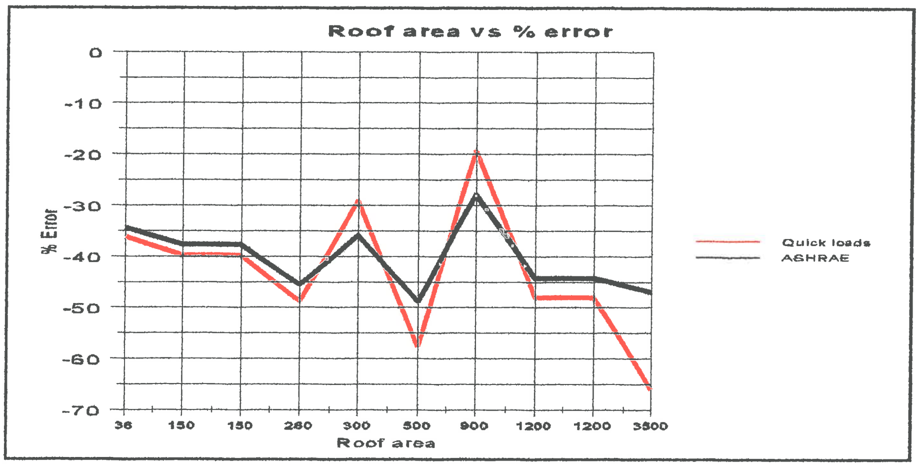


**Figure 25** Test B.3: Roof area vs % error

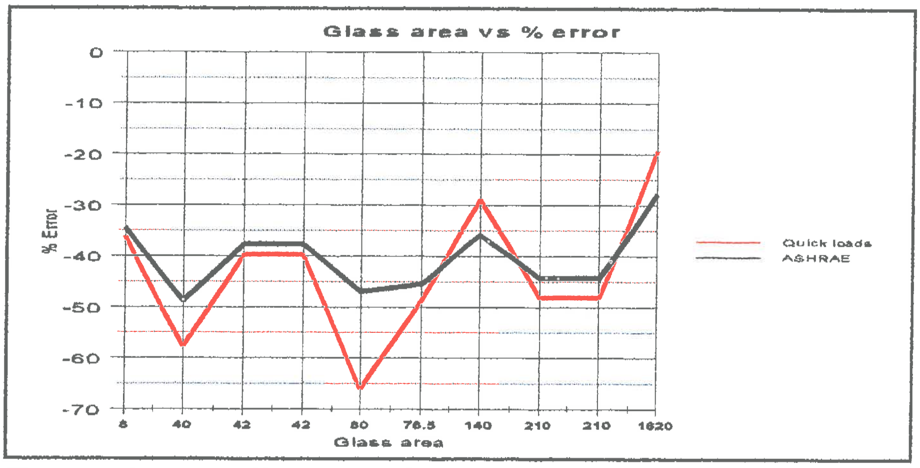


**Figure 26** Test B.3: Glass area vs % error

The previous four graphs show that there is no simple answer to the deviation of the two textbook load calculation methods. A number of other graphs were plotted that showed similar results. It is therefore necessary for the new set of tests to see what effect each element of the load calculation formulas has on the end result.

## *Discussion*

The maximum error of the different tests and methods is shown in the following table.

| Test | Quick loads | ASHRAE CLTD |
|---|---|---|
| B.1 | 20% | 17% |
| B.2 | 33% | 33% |
| B.3 | 66% | 47% |

The ASHRAE CLTD method is the most accurate, followed by Quick loads. The table also shows how the accuracy decreases as the building is emptied. It also shows that the two methods are not very accurate and that it is preferable not to use any of the two methods. From the A and B tests one can come to the conclusion that the two textbook methods underestimate the cooling load if only the shell building is considered and that this error will vary with different materials used. The second conclusion that is reached is that the two methods overestimates the effect of the people and the internal loads on the cooling load. A new set of tests were therefore needed to see if these two assumptions are true.

## 4.4 Test C: Pinpoint View

### Introduction

This test was done to pinpoint the differences between the New Quick and Quick load. The most simple case was used. This case used the same wall, roofs and floor types throughout the test. Only one variable is chanced and then plotted. The building can be compared to a simple cube. The following graphs show how the Quick load result differs from the result of New Quick.

### Results

The result of the test of the four wall areas will be shown first.

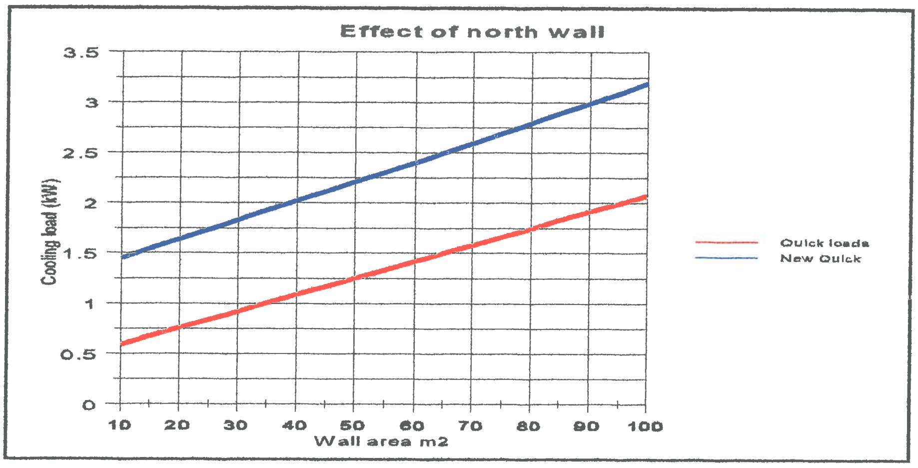


**Figure 27** The effect of the north wall on the load

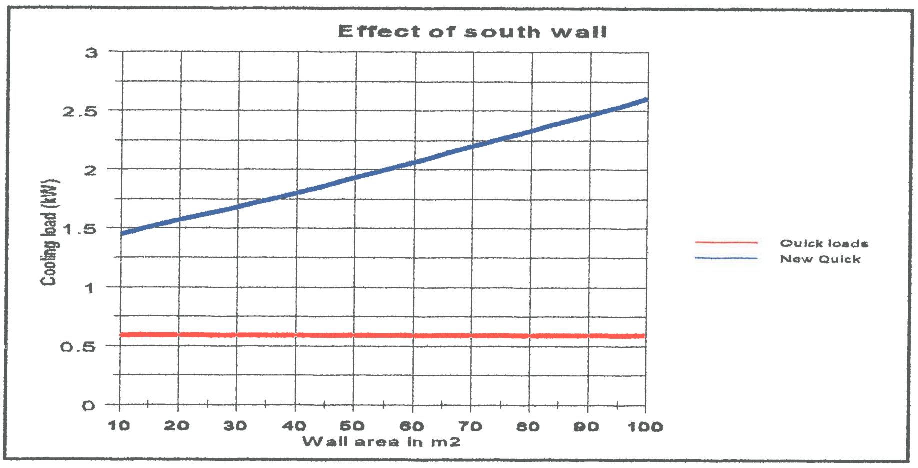


**Figure 28** The effect of the south wall on the load

Both the north and south wall will cause the simplified method to underestimate the cooling load. The effect of the south wall is especially worrying because of the negative slope.

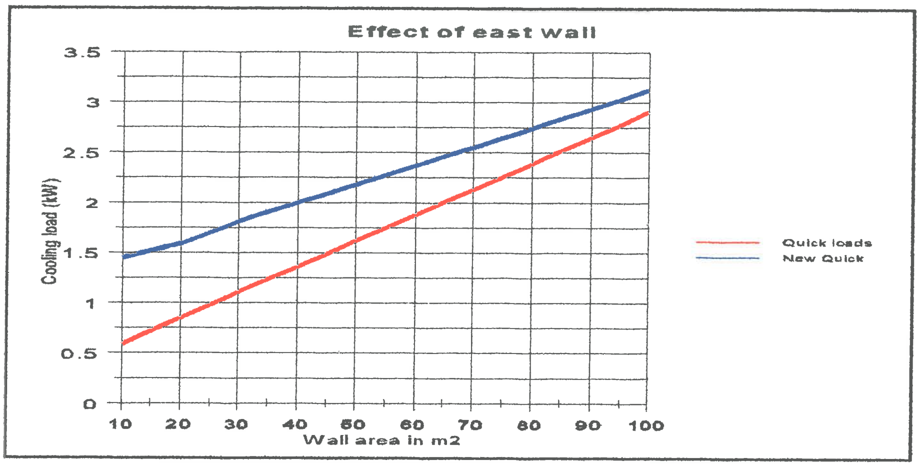


**Figure 29** The effect of the east wall on the load

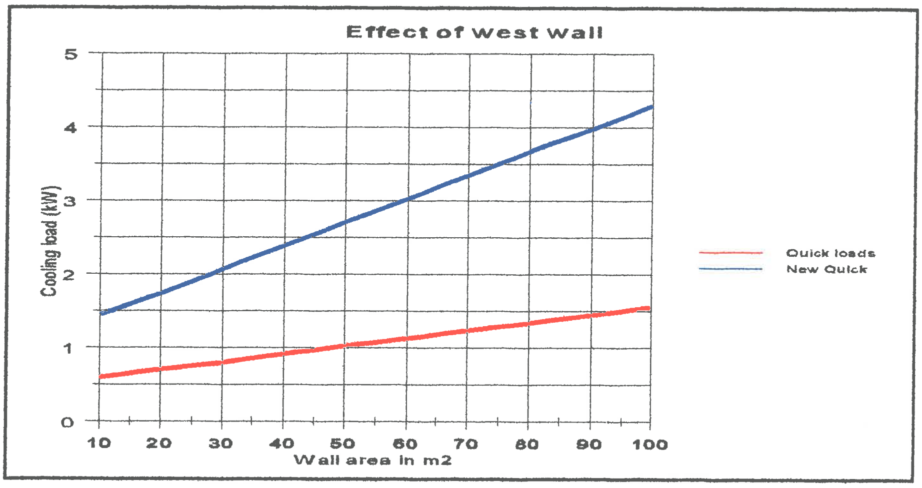


**Figure 30** The effect of the west wall on the load

The east wall shows an interesting tendency to underestimate the cooling load if the area is under about 120 $m^2$ as in this case, and that it will then start to overestimating the required cooling load after that. The west wall shows a tendency of underestimating the cooling load. The shallow slope means that the error will increase with an increase in west wall area. The glass area will be looked at next.

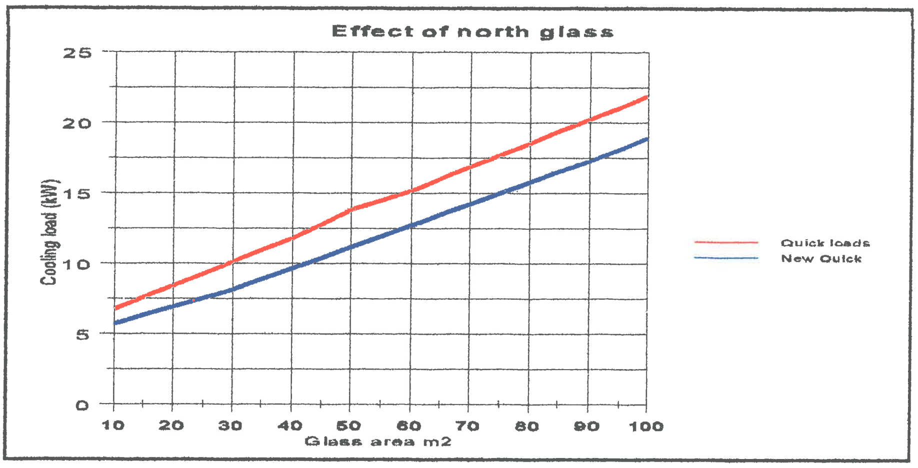


**Figure 31** The effect of the north glass area on the load

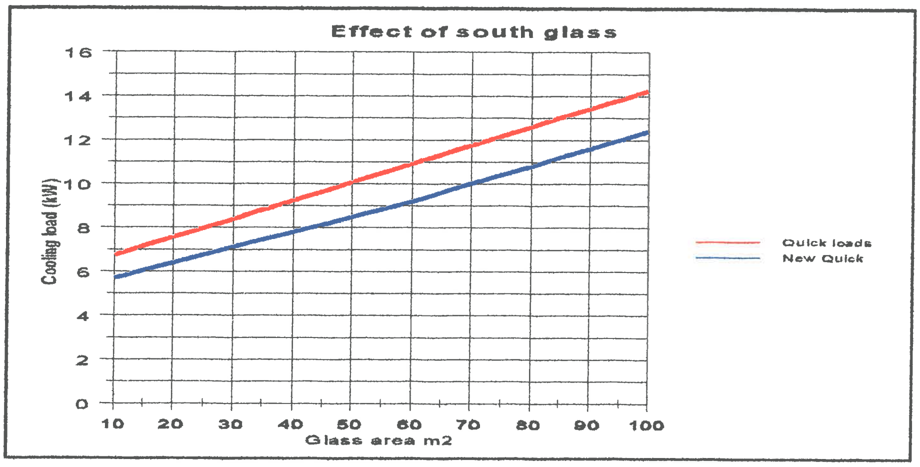


**Figure 32** The effect of the south glass area on the load

The north and south areas give results that are close in value and in slopes to New Quick. This translates to almost constant slightly increasing error.

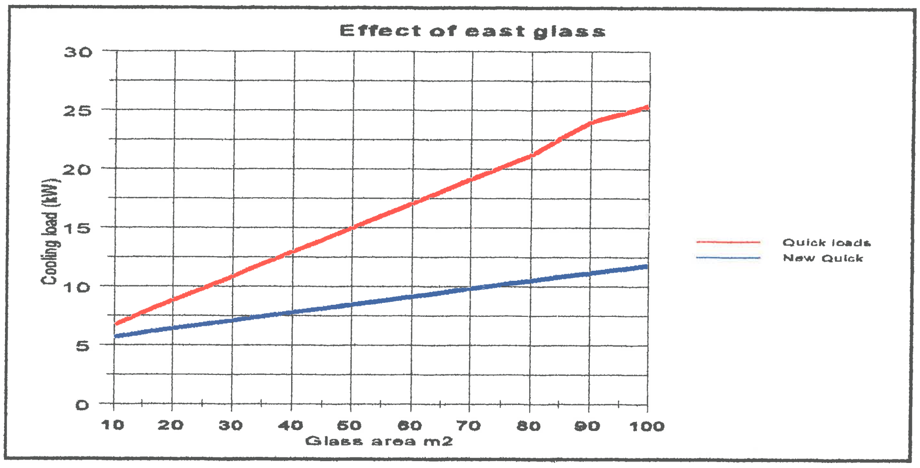


**Figure 33** The effect of the east glass area on the load

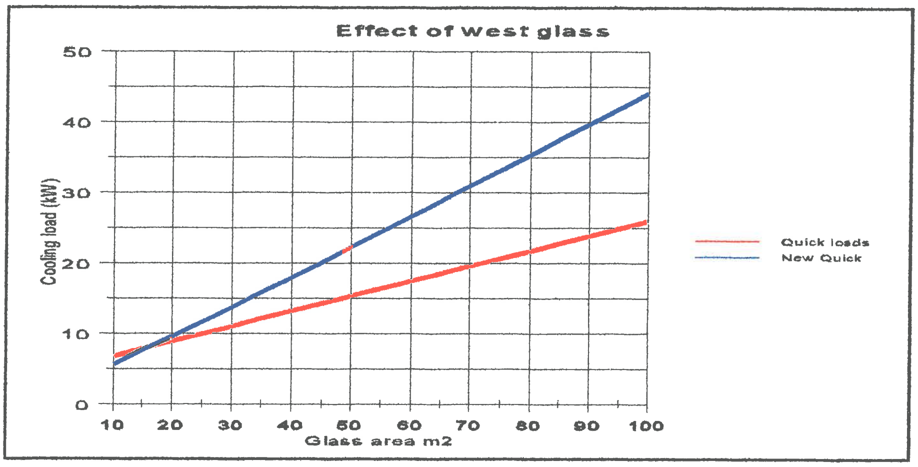


**Figure 34** The effect of the west glass area on the load

The west and east glass areas give results that underestimate the cooling load and with a difference in slope to New Quick. An increase in glass area will therefore increase the error significantly. The roof area graphs are shown next.

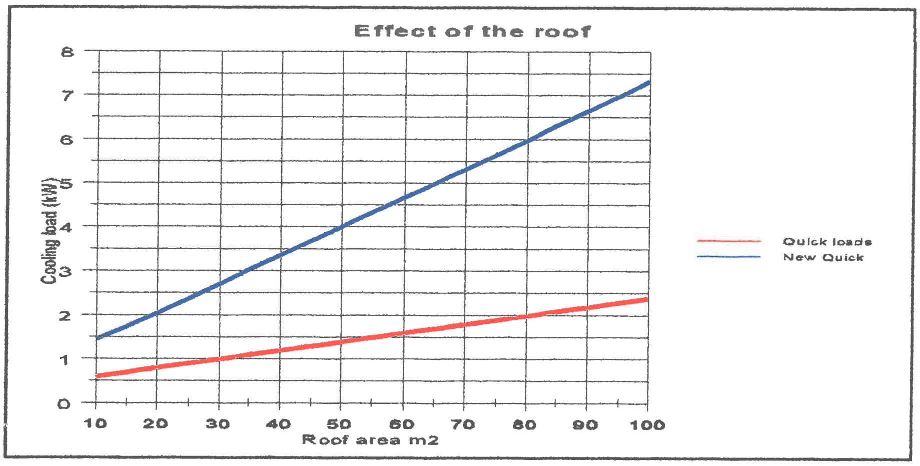


**Figure 35** The effect of the roof on the load

The roof area also underestimates the cooling load required. The difference in slope between New Quick and Quick loads will increase the error with an increase in roof area.

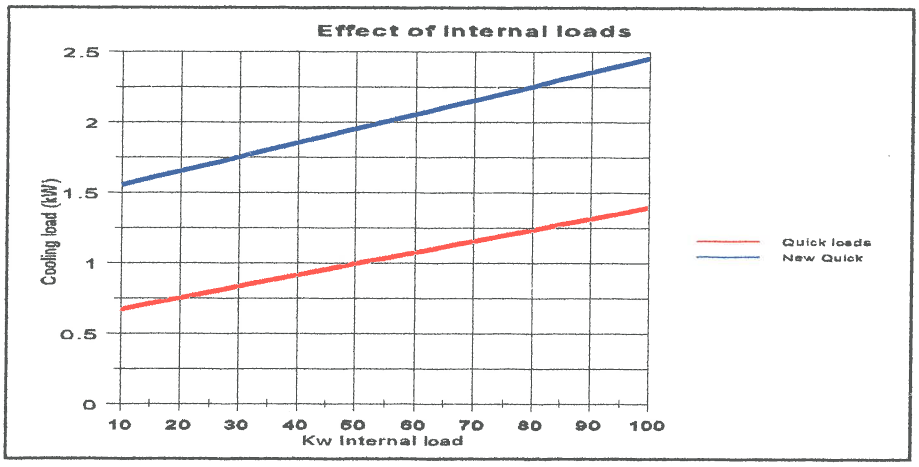


**Figure 36** The effect of internal loads on the load

This graph does not confirm our second assumption that the internal loads effect is larger than it should be. From Tests A and B one would expect that the two lines would have been the other way round. The error will increase slightly with an increase of internal loads because the slopes of the two lines are nearly the same. The graph below confirms that one half of the second assumption was correct, the effect of people is much larger than it should be.

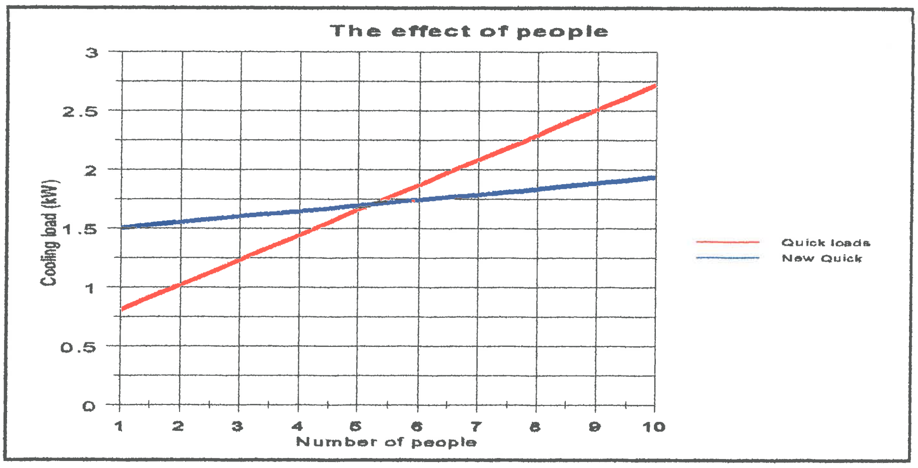


**Figure 37** The effect of people on the load

### Discussion

The graphs showed how the answers of the different methods differ. One can also see that the simplified Carrier method (Quick load) mostly underestimates the cooling load except in the case of people. This is the reason why the Real test gives reasonable answers and the empty test unusable answers. These results can unfortunately not be used to calculate a factor, by which results can be multiplied to get a closer result. This is because the factor will vary with the type of material used. This means there is not any easy fix to the accuracy problem of the module.

## 4.5 Conclusion

The cooling load program met most of the design specifications. Unfortunately the module was unable to meet the required accuracy needed. The speed and ease of use made the module ideally suited for real-time consulting work. The module can make a very valuable tool for any consultant engineer and architect if the accuracy of the module can be improved.

It may be possible to do so without losing the simplicity and ease of use of the input interface. This can be done by using the existing interface to enter data into an equivalent resistance calculation method. This will give an error closer to the allowed specification.

Several improvements to the interface can also be recommended. It must be possible to enter internal loads without using floor area. Another problem identified is that the difference between total floor area and foot print floor area must be defined more clearly. It should also be possible for the lighting loads to be incorporated without confusing the floor areas with the footprint floor area.

Several nice to have features were also identified that will improve the input interface. The users must be able to specify the time at which the calculation must be done. The calculation for a 24-hour period to determine the maximum cooling load must be possible. The graph of the cooling load for that 24 hours can then be plotted. It must also be possible to save and load projects. This will make presentations a lot easier. It will also be a good idea to verify the module with the results of existing buildings. The next chapter will deal with the development of the system selection module.

# 5

# Simplified System Selection

Artificial intelligence is better than no intelligence at all.
An unknown author

## 5.1 Introduction

A key item of the IDA design philosophy, as discussed in the prologue, is the correct selection of an HVAC system (Todesco, 1997:45). An expert system was used to do the selection of an HVAC system. Expert systems are designed to mimic the thought process of the expert in a problem-specific domain. Expert systems use reasoning techniques to manipulate knowledge in a knowledge base to solve a specific problem. Usually the problems are very knowledge intensive with several acceptable answers. The answers that an expert system generates are therefore qualitative rather than quantitative. This means that instead of generating a lot of repetitive calculations, an expert system will analyse a problem and give the most appropriate answer with an explanation of its thought process. The expert system must help the user that does not have the problem-specific knowledge, to select an HVAC system in the absence of an expert. The development of the second module, the system selection, will be discussed in this chapter. The system was developed using the same system as used for the load calculation module.

## 5.2 Stage 1: Identification and Definition

The problem has been discussed in detail in section 1.3 of the prologue. The aim of the program, as discussed in section 1.4, is to create a simplified system selection program for the brief and preliminary stages of HVAC design. The potential users of the module, as highlighted in section 1.4, are consultants, architects and sales representatives. For the selection of an air-conditioning system for a building one needs a lot of HVAC experience. This type of experience takes time and sometimes several mistakes to acquire.

A system selection program was written to simplify the selection processes and to make it possible for people with limited technical knowledge to select an air-conditioning system. The system selection module had the same design goals as the cooling load module. The interface must be very easy to use. Inputs must be as non-technical as possible, in other words, any question that the user would not understand must not be asked. The program should be fast so that it can be used for real-time consulting. The cooling load module and the selection program make it possible to calculate the cost and space implication of a selected HVAC system. This should make an excellent design tool for the brief and conceptual design phase of HVAC design.

The same criteria, as discussed in section 3.2, were used for the selection of hardware and software.

## 5.3 Stage 2: Development of a Prototype

The knowledge used for this module again comes mainly from domain-independent sources like textbooks and articles. Some domain-dependent information was also used. The reason for the use of an expert system for selection of an HVAC system is discussed next.

Most texts concerning HVAC system selection are not clear about how exactly one selects a system and only give broad outlines on how to do the selection. They usually give an outline of all the basic systems used. With the advantages and disadvantages known, they start to try to select a system. Most HVAC systems will work in any situation. However, there will usually be several systems that are more appropriate. To give an example, one will not use window-mounted units for the World Trade Centre or use an all-water system for a low-cost house. This is where intelligence comes in. An expert uses problem-specific knowledge, common sense, experience, rules of thumb and short cuts to select an HVAC system.

There are an infinite number of HVAC systems and combinations of systems. The major systems were first identified and then the main subdivision of each of them. The subdivision was kept very basic, therefore no hybrid systems were considered. This basic subsystems were used as the source of the possible answers of this module. The basic systems listed below are not an absolute selection of basic systems, it is merely a selection of the main type of systems. Some would select the systems simpler and other like Shams et al. (1995:165-172) selected a more detailed basic system. The following systems were considered as possible answers:

- Ventilation
  - Mechanical
  - Natural
- Direct expansion
  - Package
    - Water cooled
      - Economiser
      - Full fresh air
    - Air cooled
      - Economiser
      - Full fresh air
  - Window mounted
  - Split units
- Chilled water
  - All air
    - VAV
      - LVD
        - Water cooled
          - Economiser
          - Full fresh air
        - Air cooled
          - Economiser
          - Full fresh air
      - HVD
        - Water cooled
          - Economiser
          - Full fresh air
        - Air cooled
          - Economiser
          - Full fresh air
    - CVVT
      - LVD
        - Water cooled
          - Economiser
          - Full fresh air
        - Air cooled
          - Economiser
          - Full fresh air

| | | | |
|---|---|---|---|
| | - HVD | - Water cooled | - Economiser |
| | | | - Full fresh air |
| | | - Air cooled | - Economiser |
| | | | - Full fresh air |
| - Air-water | | - Water cooled | - Economiser |
| | | | - Full fresh air |
| | | - Air cooled | - Economiser |
| | | | - Full fresh air |
| - All water | | - Water cooled | - Economiser |
| | | | - Full fresh air |
| | | - Air cooled | - Economiser |
| | | | - Full fresh air |

- Evaporative cooler - Direct
  - Indirect
  - Multi stage

VAV = Variable air volume
CVVT = Constant volume variable temperature
LSD = Low velocity ducts
HSD = High velocity ducts

The standard methodology was used by using textbooks for information about each system. The advantages and disadvantages of each system were listed. This information then had to be converted into a useful form. Knowledge can be represented in several ways. The knowledge base represents the knowledge in an organised and orderly way. The knowledge gained from the information was presented as production rules for this problem. Production rules are conditions that can be written as IF THEN statements. The IF part of the statement is applicable on a condition, state or object. The THEN part is activated if the IF part is true. For example: IF there is no space for ducts THEN select a system that does not use ducts. The advantages and disadvantages of each system were used to write several production rules.

Problem solving strategies are necessary to make it possible to solve a problem. The problem solving strategy contains a search model and a control strategy. The search method is the method used by the expert system to search through the knowledge base. In this case a heuristic search method is used. Heuristic search methods take the organisation of the knowledge base into account when searching. So doing it can prune possible solution paths that must not be searched. This increases the efficiency of the method but it also decreases the completeness of the search. The expert system consists of several heuristic rules. The heuristic rules decide which branch of the search tree to expand next. Forward reasoning was used as the control strategy. Forward reasoning is a data-driven search where the search is started with an initial condition and then searches through the knowledge base to a solution. This is also known as a ground-up control strategy. The search starts in the trunk of the search tree and ends in the tip of a branch. A schematic of such a search is shown in Figure 38.

Asking the right questions that make it possible to select a specific HVAC system is very difficult because most systems are very similar. To make it possible to select a specific system, it is easier to concentrate on the main difference and special features of each system. The design philosophy in the creation of the heuristic rules was pruning. The purpose of each question was to eliminate at least one system. The questions were compiled and linked to systematically reduce the number of possible systems that meet the requirements of the user. The questions were arranged in order of importance. The questions about areas of the design the user has little control over, like space for ducts and space for plant room in a building, are asked first. Questions concerning cost are asked last to prevent the user specifying systems that have low initial cost and low running cost but cannot be installed in the building. This means that question about special cases where only one type of system will work were asked first. As the question session goes on the questions become more general because all special cases have been eliminated. The last question is usually about cost because at this stage almost any system will work. The question will quickly converge to a system if the user selects a system for a special case where only a small number of systems could possibly work. The questioning session could be considerably longer for a more general case.

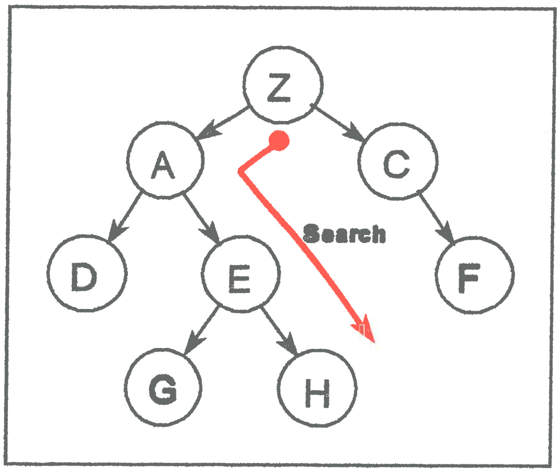


**Figure 38** OR search tree representation

An object-orientated design philosophy was followed with the design of the search algorithm. This means that each question that was asked could be seen as a black box. Each of these black boxes can be called and can receive a data string for another black box. The black box can be called and can call any other black box. The black box prompts the user for an answer for its question. The black box then reacts to the answer of the question by calls and passing the modified data string to the next black box. This process continues till the algorithm converges to an answer. The algorithm that consists of several question black boxes has the shape of an inverted tree. The branch of the search tree splits after each question box. Some branches interweave and reconnect with other branches. On the tip of each branch is a selected system.

A number of question black boxes were grouped into a black box to make it easier to understand. The fact that the algorithm was designed using the black boxes method that makes it very easy to insert a new question or to modify and rearrange the existing questions. The detailed construction is discussed next.

## 5.4 Stage 3: Construction

The program has only one input screen and output screen to meet the design specifications. The user's inputs were kept to a minimum by only giving two to three possible answers from which the user can choose. This has the effect that it limits inputs and increases the speed of selection. The questions and answers are displayed as the questions are answered to show the progress of the session. When a system is finally specified, the program gives a summary of the cooling system. The detailed knowledge structure is shown in figure 39. Each question in this tree is discussed, in Appendix A, using the following format:

Question index : The question ID number as used in the decision tree
Previous question : List of questions calling this question

Question : The question

Purpose of question : The reason behind the question

Result parameters : Gives the possible answers

Result of question : For one of the above result the following is true:

Knowledge gained : Knowledge gained out of this answer to the question
Recommended systems : Systems that can be recommended with the knowledge gained
Not recommended systems : Systems that cannot be recommended with the knowledge gained
Action : Action that must be taken now
Next question : The next question that must be called

Result of question : For the other result the following is true:

Knowledge gained : Knowledge gained out of this answer to the question
Recommended systems : Systems that can be recommended with the knowledge gained
Not recommended systems : Systems that cannot be recommended with the knowledge gained
Action : Action that must be taken now
Next question : The next question that must be called

The testing of the selection program is discussed in detail in Chapter 6, using ten case studies.

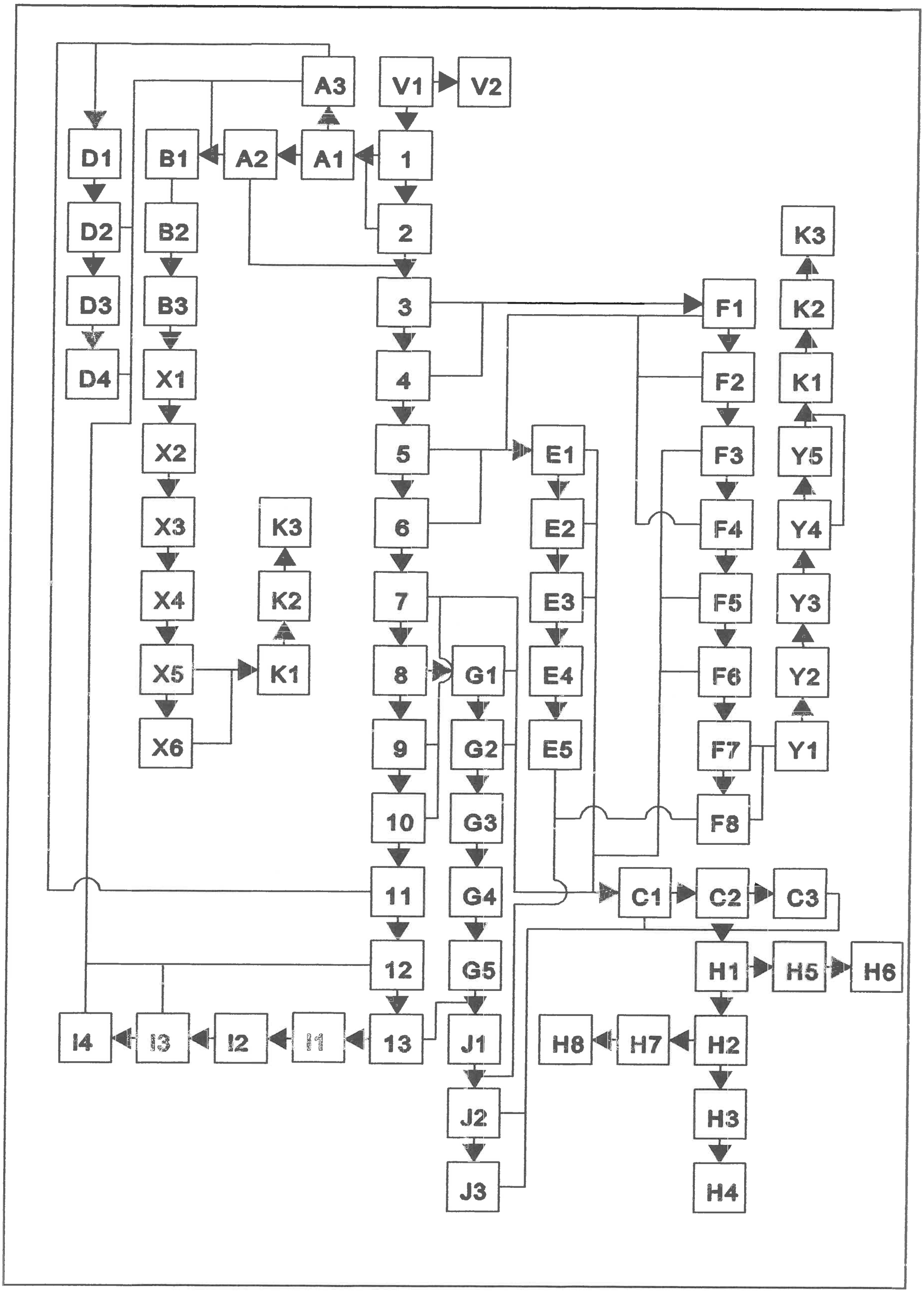


Figure 39 Detailed knowledge structure

# 6

# Stage 4: Testing and Evaluation

## 6.1 Introduction

The program was verified by selecting cooling systems for ten case studies. The selected system of each of these cases was then compared to the system installed in the building. The system selection process for each case will be discussed here. A short summary of the building is first given, then the selection process. Each question with its corresponding index number and answer are shown in a table. The selected system and installed system are then shown at the bottom of the questions table. The selected system is then discussed and evaluated. The path of questioning is shown on the detailed knowledge tree after each case study.

The following case studies were used:

1. University of Pretoria Engineering Tower Building, Pretoria
2. First National Bank Gezina, Pretoria
3. MMA Office, Vanderbijlpark
4. Cold Mills South Change House, ISCOR, Vanderbijlpark
5. Cold Mills South Administration Building, ISCOR, Vanderbijlpark
6. Main Administration Building, ISCOR, Vanderbijlpark
7. Paint Line Painting section, ISCOR, Vanderbijlpark
8. Data Centre, Computer Room, ISCOR, Vanderbijlpark
9. Direct Reduction Control Room, ISCOR, Vanderbijlpark
10. Neonatal Unit, Medivaal Hospital, Vanderbijlpark

# 6.2 Case Study

## University of Pretoria Engineering Tower Building, Pretoria

**Introduction**

The following information was used to select the system:

- The system was installed when the building was erected.
- There is limited space to install ducts.
- There is space for an equipment room to install cooling equipment.
- The building is a high-rise building.
- The building is an office building.
- All the offices are on the perimeter of the building.
- Dust is not a problem.
- It is not necessary to keep the building under a positive or negative pressure.
- Maintenance and cooling equipment is allowable in occupied zones.
- It isn't necessary to supply large volumes of fresh air.
- Cooling equipment is aesthetically not allowed on the outside of the building.
- A large cooling load is required.
- Noise control is not very important.
- There is water for a cooling tower.
- The space for the condenser cooling equipment is close to the cooling equipment.
- The design emphasis is on lowest life-cycle costs.
- The system should be selected for the lowest 20-year life-cycle cost.

**Selection**

| | | |
|---|---|---|
| V1 | Is only ventilation needed? | No |
| 1 | Is the system for a new building or for a retrofit? | New building |
| 2 | Is there space for the installation of ducts or an equipment room? | No |
| A1 | Is there space for the installation of ducting? | No |
| A3 | Is there room for cooling equipment in the building, on the roof or on the outside of the building? | Yes |
| D1 | Is the building a large medium to high-rise building? | Yes |
| P3 | Is there water for a cooling tower? | Yes |
| P4 | Is there a distance between the equipment room and space for the installation of condenser cooling equipment? | Yes |
| P5 | Should the system be selected for the lowest initial cost or on the lowest 20-year life-cycle cost? | Lowest life-cycle cost |

| | |
|---|---|
| **Selected** | Chilled water system - All water system with water cooling |
| **Installed** | Chilled water system - All water system with water cooling |

**Discussion**

The selected and installed systems are the same. The selection can be explained on the following grounds:

1. The following systems are not recommended because there is no space for ducting:
   - All air systems.
   - Air-water systems.
2. It is unpractical to use WMU, split units and evaporative coolers in a high-rise building.
3. WMU, split units and evaporative coolers are not aesthetically pleasing on the outside of the building.
4. The following systems are recommended for this application.
   - Small vertical package units.
   - All water systems.
5. A vertical package unit and an all water system are ideally suited for a large number of small perimeter zones.
6. It is sensible to use all water systems in a high-rise building where a large cooling load is needed.
7. An all water system has a better life-cycle cost than a vertical package unit.
8. Water cooling should be used because it is more effective than air cooling. This is important to ensure that the lowest 20-year life-cycle cost is achieved.

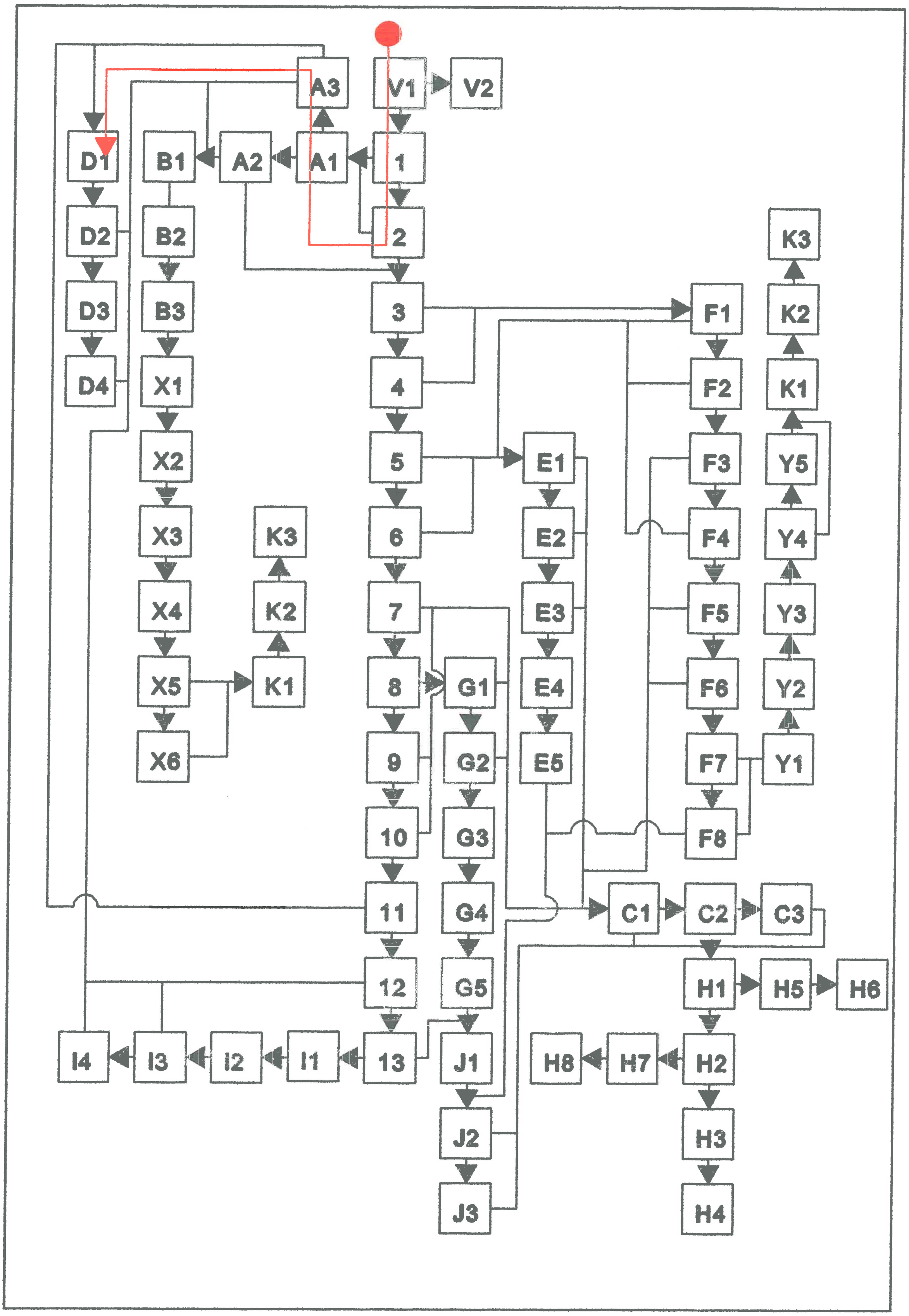


**Figure 40** Engineering tower selection path

# First National Bank Gezina, Pretoria

## Introduction

The following information was used to select the system:

- The system was installed when the building was erected.
- There is space to install ducts.
- There is space for an equipment room to install cooling equipment.
- The building is a low-rise building.
- The building is an office building.
- Most of the bank is one large zone.
- Dust is not a problem.
- It is not necessary to keep the building under a positive or negative pressure.
- Maintenance and cooling equipment in the occupied zones is not preferable.
- It is necessary to supply large volumes of fresh air because of the large number of people that can be in the bank at one time.
- Cooling equipment is aesthetically not allowed on the outside of the building except the roof.
- A medium cooling load is required.
- Noise control is not very important.
- There is water for a cooling tower.
- The space for the condenser equipment is close to the cooling equipment.
- The design emphasis is on lowest life-cycle costs.

## Selection

| | | |
|---|---|---|
| V1 | Is only ventilation needed? | No |
| 1 | Is the system for a new building or for a retrofit? | New building |
| 2 | Is there space for the installation of ducts or an equipment room? | Yes |
| 3 | Are large volumes of fresh air required in the zone? | Yes |
| F1 | Is dust a problem in the area? | No |
| F2 | Is noise control very important? | No |
| F3 | Is there stringent RH requirements in the zone? | No |
| F4 | Is cooling equipment allowed on the outside of the building (walls, windows or roof). | Yes |
| F5 | Is cooling equipment acceptable in occupied zones? | Yes |
| F6 | Is maintenance acceptable in occupied zones? | No |
| C1 | Is a large cooling load necessary? | No |
| C2 | Is the building a small low-rise building? | Yes |
| P1 | Are large volumes of fresh air required in the zone? | Yes |

| | | |
|---|---|---|
| P3 | Is there water for a cooling tower? | Yes |
| P4 | Is there a distance between the equipment room and space for the installation of condenser cooling equipment? | No |
| P5 | Must the system be selected for the lowest initial cost or the lowest 20-year life-cycle cost? | Lowest life cycle cost |

| | |
|---|---|
| **Selected** | Direct expansion cooling - Package unit with full fresh air and water cooling |
| **Installed** | Direct expansion cooling - Package unit with economiser and air cooling |

**Discussion**

The selected and installed systems are  not totally the same. This decision can be defended on the following grounds:

1. The following systems are not recommended because large volumes of air are required:
   - All water systems.
   - Window-mounted units.
   - Through-the-wall units.
   - Split units.
2. The following systems are not recommended because maintenance is not allowed in occupied zones:
   - Small evaporative coolers.
   - Air-water systems.
3. An all air system may be a slight overkill if a large cooling load is not required.
4. The following systems are recommended for this application.
   - Large evaporative cooler with ducted air supply.
   - Package units.
5. The knowledge base cannot distinguish between small through-the-wall evaporative coolers and large evaporative coolers with ducted air supply.
6. This can be rectified by redirecting the questioning to the Y group of questions and modifying this group to make it possible to discern between these types of evaporative coolers.
7. A package unit is therefore selected because of this problem.
8. Full fresh air supply is selected because of the large fresh air demand.
9. Water cooling is selected because it is more effective than air cooling. This is important to ensure the lowest 20-year life-cycle cost is achieved.

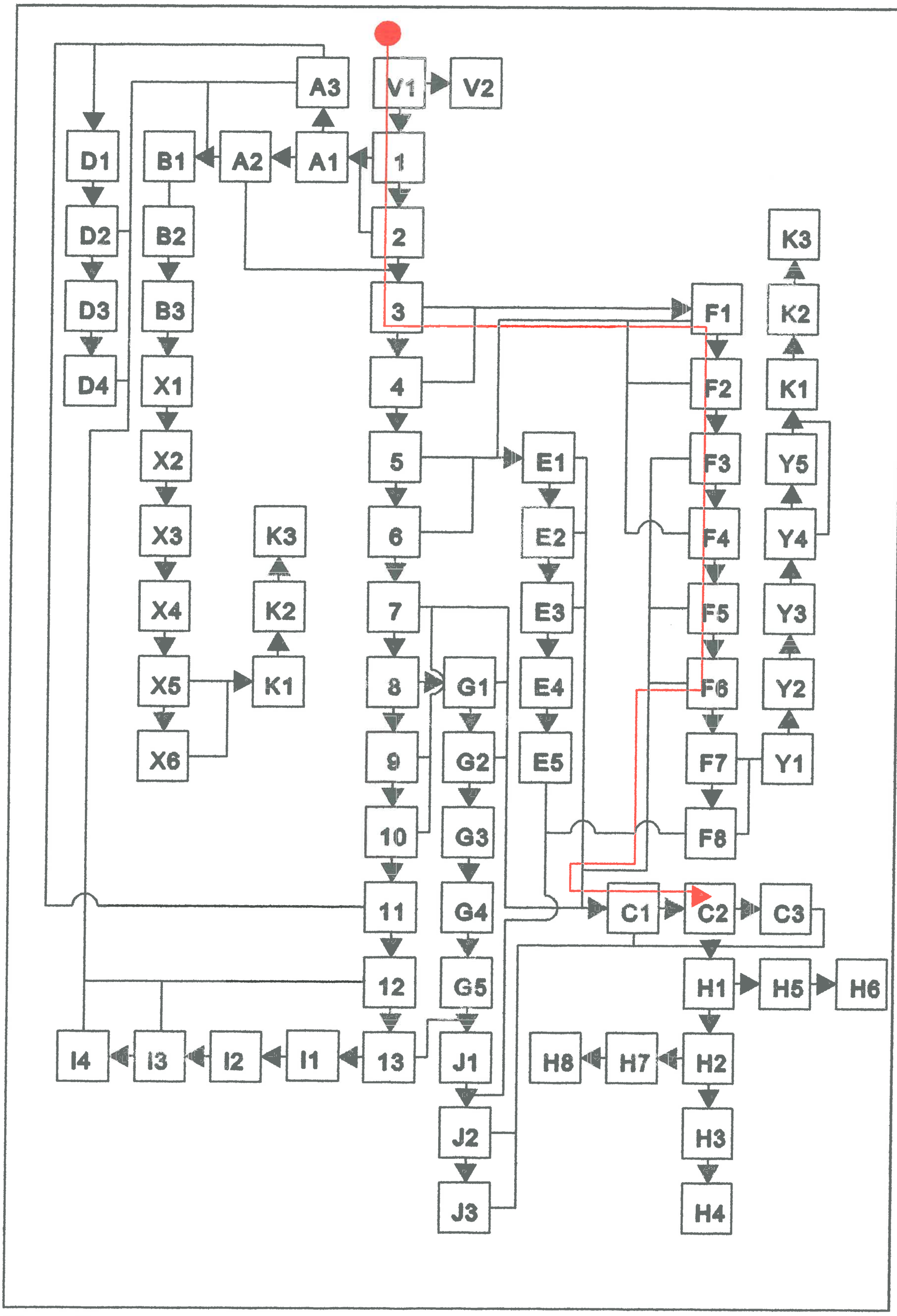


**Figure 41** First National Bank selection path

# MMA Office, Vanderbijlpark

## Introduction

The following information was used to select the system:

- The system was installed as a retrofit.
- There is no space to install ducts.
- There is no space for an equipment room to install cooling equipment.
- The building is a low-rise building.
- The building is an office building.
- The building consists of several small zones.
- Dust is not a problem.
- It is not necessary to keep the building under a positive or negative pressure.
- Maintenance and cooling equipment in occupied zones is allowed.
- It is not necessary to supply large volumes of fresh air.
- Cooling equipment is aesthetically allowed on the outside of the building.
- A small cooling load is required.
- Noise control is not very important.
- There is water for a cooling tower.
- The space for the condenser cooling equipment is close to the cooling equipment.
- The design emphasis is on lowest initial costs.

## Selection

| | | |
|---|---|---|
| V1 | Is only ventilation needed? | No |
| 1 | Is the system for a new building or for a retrofit? | Retrofit |
| A1 | Is there space for the installation of ducting? | No |
| A3 | Is there room for cooling equipment in the building, on the roof or on the out side of the building? | No |
| B1 | Are there non-perimeter zones in the building that have to be cooled? | No |
| B2 | Can and may cooling equipment be installed in the windows or through a wall? | No |

| | |
|---|---|
| **Selected** | Direct expansion cooling - Split unit |
| **Installed** | Direct expansion cooling - Split unit |

**Discussion**

The selected and installed systems are the same. This decision can be defended on the following grounds:

1. The following systems are not recommended because there is not space for ducts or an equipment room:
   - All water systems.
   - All air systems.
   - Air-water systems.
   - Large evaporative cooler with ducted air supply.
   - Large package units.
2. The following systems are not recommended because the windows are too small to install cooling equipment.
   - Window-mounted units.
   - Small evaporative coolers.
3. The following systems are recommended in this application.
   - Split units.
   - Small vertical package units.
   - Through-the-wall unit.
4. The knowledge base cannot distinguish between small vertical package units and large package units with ducted air supply.
5. This can be rectified by modifying the B group of questions to make it possible to distinguish between these types of package units.
6. A split unit is therefore selected because of this problem.
7. This is not a problem because the cooling load is so small that a vertical package unit would have been inappropriate.

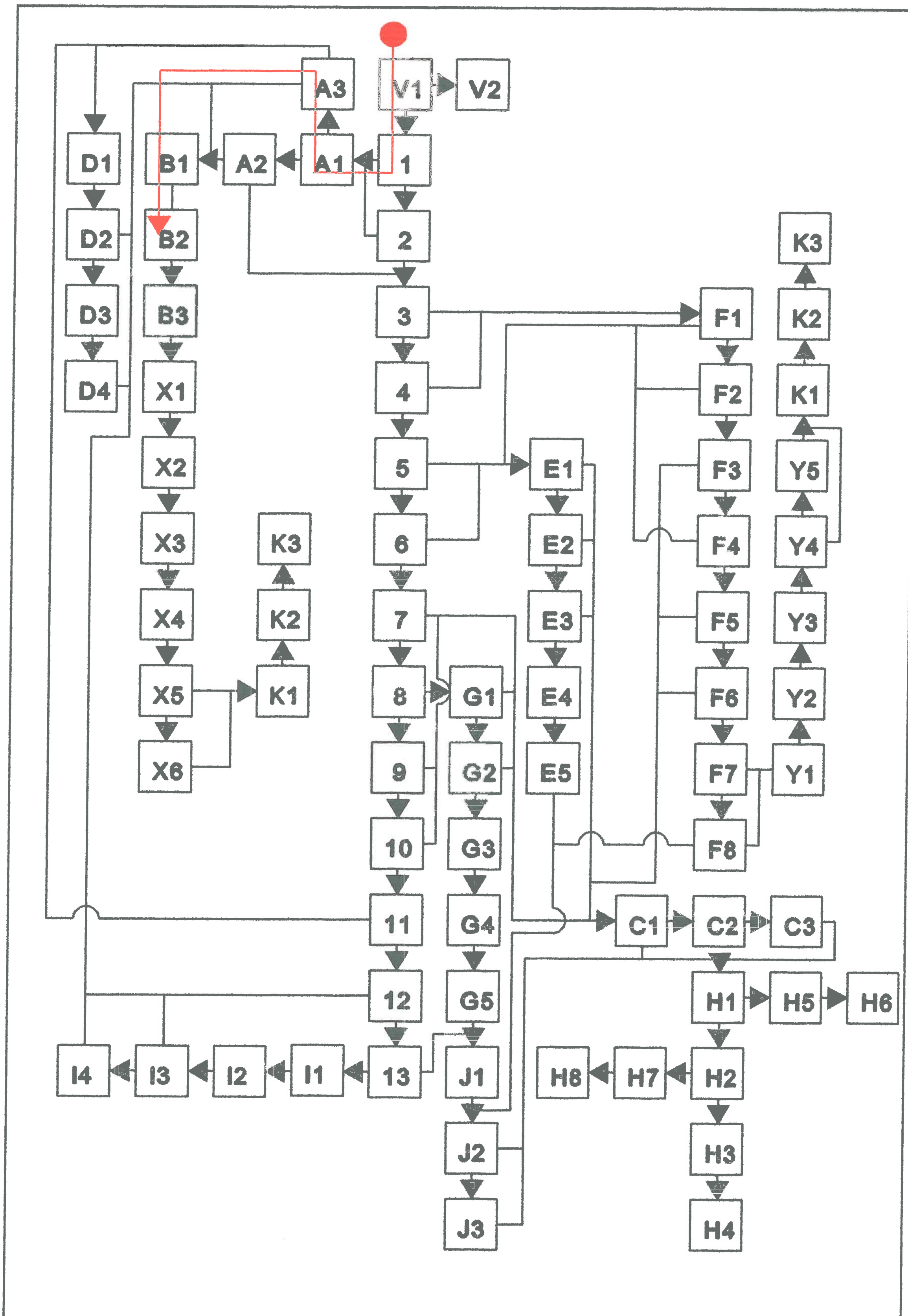


**Figure 42** MMA selection path

## Cold Mills South Change House, ISCOR Vanderbijlpark

### Introduction

The following information was used to select the system:

- The system was installed as a retrofit.
- There is no space to install ducts.
- There is no space for an equipment room to install cooling equipment.
- The building is a low-rise building.
- The building is a change house.
- The building consists of one zone.
- Dust is a bit of a problem.
- It is not necessary to keep the building under a positive or negative pressure.
- Maintenance and cooling equipment in occupied zones is allowed.
- It is necessary to supply large volumes of fresh air.
- Cooling equipment is aesthetically allowed on the outside of the building.
- No cooling load is required.
- Noise control is not very important.
- There is water for a cooling tower.
- There is a humidity problem when the people shower.
- There is an odour problem.
- The building is inside a factory.
- The design emphasis is on lowest initial costs.

### Selection

| | | |
|---|---|---|
| V1 | Is only ventilation needed? | Yes |
| V2 | Is it possible to use natural ventilation? | No |

| | |
|---|---|
| **Selected** | Mechanical ventilation |
| **Installed** | Mechanical ventilation - Extractor fan |

### Discussion

The selected and installed systems are the same. This decision can be defended on the following grounds:

1. Only large volumes of fresh are required in the zone.
2. It is not possible to use natural ventilation.

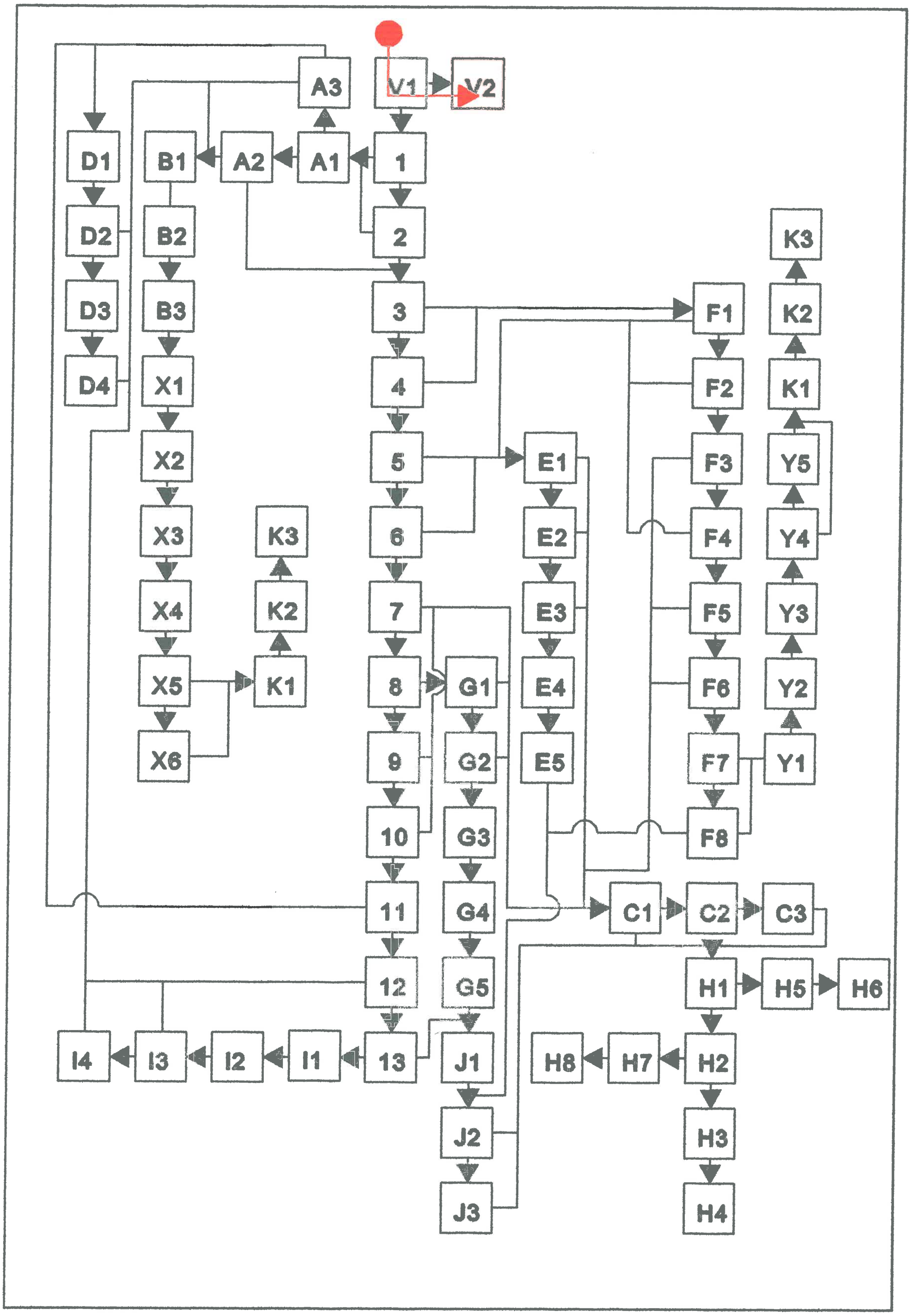


**Figure 43** Cold Mills South Change House selection path

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

# Cold Mills South Administration Building, ISCOR Vanderbijlpark

## Introduction

The following information was used to select the system:

- The system was installed as a retrofit.
- There is no space to install ducts.
- There is no space for cooling equipment in the building.
- The building is a low-rise building.
- The building is an office building.
- Dust is a small problem.
- The building consists of a large number of small perimeter zones.
- It is not necessary to keep the building under a positive or negative pressure.
- Maintenance and cooling equipment in occupied zones is allowed.
- It is not necessary to supply large volumes of fresh air.
- Cooling equipment is aesthetically allowed on the outside of the building.
- A small cooling load is required.
- Noise control is not very important.
- There is water for a cooling tower.
- The space for the condenser cooling equipment is close to the cooling equipment.
- The design emphasis is on lowest initial costs.

## Selection

| | | |
|---|---|---|
| V1 | Is only ventilation needed? | No |
| 1 | Is the system for a new building or for a retrofit? | Retrofit |
| A1 | Is there space for the installation of ducting? | No |
| A3 | Is there room for cooling equipment in the building, on the roof or on the outside of the building? | No |
| B1 | Are there non-perimeter zones in the building that have to be cooled? | No |
| B2 | Can and may cooling equipment be installed in the windows or through the walls? | Yes |
| B3 | Must the cooling equipment be aesthetically pleasing? | No |
| X1 | Is the outdoor RH high? | No |
| X2 | Is there water for an evaporative cooler? | Yes |
| X3 | Is the Rh in the zone high? | No |
| X4 | Is dust a problem in the area? | Yes |

| | |
|---|---|
| **Selected** | Direct expansion cooling - Split unit system or window-mounted units |
| **Installed** | Direct expansion cooling - Split unit system and window-mounted units |

**Discussion**

The selected and installed systems are the same. This decision can be defended on the following grounds:

1. The following systems are not recommended because there is no space for ducts or an equipment room:
   - All water systems.
   - All air systems.
   - Air-water systems.
   - Large evaporative coolers with ducted air supply.
   - Large package units.
2. The following systems are not recommended because dust is a problem.
   - Small evaporative coolers.
3. The following systems are recommended in this application.
   - Split units.
   - Window-mounted units
   - Through-the-wall units.
   - Small vertical package units.
4. The knowledge base cannot distinguish between a small vertical package unit and a large package with ducted air supply.
5. This can be rectified by modifying the B group of questions to make it possible to distinguish between these types of package units.
6. A split unit or WMU is therefore selected because of this problem.

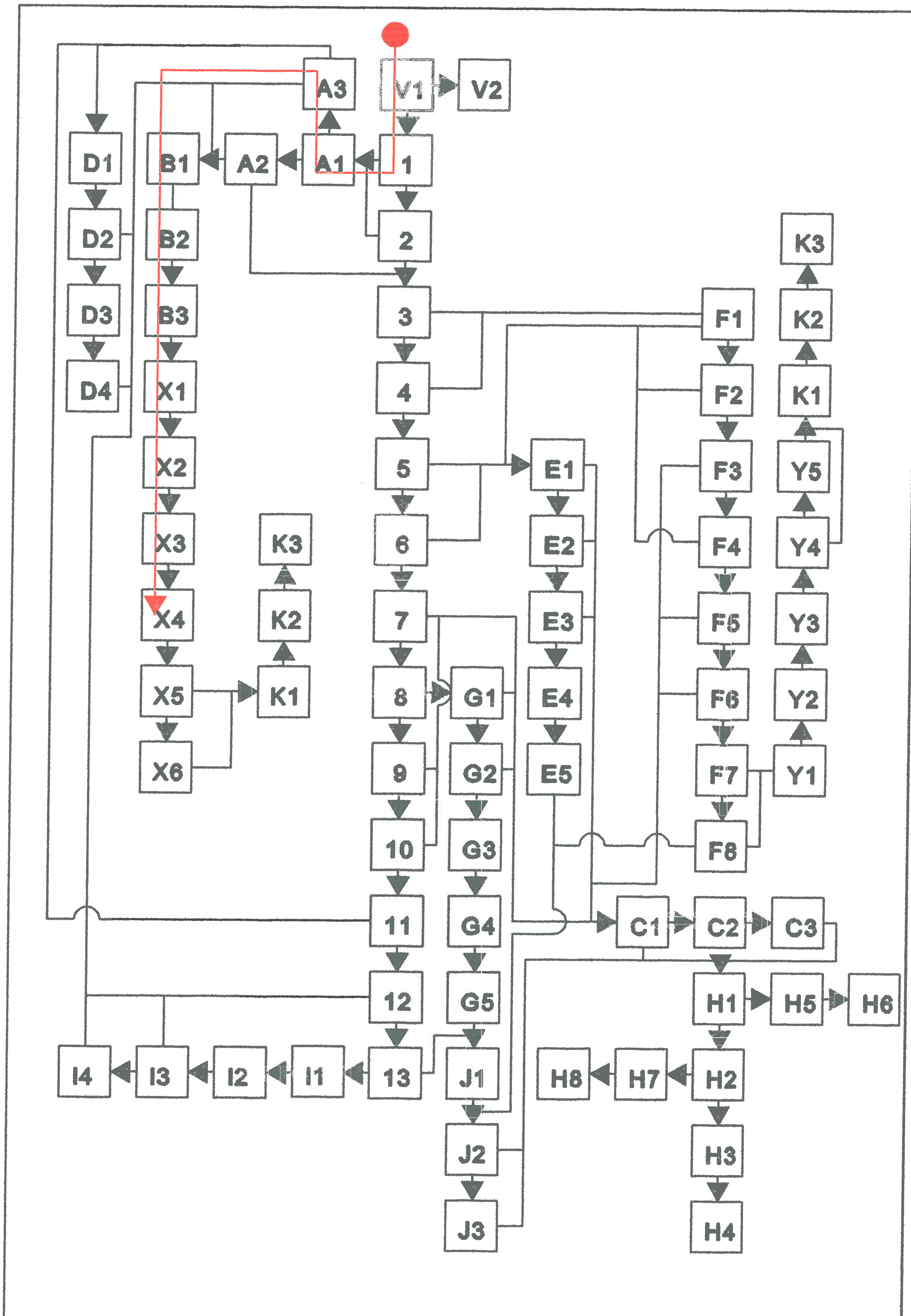


Figure 44 Cold Mills South administration building selection path.

# Main Administration Building, ISCOR Vanderbijlpark

## Introduction

The following information was used to select the system:

- The system was installed as a retrofit.
- There is space to install ducts.
- There is space for an equipment room to install cooling equipment.
- The building is a medium-rise building.
- The building is an office building.
- The building consists of a large number of small zones. Most of them are on the perimeter.
- Dust is a bit of a problem.
- It is not necessary to keep the building under a positive or negative pressure.
- Maintenance and cooling equipment in occupied zones is not allowed.
- It is not necessary to supply large volumes of fresh air.
- Cooling equipment is aesthetically allowed on the outside of the building.
- A large cooling load is required.
- Noise control is not very important.
- There is water for a cooling tower.
- The space for the condenser cooling equipment is close to the cooling equipment.
- The design emphasis is on lowest life-cycle costs.

## Selection

| | | |
|---|---|---|
| V1 | Is only ventilation needed? | No |
| 1 | Is the system for a new building or for a retrofit? | Retrofit |
| A1 | Is there space for the installation of ducting? | Yes |
| A2 | Is there room for cooling equipment in the building, on the roof or on the outside of the building? | Yes |
| 3 | Are large volumes of fresh air required in the zone? | No |
| 4 | Should the system provide + or - pressure in the zone | No |
| 5 | Is dust a problem in the area? | Yes |
| E1 | Is there stringent RH requirements in the zone? | No |
| E2 | Is cooling equipment acceptable in occupied zones? | Yes |
| E3 | Is maintenance allowed in occupied zones? | Yes |
| E4 | Is the building a small low-rise building? | No |
| E5 | Should the system be selected for the lowest initial cost or the lowest 20-year life cycle cost? | Lowest life-cycle cost |

| | | |
|---|---|---|
| J2 | Are there a small number of large open plan zones? | No |
| J3 | Are most of the zones perimeter zones? | Yes |
| H1 | Is there limited space to install ducts? | No |
| H2 | Is there big differences between temperature in different zones? | Yes |
| H7 | Is noise control very important? | Yes |
| P1 | Are large volumes of fresh air required in the zone? | No |
| P2 | Should the system be selected for the lowest initial cost or the lowest 20-year life cycle cost? | Lowest life-cycle cost |
| P3 | Is there water for a cooling tower? | Yes |
| P4 | Is there a distance between the equipment room and space for the installation of condenser cooling equipment? | Yes |

| | |
|---|---|
| **Selected** | Chilled water system - Air-water constant volume variable temperature system with economiser, low velocity ducts and water cooling. |
| **Installed** | Direct expansion - Split unit system plus a fresh air ventilation system. |

**Discussion**

The selected and installed systems are not the same. This decision can be defended on the following grounds:

1. The following systems are not recommended because dust is a problem.
   - Split units.
   - Window-mounted units.
   - Through-the-wall units.
   - Small vertical package units.
   - Small evaporative coolers.
   - All water systems.
2. The following systems are recommended for this application.
   - All air systems.
   - Air-water systems
3. The Air-water system is selected because it is ideally suited for perimeter zones.
4. The lowest 20-year life-cycle cost selection choice has several effects. The following selections are accordingly made:
   - Water cooling of condenser equipment.
   - Low velocity ducts.
   - The use of an economiser.
   - The use of a constant volume variable temperature system.
5. The knowledge base does not take hybrid system into account.

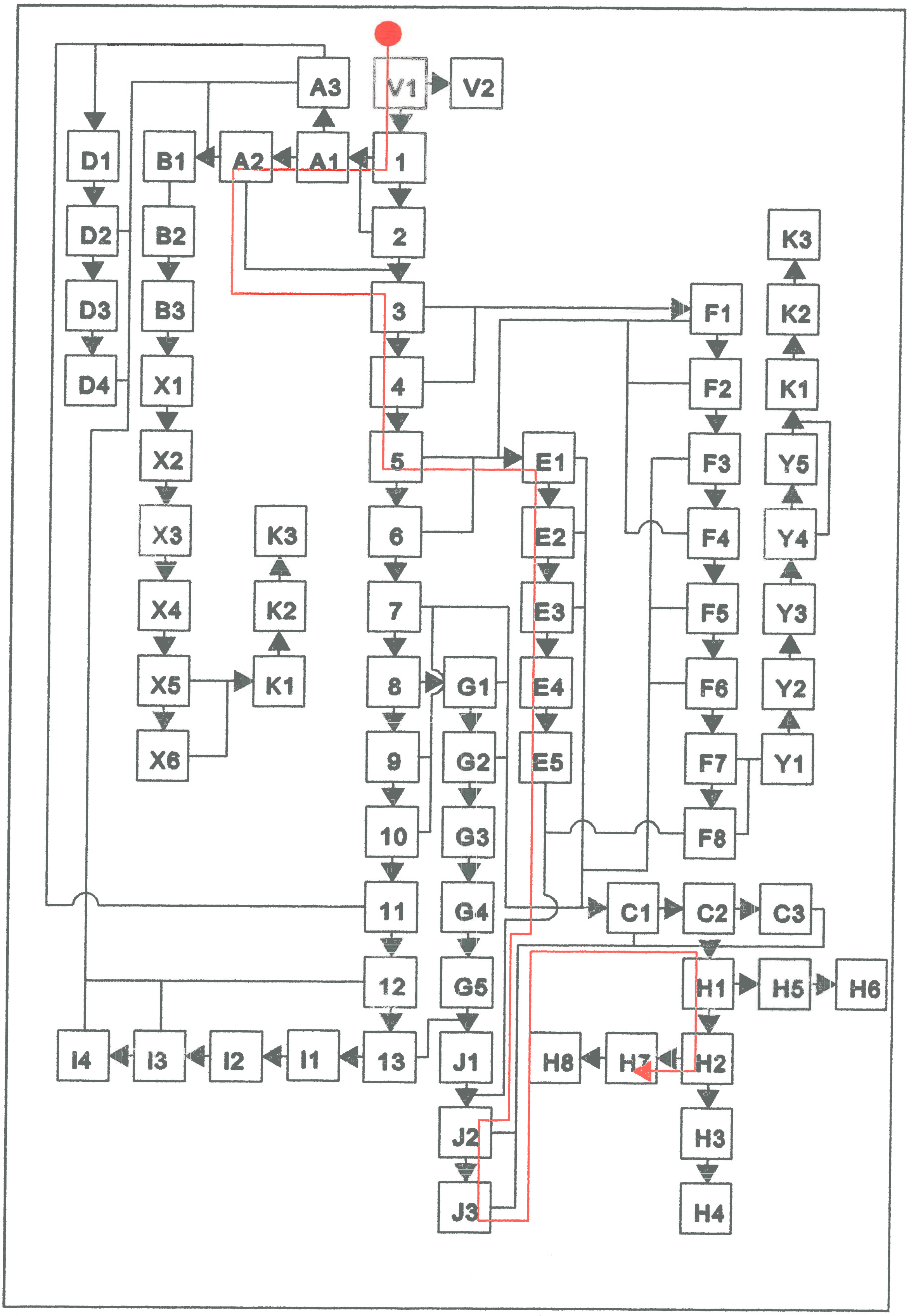


Figure 45 Main administration building selection path

## Paint Line Painting Section, ISCOR Vanderbijlpark

### Introduction

The following information was used to select the system:

- The system was installed as a retrofit.
- There is space to install ducts.
- There is space for an equipment room to install cooling equipment.
- The building is a low-rise building.
- The building is a factory.
- The building consists of a large zone.
- Dust is a bit of a problem.
- It is not necessary to keep the building under a positive or negative pressure.
- Maintenance and cooling equipment in occupied zones is allowed.
- It is necessary to supply large volumes of fresh air.
- Cooling equipment is aesthetically allowed on the outside of the building.
- A large cooling load is required.
- Noise control is not very important.
- There is water for a cooling tower.
- The space for the condenser cooling equipment is close to the cooling equipment.
- The design emphasis is on lowest life-cycle costs.

### Selection

| | | |
|---|---|---|
| V1 | Is only ventilation needed? | No |
| 1 | Is the system for a new building or for a retrofit? | Retrofit |
| A1 | Is there space for the installation of ducting? | Yes |
| A2 | Is there room for cooling equipment in the building, on the roof or on the outside of the building? | Yes |
| 3 | Are large volumes of fresh air required in the zone? | Yes |
| F1 | Is dust a problem in the area? | Yes |
| E1 | Is there stringent RH requirements in the zone? | Yes |
| C1 | Is a large cooling load necessary? | Yes |
| H1 | Is there limited space to install ducts? | No |
| H2 | Is there big differences between temperature in different zones? | No |
| H3 | Is noise control very important? | No |
| H4 | Must the system be selected for the lowest initial cost or the lowest 20-year life-cycle cost? | Lowest life-cycle cost |
| P1 | Are large volumes of fresh air required in the zone? | Yes |

| | | |
|---|---|---|
| P3 | Is there water for a cooling tower? | Yes |
| P4 | Is there a distance between the equipment room and space for the installation of condenser cooling equipment? | No |
| P5 | Must the system be selected for the lowest initial cost or the lowest 20-year life-cycle cost? | Lowest life-cycle cost |

| | |
|---|---|
| **Selected** | Chilled water system - All air variable air volume system with full fresh air, low velocity ducts and water cooling. |
| **Installed** | Chilled water system - All air constant volume variable temperature system with full fresh air, low velocity ducts and air cooling. |

**Discussion**

The selected and installed systems are not totally the same. This decision can be defended on the following grounds:

1. The following systems are not recommended because large volumes of air are required:
   - All water systems.
   - Window-mounted units.
   - Through-the-wall units.
   - Split units.
2. The following systems are not recommended because stringent Rh control is needed.
   - Small evaporative coolers.
   - Large evaporative coolers with ducted air supply.
   - Air-water systems.
3. The following systems are recommended for this application.
   - All air systems.
   - Package units.
4. An all air system is selected because a large cooling load is required.
5. Full fresh air supply is selected because of the large fresh air demand.
6. Water cooling, low velocity ducts and the variable air volume are selected to ensure the lowest 20-year life-cycle cost is achieved.

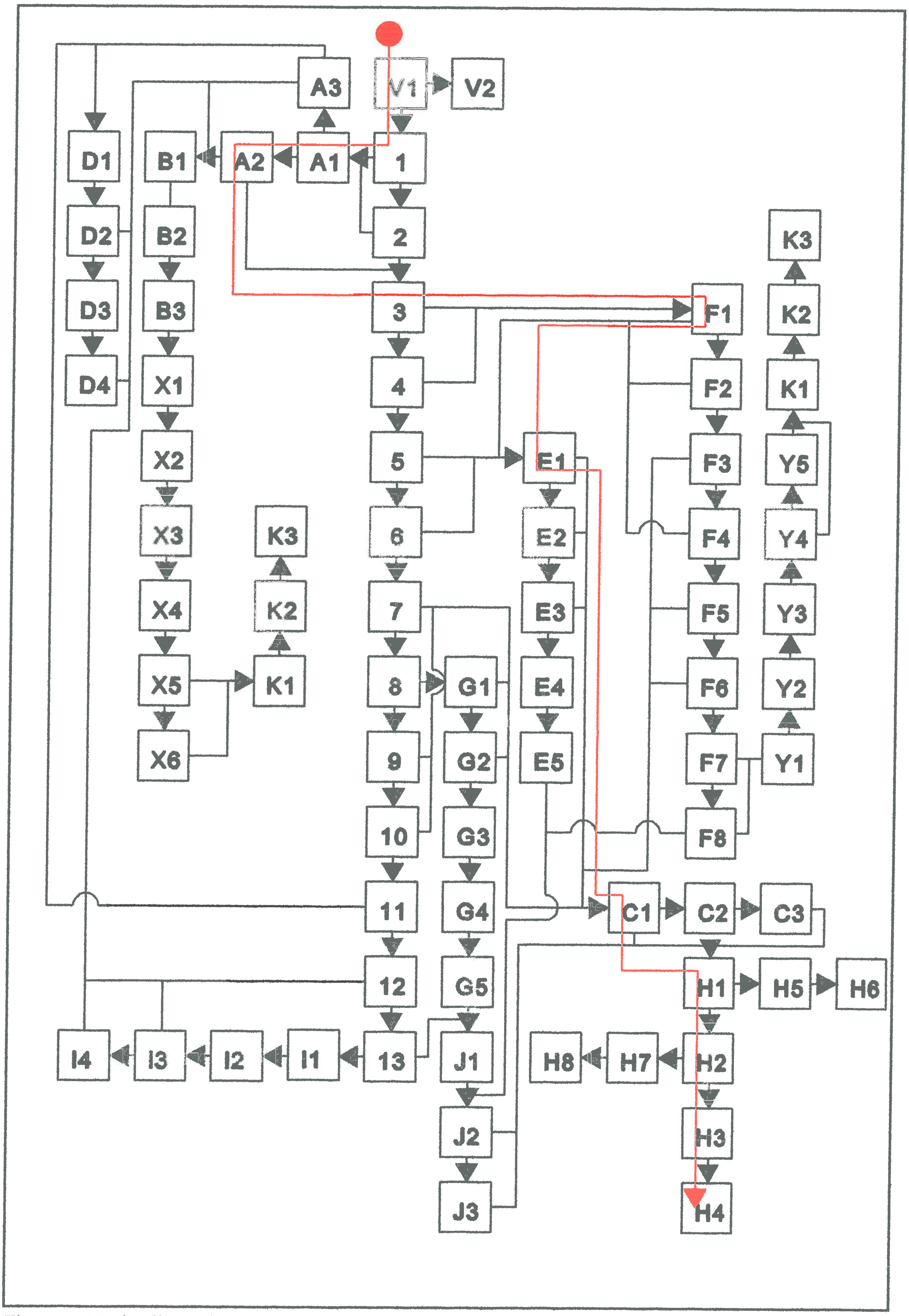


**Figure 46** Paint line selection path

# Data Centre, Computer Room, ISCOR Vanderbijlpark

## Introduction

The following information was used to select the system:

- The system was installed when the building was erected.
- There is space to install ducts.
- There is space for an equipment room to install cooling equipment.
- The building is a low-rise building.
- The building houses a computer room.
- The computer room consists of a large zone.
- Dust is a bit of a problem.
- It is necessary to keep the building under a positive pressure.
- Maintenance and cooling equipment in occupied zones is allowed.
- It is not necessary to supply large volumes of fresh air.
- Cooling equipment is aesthetically allowed on the outside of the building.
- A large cooling load is required.
- Noise control is not very important.
- There is water for a cooling tower.
- The space for the condenser cooling equipment is close to the cooling equipment.
- The design emphasis is on lowest life-cycle costs.

## Selection

| | | |
|---|---|---|
| V1 | Is only ventilation needed? | No |
| 1 | Is the system for a new building or for a retrofit? | New building |
| 2 | Is there space for the installation of ducts or an equipment room? | Yes |
| 3 | Are large volumes of fresh air required in the zone? | No |
| 4 | Should the system provide + or - pressure in the zone | Yes |
| F1 | Is dust a problem in the area? | Yes |
| E1 | Is there stringent RH requirements in the zone? | Yes |
| C1 | Is a large cooling load necessary? | Yes |
| H1 | Is there limited space to install ducts? | No |
| H2 | Is there big differences between temperature in different zones? | No |
| H3 | Is noise control very important? | No |
| H4 | Should the system be selected for the lowest initial cost or the lowest 20-year life-cycle cost? | Lowest life-cycle cost |
| P1 | Are large volumes of fresh air required in the zone? | No |

| | | |
|---|---|---|
| P2 | Should the system be selected for the lowest initial cost or the lowest 20-year life-cycle cost? | Lowest life-cycle cost |
| P3 | Is there water for a cooling tower? | Yes |
| P4 | Is there a distance between the equipment room and space for the installation of condenser cooling equipment? | No |
| P5 | Should the system be selected for the lowest initial cost or the lowest 20-year life-cycle cost? | Lowest life-cycle cost |

| | |
|---|---|
| **Selected** | Chilled water system - All air variable air volume system with economiser, low velocity ducts and water cooling. |
| **Installed** | Chilled water system - All air constant volume variable temperature system with economiser, low velocity ducts and water cooling plus all water system with water cooling |

**Discussion**

The selected and installed systems are not totally the same. This decision can be defended on the following grounds:

1. The following systems are not recommended because they cannot provide the zone with positive pressure.
   - Split units.
   - Window-mounted units.
   - Through-the-wall units.
   - Small evaporative coolers.
   - All water systems.
2. The following system is not recommended because stringent Rh control is necessary.
   - Air-water systems.
3. The following systems are recommended for this application.
   - All air systems.
   - Package units.
4. The all air system is selected because a large cooling load is required.
5. The lowest 20-year life-cycle cost selection choice has several effects. The following selections are accordingly made:
   - Water cooling of condenser equipment.
   - Low velocity ducts.
   - The use of an economiser.
   - The use of a variable air volume system.
6. The knowledge base does not take hybrid system into account.

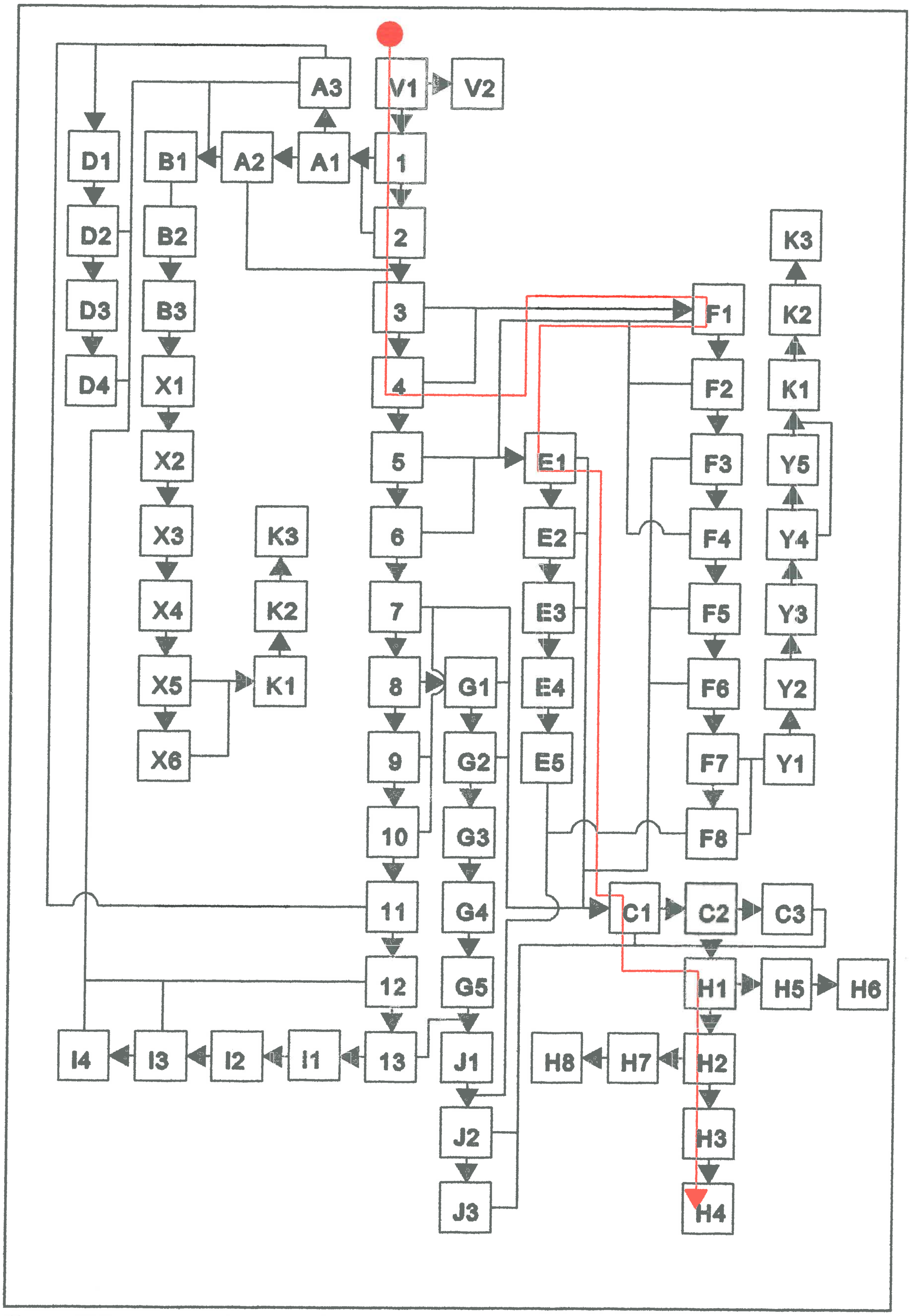


**Figure 47** Data centre selection path

# Direct Reduction Control Room, ISCOR Vanderbijlpark

## Introduction

The following information was used to select the system:

- The system was installed when the building was erected.
- There is space to install ducts.
- There is space for an equipment room to install cooling equipment.
- The building is a high-rise building.
- The building houses a control room.
- The control room consists of a large zone.
- Dust is a bit of a problem.
- It is necessary to keep the building under a positive pressure.
- Maintenance and cooling equipment in occupied zones is allowed.
- It is not necessary to supply large volumes of fresh air.
- Cooling equipment is aesthetically allowed on the outside of the building.
- A medium cooling load is required.
- Noise control is not very important.
- There is water for a cooling tower.
- The space for the condenser cooling equipment is close to the cooling equipment.
- The design emphasis is on lowest life-cycle costs.

## Selection

| | | |
|---|---|---|
| V1 | Is only ventilation needed? | No |
| 1 | Is the system for a new building or for a retrofit? | New building |
| 2 | Is there space for the installation of ducts or an equipment room? | Yes |
| 3 | Are large volumes of fresh air required in the zone? | No |
| 4 | Must the system provide + or - pressure in the zone | Yes |
| F1 | Is dust a problem in the area? | Yes |
| E1 | Is there stringent RH requirements in the zone? | Yes |
| C1 | Is a large cooling load necessary? | No |
| C2 | Is the building a small low-rise building? | No |
| C3 | Should the system be selected for the lowest initial cost or the lowest 20-year life-cycle cost? | Lowest life-cycle cost |
| H1 | Is there limited space to install ducts? | No |
| H2 | Is there big differences between temperature in different zones? | No |
| H3 | Is noise control very important? | No |

| | | |
|---|---|---|
| H4 | Should the system be selected for the lowest initial cost or the lowest 20-year life-cycle cost? | Lowest life-cycle cost |
| P1 | Are large volumes of fresh air required in the zone? | No |
| P2 | Should the system be selected for the lowest initial cost or the lowest 20-year life-cycle cost? | Lowest life-cycle cost |
| P3 | Is there water for a cooling tower? | Yes |
| P4 | Is there a distance between the equipment room and space for the installation of condenser cooling equipment? | No |
| P5 | Should the system be selected for the lowest initial cost or the lowest 20-year life-cycle cost? | Lowest life-cycle cost |

| | |
|---|---|
| **Selected** | Chilled water system - All air variable air volume system with economiser, low velocity ducts and water cooling. |
| **Installed** | Chilled water system - All air constant volume variable temperature system with economiser, low velocity ducts and water cooling. |

**Discussion**

The selected and installed systems are not exactly the same. This decision can be defended on the following grounds:

1. The following systems are not recommended because they cannot provide the zone with positive pressure.
   - Split units.
   - Window-mounted units.
   - Through-the-wall units.
   - Small evaporative coolers.
   - All water systems.
2. The following system is not recommended because stringent Rh control is necessary.
   - Air-water systems.
3. The following systems are recommended for this application.
   - All air systems.
   - Package units.
4. The all air system is selected because the lowest life-cycle cost is required.
5. The lowest 20-year life-cycle cost selection choice has several effects. The following selections are accordingly made:
   - Water cooling of condenser equipment.
   - Low velocity ducts.
   - The use of an economiser.
   - The use of a variable air volume system.

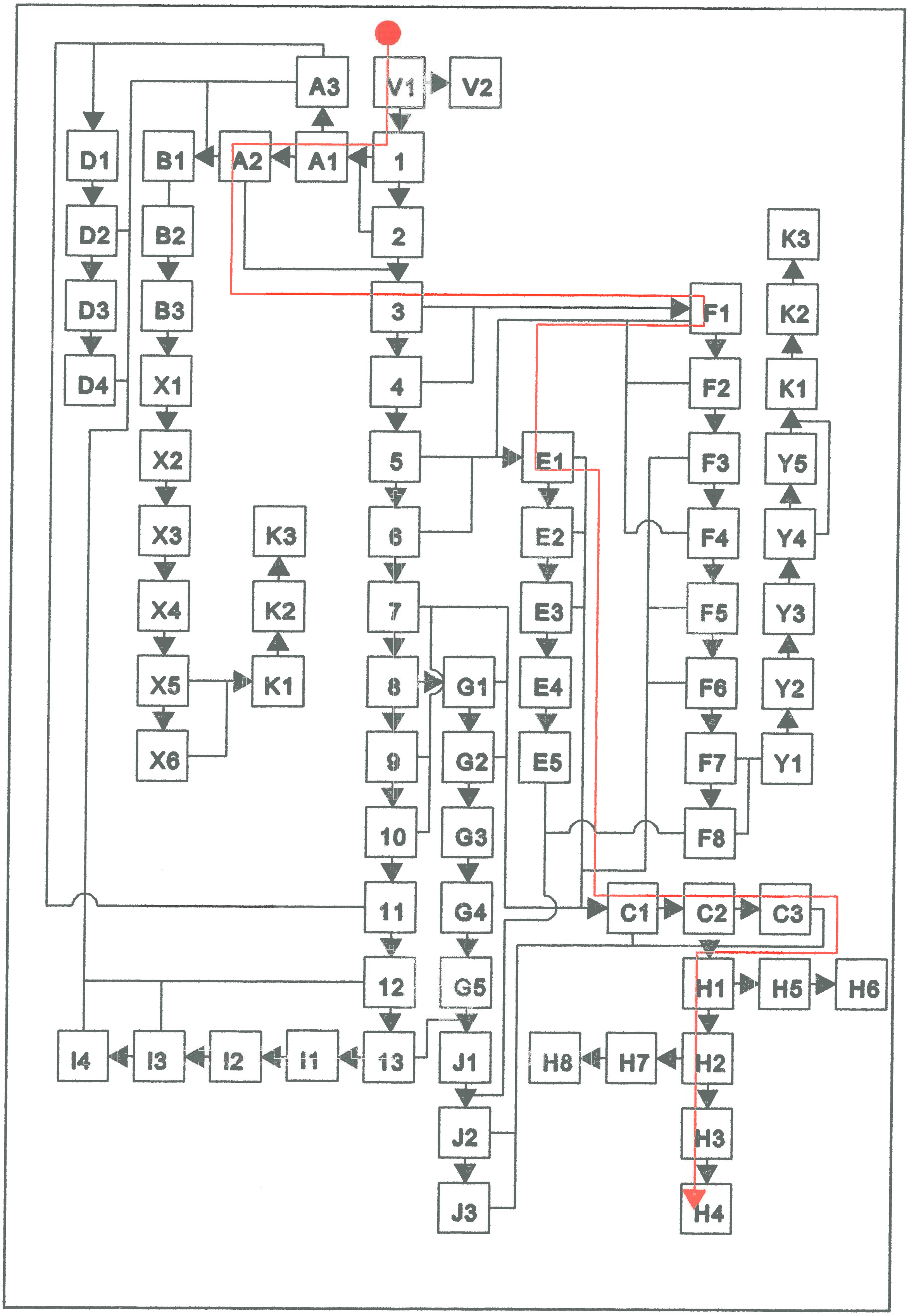


Figure 48 Direct reduction control room selection path

# Neonatal Unit, Medivaal Hospital Vanderbijlpark

## Introduction

The following information was used to select the system:

- The system was installed when the building was erected.
- There is space to install ducts.
- There is space for an equipment room to install cooling equipment.
- The building is a low-rise building.
- The building houses a neonatal unit.
- The neonatal unit is an intensive care unit for babies.
- The unit consists of a small zone.
- It is necessary to keep the unit under a positive pressure.
- Maintenance and cooling equipment in occupied zones is not allowed.
- It is necessary to supply large volumes of fresh air.
- Cooling equipment is aesthetically allowed on the outside of the building.
- A small cooling load is required.
- Noise control is important.
- There is water for a cooling tower.
- The space for the condenser cooling equipment is close to the cooling equipment.
- The design emphasis is on lowest life-cycle costs.

## Selection

| | | |
|---|---|---|
| V1 | Is only ventilation needed? | No |
| 1 | Is the system for a new building or for a retrofit? | New building |
| 2 | Is there space for the installation of ducts or an equipment room? | Yes |
| 3 | Are large volumes of fresh air required in the zone? | Yes |
| F1 | Is dust a problem in the area? | No |
| F2 | Is noise control very important | Yes |
| E1 | Is there stringent RH requirements in the zone? | Yes |
| C1 | Is a large cooling load necessary? | No |
| C2 | Is the building a small low-rise building? | Yes |
| P1 | Are large volumes of fresh air required in the zone? | Yes |
| P3 | Is there water for a cooling tower? | Yes |
| P4 | Is there a distance between the equipment room and space for the installation of condenser cooling equipment? | No |
| P5 | Must the system be selected for the lowest initial cost or the lowest 20-year life-cycle cost? | Lowest life-cycle cost |

| | |
|---|---|
| **Selected** | Direct expansion - Package unit system with full fresh air and water cooled. |
| **Installed** | Direct expansion - Split unit system plus a fresh air ventilation system. |

**Discussion**

The selected and installed systems are not the same. This decision can be defended on the following grounds:

1. The following systems are not recommended because they cannot provide the zone with large volumes of fresh air and positive pressure.
   - Split units.
   - Window-mounted units.
   - Through-the-wall units.
   - All water systems.
2. The following system is not recommended because stringent RH control is necessary.
   - Air-water systems.
   - Evaporative coolers.
3. The following systems are recommended for this application.
   - All air systems.
   - Package units.
4. The package unit is selected because of the small load required.
5. Water cooling is selected to insure that the lowest 20-year life-cycle cost is achieved.

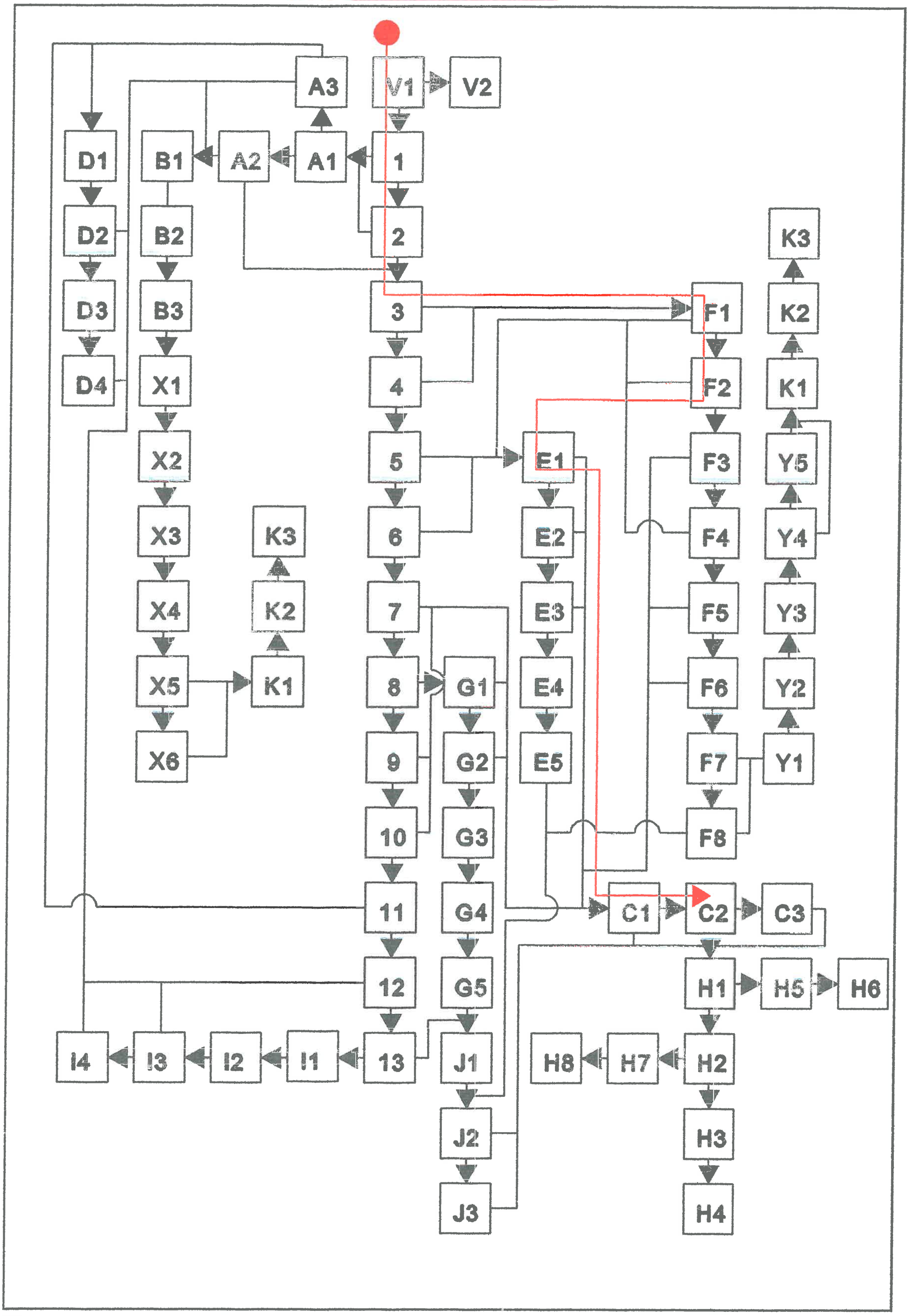


**Figure 49** Medivaal neonatal unit selection path

## 6.3 Conclusion

The module gives realistic answers in each of the ten case studies. Differences between the program and the systems installed in the existing buildings can in some cases be contributed to personal preferences of the person who selected the system. Some of the smaller differences can be attributed to a different design emphasis. An example is the use of air cooling instead of water cooling. This is because the designer selected a system for lowest initial cost instead of lowest life-cycle cost. Differences may also result from different interpretations of a question. A number of problems were identified in the case studies. The selection module does not take hybrid system into account and cannot distinguish between small vertical package units, large package units with ducted air supply and large evaporative coolers with ducted air supply.

The output interface was very successful in that it is very easy to understand. The output gives the user a summary of all the questions asked and the answer. It also gives the characteristics, advantages and disadvantages of the system selected. The program can be used in real-time consulting work. It should make a very valuable tool for any consulting engineer, architect and air-conditioning sales representatives. The selection module program met most of the design goals specified.

After the verification of the program some small improvements to the interface can be recommended. It will be convenient to be able to go back to a question if one wants to correct a wrong answer. The summary of the selected system with all its characteristics, advantages and disadvantages should be displayed in an extra window. The program must furthermore also be incorporated into the whole design program.

# 7

# Epilogue

In the prologue environmental reasons were given why HVAC simulation programs must be used while designing air-conditioning systems. It is an unfortunate fact that most developers, designers and people usually do not care about the environment and the effect that every decision has on the future of the only habitat that they and their children have. This fact can be exploited for the good of the environment because a well designed air-conditioning system costs less and uses less energy than a poorly and overdesigned system.

One of the first questions an engineer will ask is why do I need another HVAC simulation program if there are already so many other design programs on the market. This program doesn't and cannot compete with most of the other design and simulation programs in that it cannot equal these programs' accuracy, the detail of their simulations or their nice special features and graphs.

This program only comes to its full potential in the brief and design stages of a project. At this stage of a project there is very little technical data and engineers usually use their experience to quote loads and to select a system. The program is designed to make this process more reliable and easier. One of the most important design criteria of the program was that it could be used real-time while the engineer is consulting the client. This means that it must be fast and very easy to use.

One starts with a fictional ideal package. This ideal package has several characteristics that define its uses and gives a general feeling of how the interface will look. In the design of the program and its modules one strived to achieve this ideal package. Some characteristics are unfortunately unobtainable and in other cases certain trade-offs have been made between them. This made it important to set priorities between characteristics. At the end of the project one can compare the real program with the ideal, as summarised on page 5 of the prologue. The program meets most of the criteria except that the modules do not interact with each other and the cooling load calculation does not meet the required accuracy necessary.

As can be seen there is still work to be done to achieve this ideal design package. The following is recommended to improve the design package. The cost module must be completed and then all the modules must be integrated into one design package. The linking must be done in an object-orientated manner to ensure that it is possible to start at any of the modules with a design. A Load/Save function must be incorporated into the program. The two modules that have already been written are a foundation to build on and can already be used as separate programs. There is however still some work necessary.

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# Appendix A: Knowledge Base

The detail of the knowledge base will be discussed in this appendix. The detail decision tree is shown in Figure 1. Each question in this tree is discussed using the following format:

Question index : The question ID number as used in the decision tree. See Figure 1
Previous question : List of questions calling this question

Question : The question

Purpose of question : The reason behind the question

Result parameters : Give the possible answers

Result of question : For one of the above results the following is true:

- Knowledge gained : Knowledge gained from this answer to the question
- Recommended systems : Systems that can be recommended with the knowledge gained
- Systems not recommended : Systems that cannot be recommended with the knowledge gained
- Action : Action that must be taken now
- Next question : The next question that must be called

Result of question : For the other results the following is true:

- Knowledge gained : Knowledge gained from this answer to the question
- Recommended systems : Systems that can be recommended with the knowledge gained
- Systems not recommended : Systems that cannot be recommended with the knowledge gained
- Action : Action that must be taken now
- Next question : The next question that must be called

The questions will be discussed in an alphabetical order.

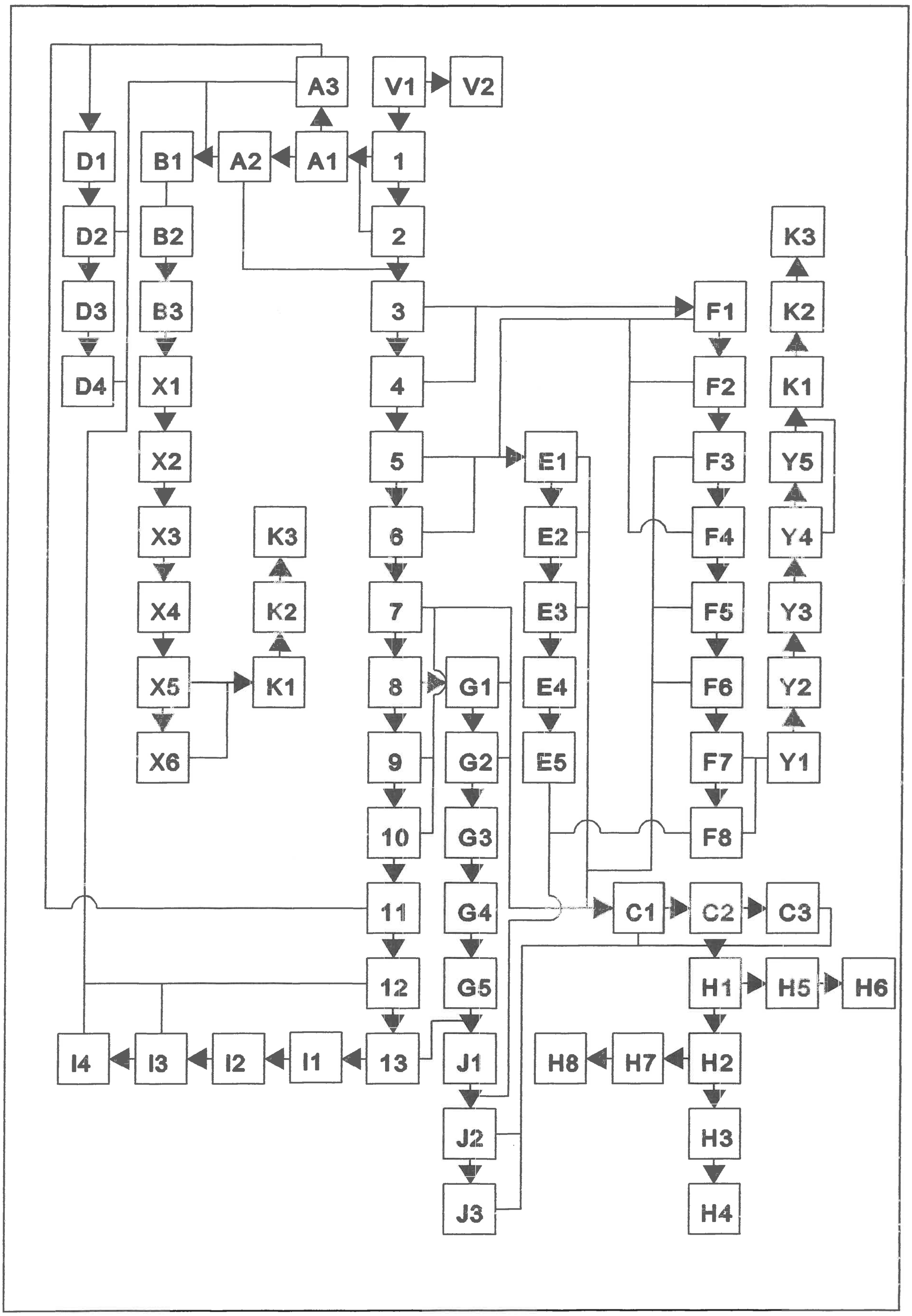


**Figure 1** Detail decision tree

# Main Question Group

## Question index : 1
## Previous question : V1

Question : Is the system for a new building or for a retrofit?

Purpose of question : There may be space limitations for the installation of ducting and cooling equipment in a retrofit. Space can be allocated for an HVAC system in a new building. Space is an important system selection parameter because some systems require ducting and central equipment rooms.

Result parameters : New building/Retrofit

Result of question : New building

| | |
|---|---|
| Knowledge gained | : Space can be allocated for ducting and cooling equipment |
| Recommended systems | : Any system |
| Systems not recommended | : None |
| Action | : Determine if the design of the building facilitates the installation of an HVAC system |
| Next question | : **2** |

Result of question : Retrofit

| | |
|---|---|
| Knowledge gained | : There may be possible space limitations for the installation of ducting and cooling equipment |
| Recommended systems | : Any system |
| Systems not recommended | : None |
| Action | : Get more information about space for ducting |
| Next question | : **A1** |

## Question index : 2
## Previous question : 1

Question : Is there space for the installation of ducts and an equipment room in the building?

Purpose of question : The design of the new building may not incorporate space for the installation of ducting and cooling equipment. This is an important parameter because some systems require ducting and central equipment rooms.

Knowledge gained in the previous questions:

- The building is a new building

Result parameters : Yes/No

Result of question : Yes

| | |
|---|---|
| Knowledge gained | : There is space for an HVAC system in the building |
| Recommended systems | : Any system |
| Systems not recommended | : None |
| Action | : Proceed with questioning |
| Next question | : **3** |

Result of question : No

| | |
|---|---|
| Knowledge gained | : Space was not allocated for the installation for HVAC equipment |
| Recommended systems | : A system with small space requirements |
| Systems not recommended | : A system with large space requirements |
| Action | : Get more information about space for ducting |
| Next question | : **A1** |

## Question index : 3
## Previous question : 2/A2

Question : Are large volumes of fresh air required in the zone?

Purpose of question : Large volumes of fresh air are needed in zones where odours are a problem. Examples of such zones are lobbies, restaurants, toilets and any zone that is occupied by smokers. Large volumes of fresh air are also needed where a large number of people get together in confined spaces. Examples of such zones are theatres, banks and other public places.

Knowledge gained in the previous questions

- The system is for a new or retrofit building
- There is no space limitation

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Large volumes of fresh air are required
Recommended systems : A system that supplies fresh air to the zone:

- Package units
- Air-water systems
- All air systems
- Evaporative cooling systems

Systems not recommended : Any system that just recirculate the air in the zone :

- Window-mounted units
- Wall-mounted units
- Split units
- All water systems

Action : Proceed with questioning to determine system that meets these requirements

Next question : **F1**

Result of question : No

Knowledge gained : Large volumes of fresh air are not required
Recommended systems : Any system
Systems not recommended : None
Action : Proceed with questioning
Next question : **4**

# Question index : 4
## Previous question : 3

Question : Must the system provide positive or negative pressures in the zone?

Purpose of question : Positive or negative pressures are required in certain applications. It is preferable to have positive pressure in computer rooms and other zones where dust entering the zone is undesirable. The positive pressure will ensure that infiltration will be from the inside of the zone. This prevents unfiltered air from entering the zone. In laboratories working with hazardous material it is preferable to have negative pressure in the zone. This prevents any hazardous gases from leaving the building through infiltration points. Laboratories usually have scrubbers in their exhaust system.

Knowledge gained in the previous questions
- The system is for a new or retrofit building
- There is no space limitation
- Large volumes of fresh air are not required in the zone

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Positive or negative pressure is required
Recommended systems : Systems that supply air to the zone:
- Package units
- Air-water systems
- All air systems
- Evaporative cooling systems

Systems not recommended : Any system that only recirculate the air in the zone
- Window-mounted units
- Wall-mounted units
- Split units
- All water systems

Action : Proceed with questioning to determine system that meets these requirements.

Next question : **F1**

Result of question : No

Knowledge gained : Positive or negative pressure is not required
Recommended systems : Any system
Systems not recommended : None
Action : Proceed with questioning
Next question : **5**

# Question index : 5
## Previous question : 4

Question : Is dust a problem in the area?

Purpose of question : It is preferable to have a central filtration system in areas where dust is a problem. This has the advantage that only one set of filters has to be cleaned regularly. Typical problem areas are offices close to foundries and open cast mines.

Knowledge gained in the previous questions

- The system is for a new or retrofit building
- There is no space limitation
- Large volumes of fresh are is not required in the zone
- Positive or negative pressure is not required

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Dust is a problem in the area
Recommended systems : Any system with a centralised filtration system:

- Package units
- All air systems
- Air-water systems

Systems not recommended : Any system that does not have a centralised filtration system:

- Window-mounted units
- Wall-mounted units
- Split units
- Air-water systems
- Evaporative cooling systems

Action : Proceed with questioning to determine a system that meets these requirements
Next question : **E1**

Result of question : No

Knowledge gained : Dust is not a problem
Recommended systems : Any system
Systems not recommended : None
Action : Proceed with questioning
Next question : 6

## Question index : 6
## Previous question : 5

Question : Is noise control very important?

Purpose of question : It is preferable that noise be kept as low as possible. Low-noise cooling systems are better for office buildings and theatres but usually a lot more expensive. Systems with cooling equipment in the zone are noisier than the other types of systems.

Knowledge gained in the previous questions

- The system is for a new or retrofit building
- There is no space limitation
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Noise control is very important
Recommended systems : Systems that have centralised cooling equipment:
- Package units
- All air systems
- Air-water systems

Systems not recommended : Any system with cooling equipment in the zone:
- Window-mounted units
- Wall-mounted units
- Split units
- Air-water system
- Evaporative cooling systems

Action : Proceed with questioning
Next question : **E1**

Result of question : No

Knowledge gained : Noise control is not very important
Recommended systems : Any system
Systems not recommended : None
Action : Proceed with questioning
Next question : 7

## Question index : 7
## Previous question : 6

**Question** : Are there very stringent Rh requirements in the zones?

**Purpose of question** : It is preferable to control the Rh because it affects the air quality of the air. Humidifiers and dehumidifiers are necessary to accomplish this. The added cost of these components is not always justified when the cooling load required is small.

**Knowledge gained in the previous questions**

- The system is for a new or retrofit building
- There is no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area
- Noise is not a very important consideration

**Result parameters** : Yes/No

**Result of question** : Yes

Knowledge gained : There are stringent Rh requirements.
Recommended systems : Systems that have centralised cooling equipment:

- Package units
- All air systems

Systems not recommended : Any system with cooling equipment in the zone:

- Window-mounted units
- Wall-mounted units
- Split units
- All water systems
- Evaporative cooling systems
- Air-water systems

Action : Proceed with questioning
Next question : **C1**

**Result of question** : No

Knowledge gained : Stringent Rh control is not required
Recommended systems : Any system
Systems not recommended : None
Action : Proceed with questioning
Next question : **8**

## Question index : 8
## Previous question : 7

Question : Is cooling equipment allowed on the outside of the building (walls, windows or roof)?

Purpose of question : Cooling systems installed in windows or on walls may not be very aesthetically pleasing.

Knowledge gained in the previous questions

- The system is for a new or retrofit building
- There is no space limitation
- Large volumes of fresh are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Equipment is allowed on the outside of the building
Recommended systems : Any system
Systems not recommended : None
Action : Proceed with questioning
Next question : **9**

Result of question : No

Knowledge gained : Equipment is not allowed on the outside
Recommended systems : Systems that have centralised cooling equipment:

- Package units
- All air systems
- Air-water systems
- All water systems

Systems not recommended : Any system with cooling equipment on the outside:

- Window-mounted units
- Wall-mounted units
- Split units
- Evaporative cooling systems

Action : Proceed with questioning
Next question : **G1**

## Question index : 9
## Previous question : 8

Question : Is cooling equipment acceptable in occupied zones?

Purpose of question : It is sometimes preferable not to have cooling equipment in the zones. Maintenance on these units can disturb office workers or can cause problems if some zones are in restricted areas. Cooling equipment may also be aesthetically undesirable in the cooling zone. Generally this however should not be a problem.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There is no space limitation
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is allowed on the outside of the building

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Cooling equipment is allowed in the zones
Recommended systems : Any system
Systems not recommended : None
Action : Proceed with questioning
Next question : **10**

Result of question : No

Knowledge gained : No cooling equipment is allowed in the zone
Recommended systems : Systems that do not have cooling equipment in the zone:

- Package units
- All air systems

Systems not recommended : Any system with cooling equipment in the zone:

- Window-mounted units
- Wall-mounted units
- Split units
- All water systems
- Air-water systems
- Evaporative cooling systems

Action : Proceed with questioning to determine system that meets these requirements

Next question : **C1**

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## Question index : 10
## Previous question : 9

Question : Is maintenance acceptable in occupied zones?

Purpose of question : It is sometimes preferable not to have cooling equipment in the zones. Maintenance on these units can disturb office workers or can cause problems if some zones are in restricted areas. Generally though, this should not be a problem.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There is no space limitation
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is allowed on the outside of the building
- Cooling equipment is allowed in the occupied zone

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Maintenance is allowed in the zones
Recommended systems : Any system
Systems not recommended : None
Action : Proceed with questioning
Next question : **11**

Result of question : No

Knowledge gained : No maintenance is allowed in the zone
Recommended systems : Systems that do not have cooling equipment in the zone:

- Package units
- All air systems

Systems not recommended : Any system with cooling equipment in the zone:

- Window-mounted units
- Wall-mounted units
- Split units
- All water systems
- Air-water systems
- Evaporative cooling systems

Action : Proceed with questioning to determine system that meets these requirements
Next question : **C1**

## Question index : 11
## Previous question : 10

**Question** : Is it important to cut off the supply to unoccupied zones?

**Purpose of question** : To cut off the supply to an unoccupied zone may be required in office buildings that are rented out. The easiest method is to supply an HVAC system for each of the zones. This leads to high initial cost. There are only a few systems with the possibility of cutting off the supply to unoccupied zones.

**Knowledge gained in the previous questions:**

- The system is for a new or retrofit building
- There is no space limitation
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is allowed on the outside of the building.
- Cooling equipment is allowed in the occupied zone
- Maintenance is allowed in occupied zone

**Result parameters** : Yes/No

**Result of question** : Yes

**Knowledge gained** : It is important to to be able to cut off the supply to unoccupied zones

**Recommended systems** : Systems that have separate units for each zone:

- Window-mounted units
- Wall-mounted units
- Split units
- All water systems
- Evaporative cooling systems

**Systems not recommended** : Any system with a central unit supplying all the zones with cooled air. It is impractical to cut off the air supply because of the expensive installation, difficult maintenance and balancing of the air supply system

- Package units
- All air systems
- Air-water systems

**Action** : Proceed with questioning

**Next question** : **D1**

Result of question : No

| | |
|---|---|
| Knowledge gained | : It is not important to cut the supply to unoccupied zones |
| Recommended systems | : Any system |
| Systems not recommended | : None |
| Action | : Proceed with questioning |
| Next question | : **12** |

## Question index : 12
## Previous question : 11

Question : Is separate zone electrical billing necessary ?

Purpose of question : Separate zone electrical billing for the HVAC system may be required in office buildings that are rented out. Only a limited number of systems of the same family make it possible to give separate electrical billing.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There is no space limitation
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is allowed on the outside of the building
- Cooling equipment is allowed in the occupied zone
- Maintenance is allowed in occupied zone
- It is not necessary to cut off the supply to unoccupied zones

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Separate electrical billing is required
Recommended systems : Systems that have separate units for each zone:
- Window-mounted units
- Wall-mounted units
- Split units
- Evaporative cooling systems

Systems not recommended : Any system with a central unit supplying all the zones:
- Air-water systems
- All air systems
- All water systems
- Package units

Action : Proceed with questioning
Next question : **B1**

Result of question : No

Knowledge gained : Separate electrical billing is not required
Recommended systems : Any system
Systems not recommended : None
Action : Proceed with questioning
Next question : **13**

## Question index : 13
## Previous question : 12

Question : Is a large cooling load needed?

Purpose of question : It is necessary to determine the size of the load because this has an effect on the type of system that is needed.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There is no space limitation
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is allowed on the outside of the building
- Cooling equipment is allowed in the occupied zone
- Maintenance is allowed in occupied zone
- It is not necessary to cut off the supply to unoccupied zone
- Separate electrical billing is not required

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : A large cooling load is required
Recommended systems : A system with a central unit supplying all the zones:

- Air-water systems
- All air systems
- All water systems

Action : Proceed with questioning
Next question : **J1**

Result of question : No

Knowledge gained : A large cooling load is not required
Recommended systems : A system that has separate units for each zone:

- Window-mounted units
- Wall-mounted units
- Split units
- Evaporative cooling system
- Package unit

Action : Proceed with questioning
Next question : **I1**

# Question Group A

## Question index : A1
## Previous question : 1/2

Question : Is there space for the installation of ducting?

Purpose of question : Several systems cannot be used if there is no space for the installation of ducts.

Knowledge gained in the previous questions

- The system is for a new or retrofit building
- There are space limitations(2)

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : There is space for ducts
Recommended systems : Any
Systems not recommended : None
Action : Proceed with questioning
Next question : **A2**

Result of question : No

Knowledge gained : There is no space for ducts
Recommended systems : Any system that does not need space for ducts:

- Window-mounted units
- Wall-mounted units
- Split units
- All water systems
- Evaporative cooling systems

Systems not recommended : Systems that use ducts:

- Package units
- All air systems
- Air-water systems

Action : Proceed with questioning
Next question : **A3**

## Question index : A2
## Previous question : A1

Question : Is there room in the building, on the roof or outside for cooling equipment?

Purpose of question : Several systems need space for cooling equipment in the building or on the roof.

Knowledge gained in the previous questions

- The system is for a new or retrofit building
- There are space limitations(2)
- There is space for ducts in the building

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : There is space for cooling equipment
Recommended systems : Any system
Systems not recommended : None
Action : Proceed with questioning
Next question : 3

Result of question : No

Knowledge gained : There is no space for cooling equipment
Recommended systems : Any system that does not need space for cooling equipment in a special room or on the roof:

- Window-mounted units
- Wall-mounted units
- Split units
- Evaporative cooling systems

Systems not recommended : Systems that needs space:

- Package units
- All air systems
- Air-water systems
- All water systems

Action : Proceed with questioning
Next question : **B1**

# Question index : A3
## Previous question : A1

Question : Is there room for cooling equipment in the building, on the roof or the outside of the building?

Purpose of question on : A number of systems need space for cooling equipment in the building or the roof.

Knowledge gained in the previous questions

- The system is for a new or retrofit building
- There are space limitations(2)
- There is no space for ducts in the building
- Any of the following systems meet the requirements of the previous questions:
    - Window-mounted units
    - Wall-mounted units
    - Split units
    - All water systems
    - Package units
    - Evaporative cooling systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : There is space for cooling equipment
Recommended systems : Any of the following:

- Window-mounted units
- Wall-mounted units
- Split units
- All water systems
- Evaporative cooling systems

Systems not recommended : None
Action : Proceed with questioning
Next question : **D1**

Result of question : No

Knowledge gained : There is no space for cooling equipment
Recommended systems : Any of the following:

- Window-mounted units
- Wall-mounted units
- Split units
- Evaporative cooling systems

Systems not recommended : None of the following:

- All water systems

Action : Proceed with questioning
Next question : **B1**

# Question Group B

## Question index : B1
## Previous question : 12/A2/A3/D2/D4/I3/I4

Question : Are there non-perimeter zones in building that have to be cooled?

Purpose of question : Wall and window units cannot be used to cool non-perimeter zones.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are space limitations(2)
- There is not space for an equipment room
- There is not space for ducts in the building(A2)
- There is space for ducts(A3)
- Any of the following systems meet the requirements of the previous questions:
  - Window-mounted units
  - Wall-mounted units
  - Split units
  - Evaporative coolers

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : There are internal zones to cool
Recommended systems : Split units
Systems not recommended : None of the following:
- Window-mounted units
- Wall-mounted units
- Evaporative cooling systems

Action : End of questioning
Next question : **End**

Result of question : No

Knowledge gained : There are no internal zones that need to be cooled.
Recommended systems : Any of the above systems
Systems not recommended : None of the above
Action : Proceed with questioning
Next question : **B2**

## Question index : B2
## Previous question : B1

Question : Can and may cooling equipment be installed in a window or through a wall?

Purpose of question : Window-mounted and wall-mounted units are not very aesthetically pleasing.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are space limitations(2)
- There are no internal zones
- There is not space for an equipment room
- There is space for ducts(A3)
- There is not space for ducts in the building(A2)
- Any of the following systems meet the requirements of the previous questions:
    - Window-mounted units
    - Wall-mounted units
    - Split units
    - Evaporative coolers

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Cooling units are allowed in the windows
Recommended systems : Any of the above systems
Systems not recommended : None of the above
Action : Proceed with questioning
Next question : **B3**

Result of question : No

Knowledge gained : Cooling units are not allowed in windows
Recommended systems : Split units
Systems not recommended : None of the following:

- Window-mounted units
- Wall-mounted units
- Evaporative cooling systems

Action : End of questioning
Next question : **End**

## Question index : B3
## Previous question : B2

Question : Should the cooling equipment be aesthetically pleasing?

Purpose of question : Window-mounted and wall-mounted units are not very aesthetically pleasing.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are space limitations(2)
- There are no internal zones
- There is not space for an equipment room
- Cooling equipment may be installed in the windows
- There is space for ducts(A3)
- There is not space for ducts in the building(A2)
- Any of the following systems meet the requirements of the previous questions:
    - Window-mounted units
    - Wall-mounted units
    - Split units
    - Evaporative coolers

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Cooling units must be aesthetically pleasing
Recommended systems : Split units
Systems not recommended : None of the following:

- Window-mounted units
- Wall-mounted units
- Evaporative cooling systems

Action : End of questioning
Next question : **End**

Result of question : No

Knowledge gained : Cooling units do not have to be aesthetically pleasing
Recommended systems : Any of the above systems
Systems not recommended : None of the above
Action : Proceed with questioning
Next question : **X1**

# Question Group C

## Question index : C1
## Previous question : 7/9/10/E1/E2/E3/F3/F5/F6/G1/G2

Question : Is a large cooling load necessary?

Purpose of question : Of the systems available it is preferable to install an all air system if a large cooling load is necessary.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area
- Noise is a very important consideration
- Stringent Rh control is necessary(7)
- Cooling equipment is not allowed on the outside of the building(8)
- Cooling equipment is not allowed in the occupied zone(9)
- Maintenance is not allowed in the occupied area
- Any of the following systems meet the requirements of the previous questions:
    - Package units
    - All air systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : A large load is needed
Recommended systems : All air systems
Systems not recommended : Package units
Action : Proceed with questioning
Next question : **H1**

Result of question : No

Knowledge gained : A large load is not needed
Recommended systems : Any system
Systems not recommended : None
Action : Proceed with questioning
Next question : **C2**

## Question index : C2
## Previous question : C1

Question : Is the building a small low-rise building?

Purpose of question : Of the systems available it is preferable to install a package system in a small low-rise building.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area
- Noise is a very important consideration
- Stringent Rh control is necessary(7)
- Cooling equipment is not allowed on the outside of the building(8)
- Cooling equipment is not allowed in the occupied zone(9)
- Maintenance is not allowed in the occupied area
- A large cooling load is not necessary
- Any of the following systems meet the requirements of the previous questions:
  - Package units
  - All air systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : It is a small low-rise building
Recommended systems : Package units
Systems not recommended : All air systems
Action : Proceed with questioning
Next question : **P1**

Result of question : No

Knowledge gained : The building is not a small low-rise building
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **C3**

# Question index : C3
## Previous question : C2

Question : Should the system be selected on the lowest initial cost or on the lowest 20-year life-cycle cost?

Purpose of question : To determine the emphasis considerations for the selection of the system. Generally systems with a low initial cost have high running costs and vice versa. A developer will usually select a system with a low initial cost, where as the owner of a building will select a system with a low life-cycle cost.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area
- Noise is a very important consideration
- Stringent Rh control is necessary(7)
- Cooling equipment is not allowed on the outside of the building(8)
- Cooling equipment is not allowed in the occupied zone(9)
- Maintenance is not allowed in the occupied area
- The building is not a small low rise building
- A large cooling load is not necessary
- Any of the following systems meet the requirements of the previous questions:
    - Package units
    - All air systems

Result parameters : Lowest initial cost / Lowest life-cycle cost

Result of question : Lowest initial cost

Knowledge gained : System with a low initial cost is preferable
Recommended systems : Package systems
Systems not recommended : All air systems
Action : Proceed with questioning
Next question : **P1**

Result of question : Low life-cycle cost

Knowledge gained : Systems with low operating costs are preferable
Recommended systems : All air systems
Systems not recommended : Package units
Action : Proceed with questioning
Next question : **H1**

# Question Group D

## Question index : D1
## Previous question : 11/A3

Question : Is the building a large, medium or high-rise building?

Purpose of question : Of the systems available it is preferable to install an all water system in a large, medium or high rise building.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are space limitations(2)
- There is no space for ducts
- There is space for an equipment room
- Any of the following systems meet the requirements of the previous questions:
  - Window-mounted units
  - Wall-mounted units
  - Split units
  - All water systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : The building is a large building
Recommended systems : All water systems
Systems not recommended : Any of following systems:

- Window-mounted units
- Wall-mounted units
- Split units

Action : Proceed with questioning
Next question : **P3**

Result of question : No

Knowledge gained : The building is not large
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **D2**

## Question index : D2
## Previous question : D1

Question : Is the building a small low-rise building?

Purpose of question : Of the systems available it is preferable to install a unitary system in a small low-rise building.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are space limitations(2)
- There is no space for ducts
- There is space for an equipment room
- The building is not a large, medium or high-rise building
- Any of the following systems meet the requirements of the previous questions:
  - Window-mounted units
  - Wall-mounted units
  - Split units
  - All water systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : It is a small low-rise building
Recommended systems : Any of following systems:
- Window-mounted units
- Wall-mounted units
- Split units

Systems not recommended : All water systems
Action : Proceed with questioning
Next question : **B1**

Result of question : No

Knowledge gained : The building is not a small low-rise building
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **D3**

## Question index : D3
## Previous question : D2

Question : Is cooling equipment allowed on the outside of the building (walls, windows or roof)?

Purpose of question : Cooling systems installed in windows or on walls may not be very aesthetically pleasing.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are space limitations(2)
- There is no space for ducts.
- There is space for an equipment room
- The building is not a large, medium or high-rise building
- The building is not a small low-rise building
- Any of the following systems meet the requirements of the previous questions:
  - Window mounted units
  - Wall mounted units
  - Split units
  - All water systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Equipment is allowed on the outside
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **D4**

Result of question : No

Knowledge gained : Equipment is not allowed on the outside of the building
Recommended systems : Systems with centralised cooling equipment:
- All water systems

Systems not recommended : Any system with cooling equipment on the outside:
- Window-mounted units
- Wall-mounted units
- Split units
- Evaporative cooling systems

Action : An all water system is selected
Next question : **P3**

## Question index : D4
## Previous question : D3

**Question** : Should the system be selected on the lowest initial cost or on the lowest 20-year life-cycle cost?

**Purpose of question** : To determine the emphasis considerations for the selection of the system. Generally systems with a low initial cost have high running costs and vice versa. A developer will usually select a system with a low initial cost, where as the owner of a building will select a system with a low life-cycle cost.

**Knowledge gained in the previous questions:**

- The system is for a new or retrofit building
- There are space limitations(2)
- There is not space for ducts
- There is space for an equipment room
- The building is not a large, medium or high-rise building
- The building is not a small low rise-building
- Cooling equipment is allowed on the outside of the building
- Any of the following systems meet the requirements of the previous questions:
  - Window-mounted units
  - Wall-mounted units
  - Split units
  - All water systems

**Result parameters** : Lowest initial cost / Lowest life-cycle cost

**Result of question** : Lowest initial cost

Knowledge gained : Systems with a low initial cost are preferable
Recommended systems : Unitary systems usually have low initial costs:

- Window-mounted units
- Wall-mounted units
- Split units

Systems not recommended : All water systems
Action : Proceed with questioning
Next question : **B1**

**Result of question** : Low life-cycle cost

Knowledge gained : Systems with low operating costs are preferable.
Recommended systems : All water systems
Systems not recommended : Unitary systems:

- Window-mounted units
- Wall-mounted units
- Split units
- Evaporative cooling systems

Action : An all water system is selected
Next question : **P3**

# Question Group E

## Question index : E1
## Previous question : 5/6/F1/F2/F4

Question : Are there very stringent Rh requirements in the zones?

Purpose of question : It is preferable to control the Rh because it affects the air quality of the air. Humidifiers and dehumidifiers are necessary to accomplish this. The added cost of these components is not always justified if the cooling load required is small.

Knowledge gained in the previous questions

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are is not required in the zone
- Positive or negative pressure is not required
- Dust is a problem in the area
- Any of the following systems meet the requirements of the previous questions:
  - Package units
  - All water systems
  - Air-water systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : There are stringent Rh requirements
Recommended systems : Systems with centralised cooling equipment:
- Package units
- All air systems

Systems not recommended : Any system with cooling equipment in the zone:
- Air-water systems

Action : Proceed with questioning
Next question : **C1**

Result of question : No

Knowledge gained : Stringent Rh control is not required
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **E2**

## Question index : E2
## Previous question : E1

Question : Is cooling equipment acceptable in occupied zones?

Purpose of question : Sometimes it is preferable not to have cooling equipment in the zones. Maintenance on these units can disturb office workers or can cause problems if some zones are in restricted areas. Cooling equipment may also be aesthetically undesirable in the cooling zone. Generally this should not be a problem though.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is a problem in the area
- Stringent Rh control is not necessary
- Any of the following systems meet the requirements of the previous questions:
  - Package units
  - All water systems
  - Air-water systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Cooling equipment is allowed in the zones
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **E3**

Result of question : No

Knowledge gained : No cooling equipment is allowed in the zone
Recommended systems : A system that does not have cooling equipment in the zone:

- Package units
- All air systems

Systems not recommended : Any system with cooling equipment in the zone:

- Air-water systems

Action : Proceed with questioning to determine system that meets these requirements
Next question : **C1**

# Question index : E3
## Previous question : E2

Question : Is maintenance acceptable in occupied zones?

Purpose of question : Sometimes it is preferable not to have cooling equipment in the zones. Maintenance on these units can disturb office workers or can cause problems if some zones are in restricted areas. Generally this should not be a problem though.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is a problem in the area
- Stringent Rh control is not necessary
- Cooling equipment is allowed in the occupied zone
- Any of the following systems meet the requirements of the previous questions:
    - Package units
    - All water systems
    - Air-water systems

Result parameters : Yes/No

Result of question : Yes

| | |
|---|---|
| Knowledge gained | : Maintenance is allowed in the zones |
| Recommended systems | : Any of the above systems |
| Systems not recommended | : None |
| Action | : Proceed with questioning |
| Next question | : **E4** |

Result of question : No

| | |
|---|---|
| Knowledge gained | : No maintenance is allowed in the zone |
| Recommended systems | : A system that does not have cooling equipment in the zone:<br>• Package units<br>• All air systems |
| Systems not recommended | : Any system with cooling equipment in the zone:<br>• Air-water systems |
| Action | : Proceed with questioning to determine system that meets these requirements |
| Next question | : **C1** |

## Question index : E4
## Previous question : E3

Question : Is the building a small low-rise building?

Purpose of question : Of the systems available it is preferable to install a unitary system in a small low-rise building.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is a problem in the area
- Stringent Rh control is not necessary
- Cooling equipment is allowed in the occupied zone
- Maintenance inside the occupied zone is allowed
- Any of the following systems meet the requirements of the previous questions:
  - Package units
  - All air systems
  - Air-water systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : It is a small low-rise building
Recommended systems : The following systems:
- Package unit

Systems not recommended : Any of the following:
- All air systems
- Air-water systems

Action : Proceed with questioning
Next question : **P1**

Result of question : No

Knowledge gained : The building is not a small low-rise building
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **E5**

## Question index : E5
## Previous question : E4

**Question** : Should the system be selected on the lowest initial cost or on the lowest 20-year life cycle cost?

**Purpose of question** : To determine the emphasis considerations for the selection of the system. Generally systems with a low initial cost have high running costs and vice versa. A developer will usually select a system with a low initial cost, where as the owner of a building will select a system with a low life-cycle cost.

**Knowledge gained in the previous questions:**

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is a problem in the area
- Stringent Rh control is not necessary
- Cooling equipment is allowed in the occupied zone
- The building is not a small low rise building
- Any of the following systems meet the requirements of the previous questions:
    - Package units
    - All air systems
    - Air-water system

**Result parameters** : Lowest initial cost / Lowest life-cycle cost

**Result of question** : Lowest initial cost.

Knowledge gained : System with a low initial cost is preferable
Recommended systems : Package units
Systems not recommended : Any of the following:
- All air systems
- Air-water systems

Action : Proceed with questioning
Next question : **P1**

**Result of question** : Low life-cycle cost

Knowledge gained : Systems with low operating costs are preferable
Recommended systems : Any of the following:
- All air systems
- Air-water systems

Systems not recommended : Package units
Action : Proceed with questioning
Next question : **J2**

# Question Group F

## Question index : F1
## Previous question : 3/4

Question : Is dust a problem in the area?

Purpose of question : It is preferable to have a central filtration system in areas where dust is a problem. This has the advantage that only one set of filters has to be cleaned regularly. Typical problem areas are offices near to foundries and open cast mines.

Knowledge gained in the previous questions

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is required
- Any of the following systems meet the requirements of the previous questions:
  - Package units
  - All water systems
  - Air-water systems
  - Evaporative cooling systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Dust is a problem in the area
Recommended systems : Any system that has a centralised filtration system:
- Package units
- All air systems
- Air-water systems

Systems not recommended : Any system that does not have a centralised filtration system:
- Evaporative cooling system

Action : Proceed with questioning to determine system that meets these requirements
Next question : **E1**

Result of question : No

Knowledge gained : Dust is not a problem
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **F2**

## Question index : F2
## Previous question : F1

Question : Is noise control very important?

Purpose of question : It is preferable that noise be kept as low as possible. Low-noise cooling systems are better for office buildings and theatres but usually a lot more expensive. Systems with cooling equipment in the zone are noisier than the other types of systems.

Knowledge gained in the previous questions

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is required
- Dust is not a problem in the area
- Any of the following systems meet the requirements of the previous questions:
  - Package units
  - All water systems
  - Air-water systems
  - Evaporative cooling systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Noise control is very important
Recommended systems : Systems that have centralised cooling equipment:
- Package units
- All air systems
- Air-water systems

Systems not recommended : Any system with cooling equipment in the zone:
- Evaporative cooling systems

Action : Proceed with questioning
Next question : **E1**

Result of question : No

Knowledge gained : Noise control is not very important
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **F3**

## Question index : F3
## Previous question : F2

Question : Are there stringent Rh requirements in the zones.?

Purpose of question : It is preferable to control the Rh because it affects the quality of the air. Humidifiers and dehumidifiers are necessary to accomplish this. The added cost of these components is not always justified if the cooling load required is not very big.

Knowledge gained in the previous questions

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Any of the following systems meet the requirements of the previous questions:
    - Package units
    - All water systems
    - Air-water systems
    - Evaporative cooling systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : There are stringent Rh requirements
Recommended systems : Systems that have centralised cooling equipment:

- Package units
- All air systems

Systems not recommended : Any system with cooling equipment in the zone:

- Evaporative cooling systems
- Air-water systems

Action : Proceed with questioning
Next question : **C1**

Result of question : No

Knowledge gained : Stringent Rh control is not required
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **F4**

# Question index : F4
## Previous question : F3

Question : Is cooling equipment allowed on the outside of the building (walls, windows or roof)?

Purpose of question : Cooling systems that are installed in windows or on walls may not be very aesthetically pleasing.

Knowledge gained in the previous questions

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Any of the following systems meet the requirements of the previous questions:
  - Package units
  - All water systems
  - Air-water systems
  - Evaporative cooling systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Equipment is allowed on the outside of the building
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **F5**

Result of question : No

Knowledge gained : Equipment is not allowed on the outside
Recommended systems : Systems that have centralised cooling equipment:

- Package units
- All air systems
- Air-water systems

Systems not recommended : Any system with cooling equipment on the outside:

- Evaporative cooling systems

Action : Proceed with questioning
Next question : **E1**

## Question index : F5
## Previous question : F4

**Question** : Is cooling equipment acceptable in occupied zones?

**Purpose of question** : Sometimes it is preferable not to have cooling equipment in the zones. Maintenance on these units can disturb office workers or can cause problems if some zones are in restricted areas. Cooling equipment may also be aesthetically undesirable in the cooling zone but generally this should not be a problem.

**Knowledge gained in the previous questions:**

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is allowed on the outside of the building
- Any of the following systems meet the requirements of the previous questions:
  - Package units
  - All water systems
  - Air-water systems
  - Evaporative cooling systems

**Result parameters** : Yes/No

**Result of question** : Yes

| | |
|---|---|
| Knowledge gained | : Cooling equipment is allowed in the zones |
| Recommended systems | : Any of the above systems |
| Systems not recommended | : None |
| Action | : Proceed with questioning |
| Next question | : **F6** |

**Result of question** : No

Knowledge gained : No cooling equipment is allowed in the zone

Recommended systems : A system that does not have cooling equipment in the zone:

- Package units
- All air systems

Systems not recommended : Any system that has cooling equipment in the zone:

- Air-water systems
- Evaporative cooling systems

Action : Proceed with questioning to determine system that meets these requirements

Next question : **C1**

# Question index : F6
## Previous question : F5

Question : Is maintenance acceptable in occupied zones?

Purpose of question : Sometimes it is preferable not to have cooling equipment in the zones. Maintenance on these units can disturb office workers or can cause problems if some zones are in restricted areas. Generally this should not be a problem though.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is allowed on the outside of the building
- Cooling equipment is allowed in the occupied zone
- Any of the following systems meet the requirements of the previous questions:
  - Package units
  - All water systems
  - Air-water systems
  - Evaporative cooling systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Maintenance is allowed in the zones
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **F7**

Result of question : No

Knowledge gained : No maintenance is allowed in the zone
Recommended systems : A system that does not have cooling equipment in the zone:

- Package units
- All air systems

Systems not recommended : Any system that has cooling equipment in the zone:

- Air-water systems
- Evaporative cooling systems

Action : Proceed with questioning to determine system that meets these requirements
Next question : **C1**

## Question index : F7
## Previous question : F6

Question : Is the building a small low-rise building?

Purpose of question : Of the systems available it is preferable to install a unitary system in a small low-rise building.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is allowed on the outside of the building
- Cooling equipment is allowed in the occupied zone
- Maintenance inside the occupied zone is allowed
- Any of the following systems meet the requirements of the previous questions:
    - Package units
    - All air systems
    - Air-water systems
    - Evaporative cooling systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : It is a small low-rise building
Recommended systems : The following systems:

- Package units
- Evaporative cooling systems

Systems not recommended : Any of the following:

- All air systems
- Air-water systems

Action : Proceed with questioning
Next question : **Y1**

Result of question : No

Knowledge gained : The building is not a small low-rise building
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **F8**

# Question index : F8
## Previous question : F7

**Question** : Should the system be selected on the lowest initial cost or on the lowest 20-year life-cycle cost?

**Purpose of question** : To determine the emphasis considerations for the selection of the system. Generally systems with a low initial cost have high running costs and vice versa. A developer will usuablly select a system with a low initial cost, where as the owner of a building will select a system with a low life-cycle cost.

**Knowledge gained in the previous questions:**

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is allowed on the outside of the building
- Cooling equipment is allowed in the occupied zone
- Maintenance inside the occupied zone is allowed
- The building is not a small low-rise building
- Any of the following systems meet the requirements of the previous questions:
    - Package units
    - All air systems
    - Air-water systems
    - Evaporative cooling systems

**Result parameters** : Lowest initial cost / Lowest life cycle cost

**Result of question** : Lowest initial cost

**Knowledge gained** : Systems with a low initial cost are preferable

**Recommended systems** : The following systems:

- Package units
- Evaporative cooling systems

**Systems not recommended** : Any of the following:

- All air systems
- Air-water systems

**Action** : Proceed with questioning

**Next question** : **Y1**

Result of question : Low life-cycle cost

Knowledge gained : Systems with low operating costs are preferable
Recommended systems : Any of the following:

- All air systems
- Air-water systems

Systems not recommended : The following systems:

- Package units
- Evaporative cooling systems

Action : Proceed with questioning
Next question : **J2**

## Question Group G

### Question index : G1
### Previous question : 8

Question : Is cooling equipment acceptable in occupied zones?

Purpose of question : Sometimes it is preferable not to have cooling equipment in the zones. Maintenance on these units can disturb office workers or can cause problems if some zones are in restricted areas. Cooling equipment may also be aesthetically undesirable in the cooling zone. Generally this should not be a problem though.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is not allowed on the outside of the building
- Any of the following systems meet the requirements of the previous questions:
    - Package units
    - All air systems
    - All water systems
    - Air-water systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Cooling equipment is allowed in the zones
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **G2**

Result of question : No

Knowledge gained : No cooling equipment is allowed in the zone

Recommended systems : A system that does not have cooling equipment in the zone:

- Package unit
- All air system

Systems not recommended : Any system with cooling equipment in the zone:

- All water system
- Air-water system

Action : Proceed with questioning to determine system that meets these requirements

Next question : **C1**

## Question index : G2
## Previous question : G1

Question : Is maintenance acceptable in occupied zones?

Purpose of question : Sometimes it is preferable not to have cooling equipment in the zones. Maintenance on these units can disturb office workers or can cause problems if some zones are in restricted areas, but generally this should not be a problem.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is not allowed on the outside of the building
- Cooling equipment is allowed in the occupied zone
- Any of the following systems meet the requirements of the previous questions:
    - Package units
    - All air systems
    - All water systems
    - Air-water systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Maintenance is allowed in the zones
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **G3**

Result of question : No

Knowledge gained : No maintenance is allowed in the zone
Recommended systems : A system that does not have cooling equipment in the zone:

- Package units
- All air systems

Systems not recommended : Any system that has cooling equipment in the zone:

- Air-water systems
- All water systems

Action : Proceed with questioning to determine system that meets these requirements
Next question : **C1**

## Question index : G3
## Previous question : G2

**Question** : Is it important to cut off the supply to unoccupied zones?

**Purpose of question** : To cut off the supply to unoccupied zones may be required in office buildings that are rented out. The easiest method is to supply an HVAC system for each of the zones. This leads to high initial cost. There are only a few systems that allows the possibility to cut off the supply to unoccupied zones.

**Knowledge gained in the previous questions:**

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is not allowed on the outside of the building
- Cooling equipment is allowed in the occupied zone
- Maintenance is allowed in occupied zone
- Any of the following systems meet the requirements of the previous questions:
    - Package units
    - All air systems
    - All water systems
    - Air-water systems

**Result parameters** : Yes/No

**Result of question** : Yes

**Knowledge gained** : It is important to cut off the supply to unoccupied zones

**Recommended systems** : Systems that have separate units for each zone:

- All water systems

**Systems not recommended** : Any system with a central unit supplying all the zones of cooled air. It is impractical to cut off the air supply because of the expensive installation, difficult maintenance and balancing of the air supply system

- Package units
- All air systems
- Air-water systems

**Action** : An all water system is selected

**Next question** : **P3**

Result of question : No

| | |
|---|---|
| Knowledge gained | :It is not important to cut off the supply to unoccupied zones |
| Recommended systems | : Any of the above systems |
| Systems not recommended | : None |
| Action | : Proceed with questioning |
| Next question | : **G4** |

## Question index : G4
## Previous question : G3

Question : Is the building a small low-rise building?

Purpose of question : Of the systems available it is preferable to install a unitary system in a small low-rise building.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is not allowed on the outside of the building
- Cooling equipment is allowed in the occupied zone
- Maintenance is allowed in occupied zone
- It is not necessary to cut off the supply to a zone
- Any of the following systems meet the requirements of the previous questions:
  - Package units
  - All air systems
  - All water systems
  - Air-water systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : It is a small low-rise building
Recommended systems : Package units
Systems not recommended : Any of the following:

- All water systems
- All air systems
- Air-water systems

Action : A package unit is selected
Next question : **P1**

Result of question : No

Knowledge gained : The building is not a small low-rise building
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **G5**

## Question index : G5
## Previous question : G4

Question : Should the system be selected on the lowest initial cost or on the lowest 20-year life-cycle cost?

Purpose of question : To determine the emphasis considerations for the selection of the system. Generally systems with a low initial cost have high running costs and vice versa. A developer will usually select a system with a low initial cost, where as the owner of a building will select a system with a low life-cycle cost.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is not allowed on the outside of the building
- Cooling equipment is allowed in the occupied zone
- Maintenance is allowed in occupied zone
- It is not necessary to cut off the supply to a zone
- The building is not a small low rise building
- Any of the following systems meet the requirements of the previous questions:
    - Package units
    - All air systems
    - All water systems
    - Air-water systems

Result parameters : Lowest initial cost / Lowest life-cycle cost

Result of question : Lowest initial cost.

Knowledge gained : Systems with a low initial cost are preferable
Recommended systems : Package units
Systems not recommended : Any of the following:

- All air systems
- Air-water systems
- All water systems

Action : A package unit is selected
Next question : **P1**

Result of question : Low life-cycle cost

Knowledge gained : Systems with low operating costs are preferable
Recommended systems : Any of the following:

- All air systems
- Air-water systems
- All water systems

Systems not recommended : Package units
Action : Proceed with questioning
Next question : **J1**

## Question Group H

Question index : H1
Previous question : C1/C3/J2/J3

Question : Is there limited space to install ducts?

Purpose of question : High-speed ducts require less space than low-speed ducts.

Knowledge gained in the previous questions:

- Any of the following systems meet the requirements of the previous questions:
  - High-speed ducts
  - Low-speed ducts
  - Constant volume variable temperature systems
  - Variable air volume systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : There is limited space for ducts
Recommended systems : High-speed ducts
Systems not recommended : Low-speed ducts
Action : Proceed with questioning
Next question : **H5**

Result of question : No

Knowledge gained : There is enough space for ducts
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **H2**

## Question index : H2
## Previous question : H1

Question : Is there a big difference between the temperatures in different zones?

Purpose of question : It is preferable to use a constant volume variable temperature system if there is a big difference in the temperatures in the different zones.

Knowledge gained in the previous questions:

- There is space to install ducts
- Any of the following systems meet the requirements of the previous questions:
  - High-speed ducts
  - Low-speed ducts
  - Constant volume variable temperature systems
  - Variable air volume systems

Result parameters : Yes/No

Result of question : Yes

| | |
|---|---|
| Knowledge gained | : There is a big difference in temperature |
| Recommended systems | : Constant volume variable temperature systems |
| Systems not recommended | : Variable air volume systems |
| Action | : Proceed with questioning |
| Next question | : **H7** |

Result of question : No

| | |
|---|---|
| Knowledge gained | : There is not a big difference in temperature |
| Recommended systems | : Any of the above systems |
| Systems not recommended | : None |
| Action | : Proceed with questioning |
| Next question | : **H3** |

## Question index : H3
## Previous question : H2

Question : Is noise control very important?

Purpose of question : It is preferable that noise be kept as low as possible. Low-noise cooling systems are better for office buildings and theatres but usually a lot more expensive.

Knowledge gained in the previous questions

- There is space to install ducts
- There is not a big difference in temperatures
- Any of the following systems meet the requirements of the previous questions:
  - High-speed ducts
  - Low-speed ducts
  - Constant volume variable temperature
  - Variable air volume

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Noise control is very important
Recommended systems : Low-speed duct constant volume variable temperature system
Systems not recommended : High-speed duct system
Action : Proceed with questioning
Next question : **P1**

Result of question : No

Knowledge gained : Noise control is not very important
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **H4**

## Question index : H4
## Previous question : H2

Question : Should the system be selected on the lowest initial cost or on the lowest 20-year life-cycle cost?

Purpose of question :To determine the emphasis considerations for the selection of the system. Generally systems with a low initial cost have high running costs and vice versa. A developer will usually select a system with a low initial cost, where as the owner of a building will select a system with a low life-cycle cost.

Knowledge gained in the previous questions

- There is space to install ducts
- There is not a big difference in temperatures
- Noise is not very important
- Any of the following systems meet the requirements of the previous questions:
  - High-speed ducts
  - Low-speed ducts
  - Constant volume variable temperature systems
  - Variable air volume systems

Result parameters : Lowest initial cost / Lowest life-cycle cost

Result of question : Lowest initial cost

Knowledge gained : Systems with a low initial cost are preferable
Recommended systems : High-speed ducts variable air volume system
Systems not recommended : None
Action : Proceed with questioning
Next question : **P1**

Result of question : Low life-cycle cost.

Knowledge gained : Systems with low operating costs are preferable
Recommended systems : Low-speed duct variable air volume system
Systems not recommended : None
Action : Proceed with questioning
Next question : **P1**

## Question index : H5
## Previous question : H1

Question : Is there a big difference between the temperatures in the different zones?

Purpose of question : It is preferable to use a constant volume variable temperature system if there is a big difference in temperatures in the different zones.

Knowledge gained in the previous questions:

- There is not space to install ducts
- Any of the following systems meet the requirements of the previous questions:
  - High-speed ducts
  - Constant volume variable temperature systems
  - Variable air volume systems

Result parameters : Yes/No

Result of question : Yes

| | |
|---|---|
| Knowledge gained | : There is a big difference in temperature |
| Recommended systems | : High-speed duct constant volume variable temperature system |
| Systems not recommended | : Variable air volume system |
| Action | : Proceed with questioning |
| Next question | : **P1** |

Result of question : No

| | |
|---|---|
| Knowledge gained | : There is not a big difference in temperatures |
| Recommended systems | : Any of the above systems |
| Systems not recommended | : None |
| Action | : Proceed with questioning |
| Next question | : **H6** |

## Question index : H6
## Previous question : H5

Question : Is noise control very important?

Purpose of question : It is preferable that noise be kept as low as possible. Low-noise cooling systems are better for office buildings and theatres but usually a lot more expensive.

Knowledge gained in the previous questions

- There is space to install ducts
- There is not a big difference in temperatures
- Any of the following systems meet the requirements of the previous questions:
  - High-speed ducts
  - Constant volume variable temperature systems
  - Variable air volume systems

Result parameters : Yes/No

Result of question : Yes

| | |
|---|---|
| Knowledge gained | : Noise control is very important |
| Recommended systems | : High-speed duct constant volume variable temperature system |
| Systems not recommended | : Variable volume system |
| Action | : Proceed with questioning |
| Next question | : **P1** |

Result of question : No

| | |
|---|---|
| Knowledge gained | : Noise control is not very important |
| Recommended systems | : High-speed duct variable volume system |
| Systems not recommended | : None |
| Action | : Proceed with questioning |
| Next question | : **P1** |

## Question index : H7
## Previous question : H2

Question : Is noise control very important?

Purpose of question : It is preferable that noise be kept as low as possible. Low-noise cooling systems are better for office buildings and theatres but usually a lot more expensive.

Knowledge gained in the previous questions

- There is space to install ducts
- There is not a big difference in temperatures
- Any of the following systems meet the requirements of the previous questions:
    - High-speed ducts
    - Low-speed ducts
    - Constant volume variable temperature systems

Result parameters : Yes/No

Result of question : Yes

| | |
|---|---|
| Knowledge gained | : Noise control is very important |
| Recommended systems | : Low-speed duct constant volume variable temperature system |
| Systems not recommended | : High-speed duct system |
| Action | : Proceed with questioning |
| Next question | : **P1** |

Result of question : No

| | |
|---|---|
| Knowledge gained | : Noise control is not very important |
| Recommended systems | : Any of the above systems |
| Systems not recommended | : None |
| Action | : Proceed with questioning |
| Next question | : **H8** |

## Question index : H8
## Previous question : H7

**Question** : Should the system be selected on the lowest initial cost or on the lowest 20-year life-cycle cost?

**Purpose of question** : To determine the emphasis considerations for the selection of the system. Generally systems with a low initial cost have high running costs and vice versa. A developer will usually select a system with a low initial cost, where as the owner of a building will select a system with a low life-cycle cost.

**Knowledge gained in the previous questions**

- There is space to install ducts
- There is a big difference in temperatures
- Noise is not very important
- Any of the following systems meet the requirements of the previous questions:
  - High-speed ducts
  - Low-speed ducts
  - Constant volume variable temperature system

**Result parameters** : Lowest initial cost / Lowest life-cycle cost

**Result of question** : Lowest initial cost.

Knowledge gained : Systems with a low initial cost are preferable
Recommended systems : High-speed duct constant volume variable temperature system.
Systems not recommended : None
Action : Proceed with questioning
Next question : **P1**

**Result of question** : Low life-cycle cost

Knowledge gained : Systems with low operating costs are preferable
Recommended systems : Low-speed duct constant volume variable temperature
Systems not recommended : None
Action : Proceed with questioning
Next question : **P1**

# Question Group I

## Question index : I1
## Previous question : 13

Question : Is the building a small low-rise building?

Purpose of question : Of the systems available it is preferable to install a unitary system in a small low-rise building.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is not allowed on the outside of the building
- Cooling equipment is allowed in the occupied zone
- Maintenance is allowed in occupied zone
- It is not necessary to cut off the supply to a zone
- Separate electrical billing is not required
- Design of the system is for lowest initial cost
- Any of the following systems meet the requirements of the previous questions:
  - Window-mounted units
  - Wall-mounted units
  - Split units
  - Evaporative cooling systems
  - Package units

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : It is a small low-rise building
Recommended systems : Any of the above
Systems not recommended : None
Action : Proceed with questioning
Next question : **I2**

Result of question : No

Knowledge gained : The building is not a small low-rise building
Recommended systems : Package unit
Systems not recommended : None
Action : A package unit was selected
Next question : **P1**

## Question index : I2
## Previous question : I1

Question : Are there a small number of large open plan zones?

Purpose of question : Package units are ideally suited for large open plan zones.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is not allowed on the outside of the building
- Cooling equipment is allowed in the occupied zone
- Maintenance is allowed in occupied zone
- It is not necessary to cut off the supply to a zone
- Separate electrical billing is not required
- Design of the system is for lowest initial cost
- The building is a small low-rise building
- Any of the following systems meet the requirements of the previous questions:
  - Window-mounted units
  - Wall-mounted units
  - Split units
  - Evaporative cooling systems
  - Package units

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : There are a small number of large open plan zones
Recommended systems : Package unit
Systems not recommended : One of the following:
- Window-mounted units
- Wall-mounted units
- Split units
- Evaporative cooling systems

Action : A package unit is selected
Next question : **P1**

Result of question : No

Knowledge gained : There are not a small number of large open plan zones
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **I3**

## Question index : I3
## Previous question : I2

Question : Is a large cooling load required?

Purpose of question : Package units are ideally suited if large cooling load is required.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is not allowed on the outside of the building
- Cooling equipment is allowed in the occupied zone
- Maintenance is allowed in occupied zone
- It is not necessary to cut off the supply to a zone
- Separate electrical billing is not required
- Design of the system is for lowest initial cost
- The building is a small low-rise office building
- The zones aren't large open plan zones
- Any of the following system meet the requirements of the previous questions:
  - Window-mounted units
  - Wall-mounted units
  - Split units
  - Evaporative cooling systems
  - Package units

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : A large cooling load is needed
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **I4**

Result of question : No

Knowledge gained : A small cooling load is needed
Recommended systems : Any system of the following:

- Window-mounted units
- Wall-mounted units
- Split units
- Evaporative cooling systems

Systems not recommended : Package unit
Action : Proceed with questioning
Next question : **B1**

## Question index : I4
## Previous question : I3

**Question** : Should the system be selected on the lowest initial cost or on the lowest 20-year life-cycle cost?

**Purpose of question** : To determine the emphasis considerations for selection of the system. Generally systems with a low initial cost have high running costs and vice versa. A developer will usually select a system with a low initial cost, where as the owner of a building will select a system with a low life-cycle cost.

**Knowledge gained in the previous questions:**

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is not allowed on the outside of the building
- Cooling equipment is allowed in the occupied zone
- Maintenance is allowed in occupied zone
- It is not necessary to cut off the supply to a zone
- Separate electrical billing is not required
- Design of the system is for lowest initial cost
- The building is a small low-rise office building
- The zones aren't large open plan buildings
- A large cooling load is needed
- Any of the following system meets the requirements of the previous questions:
  - Window-mounted units
  - Wall-mounted units
  - Split units
  - Evaporative cooling systems
  - Package units

**Result parameters** : Lowest initial cost / Lowest life-cycle cost

**Result of question** : Lowest initial cost

**Knowledge gained** : System with a low initial cost is preferable
**Recommended systems** : The following systems:

- Window-mounted units
- Wall-mounted units
- Split units
- Evaporative cooling systems

**Systems not recommended** : Package unit
**Action** : Proceed with questioning
**Next question** : **B1**

Result of question : Low life-cycle cost

Knowledge gained : Systems with low operating costs are preferable
Recommended systems : Package unit
Systems not recommended : The following systems:

- Window-mounted units
- Wall-mounted units
- Split units
- Evaporative cooling systems

Action : A package unit is selected
Next question : **P1**

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# Question Group J

## Question index : J1
## Previous question : 13/G5

Question : Is the building a high-rise building?

Purpose of question : All water systems are ideally suited for high-rise buildings.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is not allowed on the outside of the building
- Cooling equipment is allowed in the occupied zone
- Maintenance is allowed in occupied zone
- It is not necessary to cut off the supply to a zone
- Separate electrical billing is not required
- Design of the system is for lowest initial cost
- Any of the following systems meet the requirements of the previous questions:
    - All air systems
    - All water systems
    - Air-water systems

Result parameters : Yes/No

Result of question : Yes

| | |
|---|---|
| Knowledge gained | : The building is a high-rise building |
| Recommended systems | : All water system |
| Systems not recommended | : None |
| Action | : An all water system is selected |
| Next question | : **P3** |

Result of question : No

| | |
|---|---|
| Knowledge gained | : The building is not a high rise |
| Recommended systems | : Any of the above systems |
| Systems not recommended | : None |
| Action | : Proceed with questioning |
| Next question | : **J2** |

## Question index : J2
## Previous question : E5/F8/J1

Question : Are there a small number of large open plan zones?

Purpose of question : All air systems are ideally suited for large open plan zones.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is not allowed on the outside of the building
- Cooling equipment is allowed in the occupied zone
- Maintenance is allowed in occupied zone
- It is not necessary to cut off the supply to a zone
- Separate electrical billing is not required
- Design of the system is for lowest initial cost
- The building is not a high-rise building
- Any of the following systems meet the requirements of the previous questions:
    - All air systems
    - All water systems
    - Air-water systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : The zones are large open plan zones
Recommended systems : All air system
Systems not recommended : None
Action : An all air system is selected
Next question : **H1**

Result of question : No

Knowledge gained : The zones are not large open plan zones
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **J3**

## Question index : J3
## Previous Question : J2

Question : Are most of the zones perimeter zones?

Purpose of question : Air-water systems are ideally suited when most of the zones are perimeter zones.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is not required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is not allowed on the outside of the building
- Cooling equipment is allowed in the occupied zone
- Maintenance is allowed in occupied zone
- It is not necessary to cut off the supply to a zone
- Separate electrical billing is not required
- Design of the system is for lowest initial cost
- The building is not a high rise building
- The zones aren't open plan zones
- Any of the following systems meet the requirements of the previous questions:
    - All air systems
    - All water systems
    - Air-water systems

Result parameters : Yes/No

Result of question : Yes

| | |
|---|---|
| Knowledge gained | : The zones are mostly perimeter zones |
| Recommended systems | : Air-water system |
| Systems not recommended | : None |
| Action | : An air-water system is selected |
| Next question | : **H1** |

Result of question : No

| | |
|---|---|
| Knowledge gained | : The zones are not large open plan zones |
| Recommended systems | : All air system |
| Systems not recommended | : None |
| Action | : An all air system is selected |
| Next question | : **H1** |

# Question Group K

## Question index : K1
## Previous question : X1/Y1

Question : Is the Rh in the zone high?

Purpose of question : It is better to use an indirect evaporative cooler if the Rh in the zone is high

Knowledge gained in the previous questions:

- Any of the following systems meet the requirements of the previous questions:
  - Direct evaporative coolers
  - Indirect evaporative coolers
  - Multistage evaporative coolers

Result parameters : Yes/No

Result of question : Yes

| | |
|---|---|
| Knowledge gained | : The Rh in the zone is high |
| Recommended systems | : Indirect evaporative cooler |
| Systems not recommended | : Direct evaporative cooler |
| Action | : An indirect evaporative cooler is selected |
| Next question | : **End** |

Result of question : No

| | |
|---|---|
| Knowledge gained | : The Rh is zone is not high |
| Recommended systems | : Any of the above systems |
| Systems not recommended | : None |
| Action | : Proceed with questioning |
| Next question | : **K2** |

## Question index : K2
## Previous question : K1

Question : Should the Rh be controlled?

Purpose of question : It is better to use a multistage evaporative cooler if the Rh must be controlled in the zone.

Knowledge gained in the previous questions:

- The Rh in the zone is not high.
- Any of the following systems meet the requirements of the previous questions:
  - Direct evaporative coolers
  - Indirect evaporative coolers
  - Multistage evaporative coolers

Result parameters : Yes/No

Result of question : Yes

| | |
|---|---|
| Knowledge gained | : The Rh must be controlled |
| Recommended systems | : Multistage evaporative cooler |
| Systems not recommended | : Direct evaporative cooler |
| Action | : A multistage evaporative cooler is selected |
| Next question | : **End** |

Result of question : No

| | |
|---|---|
| Knowledge gained | : The Rh is not a problem |
| Recommended systems | : Any system |
| Systems not recommended | : None |
| Action | : Proceed with questioning |
| Next question | : **K3** |

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Question index : K3
Previous question : K2

Question : Should the system be selected on the lowest initial cost or on the lowest 20-year life-cycle cost?

Purpose of question : To determine the emphasis considerations for the selection of the system. Generally systems with a low initial cost have high running costs and vice versa. A developer will usually select a system with a low initial cost, where as the owner of a building will select a system with a low life-cycle cost.

Knowledge gained in the previous questions:

- The Rh in the zone is not high
- It is unnecessary to control the Rh in the zone.
- Any of the following systems meet the requirements of the previous questions:
    - Direct evaporative coolers
    - Indirect evaporative coolers
    - Multistage evaporative coolers

Result parameters : Lowest Initial cost / Lowest life-cycle cost

Result of question : Lowest initial cost.

Knowledge gained : Systems with a low initial cost are preferable
Recommended systems : Direct evaporative cooler
Systems not recommended : None
Action : A direct evaporative cooler is selected
Next question : **End**

Result of question : Low life-cycle cost

Knowledge gained : Systems with low operating costs are preferable
Recommended systems : Multistage evaporative cooler
Systems not recommended : None
Action : A multistage evaporative cooler is selected
Next question : **End**

## Question Group P

### Question index : P1
### Previous question : C2/C4/C5/H3/H4/H5/H6/H7/H8/I1/I2/I3/I4/Y1/ Y2/Y3/Y5

Question : Are large volumes of fresh air required in the zone?

Purpose of question : Large volumes of fresh air are needed in zones where odours are a problem. Examples of such zones are lobbies, restaurants, toilets and any zone that is occupied by smokers. Large volumes of fresh air are also needed where a large number of people get together in confined spaces. Examples of such zones are theatres, banks and other public places.

Knowledge gained in the previous questions:

- Any of the following systems meet the requirements of the previous questions:
  - Full fresh air systems
  - Economiser system
  - Air-cooled system
  - Water-cooled system

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Large volumes of fresh air are required
Recommended systems : Full fresh air
Systems not recommended : Economiser
Action : Proceed with questioning to determine system that meets these requirements
Next question : **P3**

Result of question : No

Knowledge gained : Large volumes of fresh air are not required
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **P2**

## Question index : P2
## Previous question : P1

Question : Should the system be selected on the lowest initial cost or on the lowest 20-year life-cycle cost?

Purpose of question : To determine the emphasis considerations for the selection of the system. Generally systems with a low initial cost have high running costs and vice versa. A developer will usually select a system with a low initial cost, where as the owner of a building will select a system with a low life-cycle cost.

Knowledge gained in the previous questions:

- Large volumes of fresh air are not needed
- Any of the following systems meet the requirements of the previous questions:
    - Full fresh air systems
    - Economiser system
    - Air-cooled system
    - Water-cooled system

Result parameters : Lowest initial cost / Lowest life-cycle cost

Result of question : Lowest initial cost

| | |
|---|---|
| Knowledge gained | : Systems with a low initial cost are preferable |
| Recommended systems | : Full fresh air system |
| Systems not recommended | : Economiser system |
| Action | : Proceed with questioning |
| Next question | : **P3** |

Result of question : Low life-cycle cost

| | |
|---|---|
| Knowledge gained | : Systems with low operating costs are preferable |
| Recommended systems | : Economiser system |
| Systems not recommended | : Full fresh air system |
| Action | : Proceed with questioning |
| Next question | : **P3** |

## Question index : P3
## Previous question : D1/D3/E4/E5/G3/J1/P1/P2

Question : Is there water for a cooling tower?

Purpose of question : Air-cooled systems must be used if water is available in limited amounts.

Knowledge gained in the previous questions:

- Any of the following systems meet the requirements of the previous questions:
  - Air-cooled system
  - Water-cooled system

Result parameters : Yes/No

Result of question : Yes

| | |
|---|---|
| Knowledge gained | : There is water for a cooling tower |
| Recommended systems | : Any system |
| Systems not recommended | : None |
| Action | : Proceed with questioning |
| Next question | : **P4** |

Result of question : No

| | |
|---|---|
| Knowledge gained | : There is no water for a cooling system |
| Recommended systems | : Air-cooled system |
| Systems not recommended | : Water-cooled |
| Action | : An air-cooled system is selected |
| Next question | : **End** |

## Question index : P4
## Previous question : P3

Question : Is there some distance between the equipment room and the installation space for the condenser cooling equipment?

Purpose of question : It is easier to use a water-cooled system if the cooling tower is some distance from the equipment room.

Knowledge gained in the previous questions:

- Any of the following systems meet the requirements of the previous questions:
  - Air-cooled systems
  - Water-cooled systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : There is some distance
Recommended systems : Water-cooled system
Systems not recommended : None
Action : A water-cooled system is selected
Next question : **End**

Result of question : No

Knowledge gained : The two are close together
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **P5**

Question index : P5
Previous question : P4

Question : Should the system be selected on the lowest initial cost or on the lowest 20-year life-cycle cost?

Purpose of question : To determine the emphasis considerations for the selection of the system. Generally systems with a low initial cost have high running costs and vice versa. A developer will usually select a system with a low initial cost, where as the owner of a building will select a system with a low life-cycle cost.

Knowledge gained in the previous questions:

- Any of the following systems meet the requirements of the previous questions:
  - Air-cooled system
  - Water-cooled system

Result parameters : Lowest initial cost / Lowest life-cycle cost

Result of question : Lowest initial cost

| | |
|---|---|
| Knowledge gained | : Systems with a low initial cost are preferable |
| Recommended systems | : Air-cooled system |
| Systems not recommended | : Water-cooled system |
| Action | : An air-cooled system is selected |
| Next question | : **End** |

Result of question : Low life-cycle cost

| | |
|---|---|
| Knowledge gained | : Systems with low operating costs are preferable |
| Recommended systems | : Water-cooled system |
| Systems not recommended | : Air-cooled system |
| Action | : A water-cooled system is selected |
| Next question | : **End** |

# Question Group V

## Question index : V1
## Previous question : NA

Question : Is only ventilation needed?

Purpose of question : Sometimes only ventilation is needed.

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Only ventilation is necessary
Recommended systems : Any ventilation system
Systems not recommended : None
Action : Resume questioning
Next question : **V2**

Result of question : No

Knowledge gained : An air-conditioning system is required
Recommended systems : Any air-conditioning system
Systems not recommended : Any ventilation system
Action : Resume questioning
Next question : **1**

Question index : V2
Previous question : V1

Question : Is it possible to use natural ventilation?

Purpose of question : It may be possible to design the building to facilitate natural ventilation.

Knowledge gained in the previous questions:

- Only ventilation is necessary

Result parameters : Yes/No

Result of question : Yes

| | |
|---|---|
| Knowledge gained | : It is possible to use natural ventilation |
| Recommended systems | : Natural ventilation |
| Systems not recommended | : None |
| Action | : Natural ventilation is selected |
| Next question | : **End** |

Result of question : No

| | |
|---|---|
| Knowledge gained | : Mechanical ventilation is necessary |
| Recommended systems | : Mechanical ventilation |
| Systems not recommended | : Natural ventilation |
| Action | : Mechanical ventilation is selected |
| Next question | : **End** |

# Question Group X

## Question index : X1
## Previous question : B3

Question : Is the outdoor Rh high?

Purpose of question : Evaporative coolers are very sensitive to the outside Rh because of their method of operation. Evaporative cooling becomes very ineffective with high Rh. The outside Rh is typically high at the coast.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are space limitations(2)
- There are no internal zones
- There is no space for an equipment room
- Cooling equipment may be installed in the windows
- There is space for ducts(A3)
- There is no space for ducts in the building(A2)
- The cooling equipment doesn't have to be aesthetically pleasing
- Any of the following systems meet the requirements of the previous questions:
  - Window-mounted units
  - Wall-mounted units
  - Evaporative coolers

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : The outside Rh is high
Recommended systems : The following systems:
- Window-mounted units
- Wall-mounted units

Systems not recommended : Evaporative cooling system
Action : End of questioning
Next question : **End**

Result of question : No

Knowledge gained : The outside Rh is not high.
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **X2**

Question index : X2
Previous question : X1

Question : Is there water for an evaporative cooler?

Purpose of question : It is preferable to use clean water for an evaporative cooler. Sometimes it may not be acceptable to use drinking water.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are space limitations(2)
- There are no internal zones
- There is no space for an equipment room
- Cooling equipment may be installed in the windows
- There is space for ducts(A3)
- There is no space for ducts in the building(A2)
- The cooling equipment does not have to be aesthetically pleasing
- The outside Rh is not high
- Any of the following systems meet the requirements of the previous questions:
    - Window-mounted units
    - Wall-mounted units
    - Evaporative coolers

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : There is water
Recommended systems : Any of the above systems
Systems not recommended : None of the above
Action : Proceed with questioning
Next question : **X3**

Result of question : No

Knowledge gained : There is no water
Recommended systems : The following systems:

- Window-mounted units
- Wall-mounted units

Systems not recommended : Evaporative cooling system
Action : End of questioning
Next question : **End**

## Question index : X3
## Previous question : X2

Question : Is the Rh in the zone high?

Purpose of question : The air leaving an evaporative cooler has a very high Rh. This makes it unsuitable for application where the zone Rh is high. A typical example is a change house where a large number of people are showering.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are space limitations(2)
- There are no internal zones
- There is no space for an equipment room
- Cooling equipment may be installed in the windows
- There is space for ducts(A3)
- There is no space for ducts in the building(A2)
- The cooling equipment does not have to be aesthetically pleasing
- The outside Rh is not high
- There is water for a cooling system
- Any of the following systems meet the requirements of the previous questions:
  - Window-mounted units
  - Wall-mounted units
  - Evaporative coolers

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : The zone Rh is high
Recommended systems : The following systems
- Window-mounted units
- Wall-mounted units

Systems not recommended : Evaporative cooling system
Action : End of questioning
Next question : **End**

Result of question : No

Knowledge gained : The zone Rh is not high
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **X4**

## Question index : X4
## Previous question : X3

Question : Is dust a problem in the area?

Purpose of question : The membranes of an evaporative cooler get blocked by dust and must be cleaned regularly. Typical problem areas are offices near to foundries and open cast mines.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are space limitations(2)
- There are no internal zones
- There is no space for a equipment room
- Cooling equipment may be installed in the windows
- There is space for ducts(A3)
- There is no space for ducts in the building(A2)
- The cooling equipment does not have to be aesthetically pleasing
- The outside Rh is not high
- There is water for a cooling system
- The Rh in the zone is not high
- Any of the following systems meet the requirements of the previous questions:
  - Window-mounted units
  - Wall-mounted units
  - Evaporative coolers

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Dust is a problem
Recommended systems : The following systems
- Window-mounted units
- Wall-mounted units

Systems not recommended : Evaporative cooling system
Action : End of questioning
Next question : **End**

Result of question : No

Knowledge gained : Dust is not a problem
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **X5**

Question index : X5
Previous question : X4

Question : Should the building be environmentally friendly?

Purpose of question : Evaporative coolers have a lower impact on the environment because of their low energy consumption and because they do not use refrigerants.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are space limitations(2)
- There are no internal zones
- There is no space for a equipment room
- Cooling equipment may be installed in the windows
- There is space for ducts(A3)
- There is no space for ducts in the building (A2)
- The cooling equipment does not have to be aesthetically pleasing
- The outside Rh is not high
- There is water for a cooling system
- The Rh in the zone is not high
- Dust is not a problem
- Any of the following systems meet the requirements of the previous questions:
    - Window-mounted units
    - Wall-mounted units
    - Evaporative coolers

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : Systems should be environmentally friendly
Recommended systems : Evaporative coolers
Systems not recommended : The following systems
- Window-mounted units
- Wall-mounted units

Action : Proceed with questioning
Next question : **K1**

Result of question : No

Knowledge gained : System does not have to be environmentally friendly
Recommended systems : Any of the above system
Systems not recommended : None of the above
Action : Proceed with questioning
Next question : **X6**

## Question index : X6
## Previous question : X5

**Question** : Should the system be selected on the lowest initial cost or on the lowest 20-year life-cycle cost?

**Purpose of question** : To determine the emphasis considerations for the selection of the system. Generally systems with a low initial cost have high running costs and vice versa. A developer will usually select a system with a low initial cost, where as the owner of a building will select a system with a low life-cycle cost.

**Knowledge gained in the previous questions:**

- The system is for a new or retrofit building
- There are space limitations(2)
- There are no internal zones
- There is no space for a equipment room
- Cooling equipment may be installed in the windows
- There is space for ducts(A3)
- There is no space for ducts in the building(A2)
- The cooling equipment does not have to be aesthetically pleasing
- The outside Rh is not high
- There is water for a cooling system
- The Rh in the zone is not high
- Dust is not a problem
- The system does have to be environmentally friendly
- Any of the following system meet the requirements of the previous questions:
    - Window-mounted Units
    - Wall-mounted Units
    - Evaporative coolers

**Result parameters** : Lowest initial cost / Lowest life-cycle cost

**Result of question** : Lowest initial cost

**Knowledge gained** : Systems with a low initial cost are preferable
**Recommended systems** : The following systems
- Window-mounted units
- Wall-mounted units

**Systems not recommended** : Evaporative coolers
**Action** : End of questioning
**Next question** : **End**

Result of question : Low life-cycle cost

| | |
|---|---|
| Knowledge gained | : Systems with low operating costs are preferable |
| Recommended systems | : Evaporative coolers |
| Systems not recommended | : The following systems<br>• Window-mounted units<br>• Wall-mounted units |
| Action | : Proceed with questioning |
| Next question | : **K1** |

# Question Group Y

## Question index : Y1
## Previous question : F7/F8

Question : Is the outdoor Rh high?

Purpose of question : Evaporative coolers are very sensitive to the outside Rh because of their method of operation. Evaporative cooling becomes very ineffective with high Rh. The outside Rh is typically high at the coast.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is allowed on the outside of the building
- Cooling equipment is allowed in the occupied zone
- Maintenance inside the occupied zone is allowed
- The building is a small low-rise building
- The design emphasis is on lowest initial cost
- Any of the following systems meet the requirements of the previous questions:
  - Package units
  - Evaporative cooling systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : The outside Rh is high
Recommended systems : Package unit
Systems not recommended : Evaporative cooling system
Action : A package unit is selected
Next question : **P1**

Result of question : No

Knowledge gained : The outside Rh is not high
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **Y2**

## Question index : Y2
## Previous question : Y1

Question : Is there water for an evaporative cooler?

Purpose of question : It is preferable to use clean water for an evaporative cooler. Sometimes it may not be acceptable to use drinking water.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is allowed on the outside of the building
- Cooling equipment is allowed in the occupied zone
- Maintenance inside the occupied zone is allowed
- The building is a small low-rise building
- The design emphasis is on lowest initial cost
- The Rh outside is not high
- Any of the following systems meet the requirements of the previous questions:
  - Package units
  - Evaporative cooling systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : There is water
Recommended systems : Any of the above systems
Systems not recommended : None of the above
Action : Proceed with questioning
Next question : **Y3**

Result of question : No

Knowledge gained : There is no water
Recommended systems : Package unit
Systems not recommended : Evaporative cooling system
Action : A package unit is selected
Next question : **P1**

## Question index : Y3
## Previous question : Y2

Question : Is the Rh in the zone high?

Purpose of question : The air leaving a evaporative cooler has a very high Rh. This makes it unsuitable for application where the zone Rh is high. A typical example is a change house where a large number of people are showering.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is allowed on the outside of the building
- Cooling equipment is allowed in the occupied zone
- Maintenance inside the occupied zone is allowed
- The building is a small low-rise building
- The design emphasis is on lowest initial cost
- The Rh outside is not high
- There is a water for a evaporative cooler
- Any of the following systems meet the requirements of the previous questions:
  - Package units
  - Evaporative cooling systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : The zone Rh is high
Recommended systems : Package unit
Systems not recommended : Evaporative cooling system
Action : A package unit is selected
Next question : **P1**

Result of question : No

Knowledge gained : The zone Rh is not high
Recommended systems : Any of the above systems
Systems not recommended : None
Action : Proceed with questioning
Next question : **Y4**

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## Question index : Y4
## Previous question : Y3

**Question** : Should the building be environmentally friendly?

**Purpose of question** : Evaporative coolers have a lower impact on the environment because of their low energy consumption and because they do not use refrigerants.

**Knowledge gained in the previous questions:**

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is allowed on the outside of the building
- Cooling equipment is allowed in the occupied zone
- Maintenance inside the occupied zone is allowed
- The building is a small low-rise building
- The design emphasis is on lowest initial cost
- The Rh outside is not high
- There is water for an evaporative cooler
- The zone Rh is not high
- Any of the following systems meet the requirements of the previous questions:
  - Package units
  - Evaporative cooling systems

**Result parameters** : Yes/No

**Result of question** : Yes

| | |
|---|---|
| Knowledge gained | : Systems should be environmentally friendly |
| Recommended systems | : Evaporative cooler |
| Systems not recommended | : Package unit |
| Action | : An evaporative cooler is selected |
| Next question | : **K1** |

**Result of question** : No

| | |
|---|---|
| Knowledge gained | : System does not have to be environmentally friendly |
| Recommended systems | : Any of the above systems |
| Systems not recommended | : None of the above |
| Action | : Proceed with questioning |
| Next question | : **Y5** |

# Question index : Y5
# Previous question : Y4

Question : Is a large cooling load necessary?

Purpose of question : It is preferable to use a package unit when a large cooling load is needed.

Knowledge gained in the previous questions:

- The system is for a new or retrofit building
- There are no space limitations
- Large volumes of fresh air are not required in the zone
- Positive or negative pressure is required
- Dust is not a problem in the area
- Noise is not a very important consideration
- Stringent Rh control is not necessary
- Cooling equipment is allowed on the outside of the building
- Cooling equipment is allowed in the occupied zone
- Maintenance inside the occupied zone is allowed
- The building is a small low-rise building
- The design emphasis is on lowest initial cost
- The Rh outside is not high
- There is water for an evaporative cooler
- The zone Rh is high
- The system does not have to be environmentally friendly
- Any of the following systems meet the requirements of the previous questions:
    - Package units
    - Evaporative cooling systems

Result parameters : Yes/No

Result of question : Yes

Knowledge gained : The cooling load is large
Recommended systems : Package unit
Systems not recommended : None
Action : A package unit is selected
Next question : **P1**

Result of question : No

Knowledge gained : The cooling load is not large
Recommended systems : Evaporative cooling system
Systems not recommended : None
Action : An evaporative cooling system is selected
Next question : **K1**