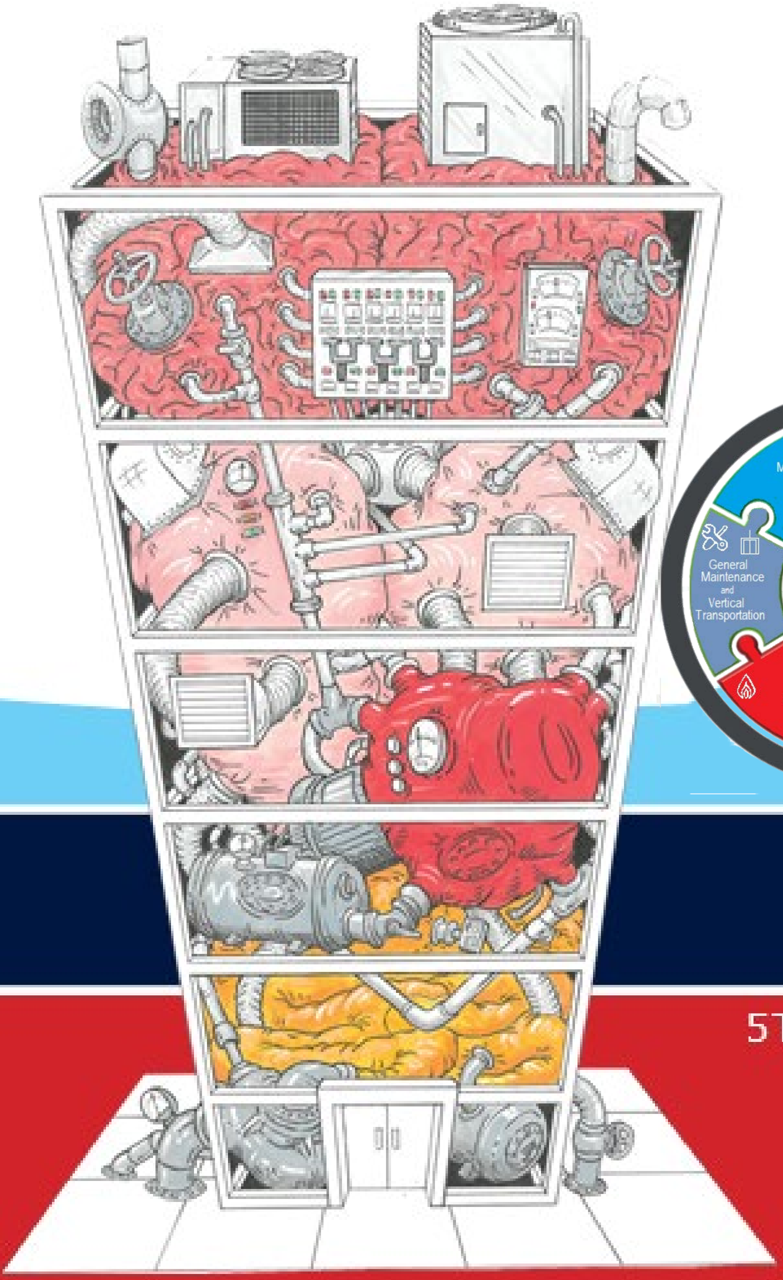
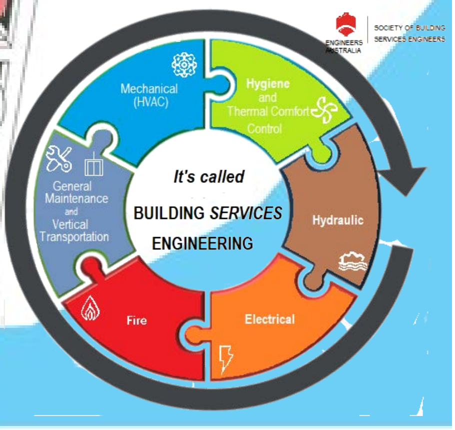
BUILDING SERVICES

ENGINEERING FOR ARCHITECTS & BUILDING DESIGN PROFESSIONALS

A GUIDE TO INTEGRATED DESIGN





PARLOUR

5TH EDITION

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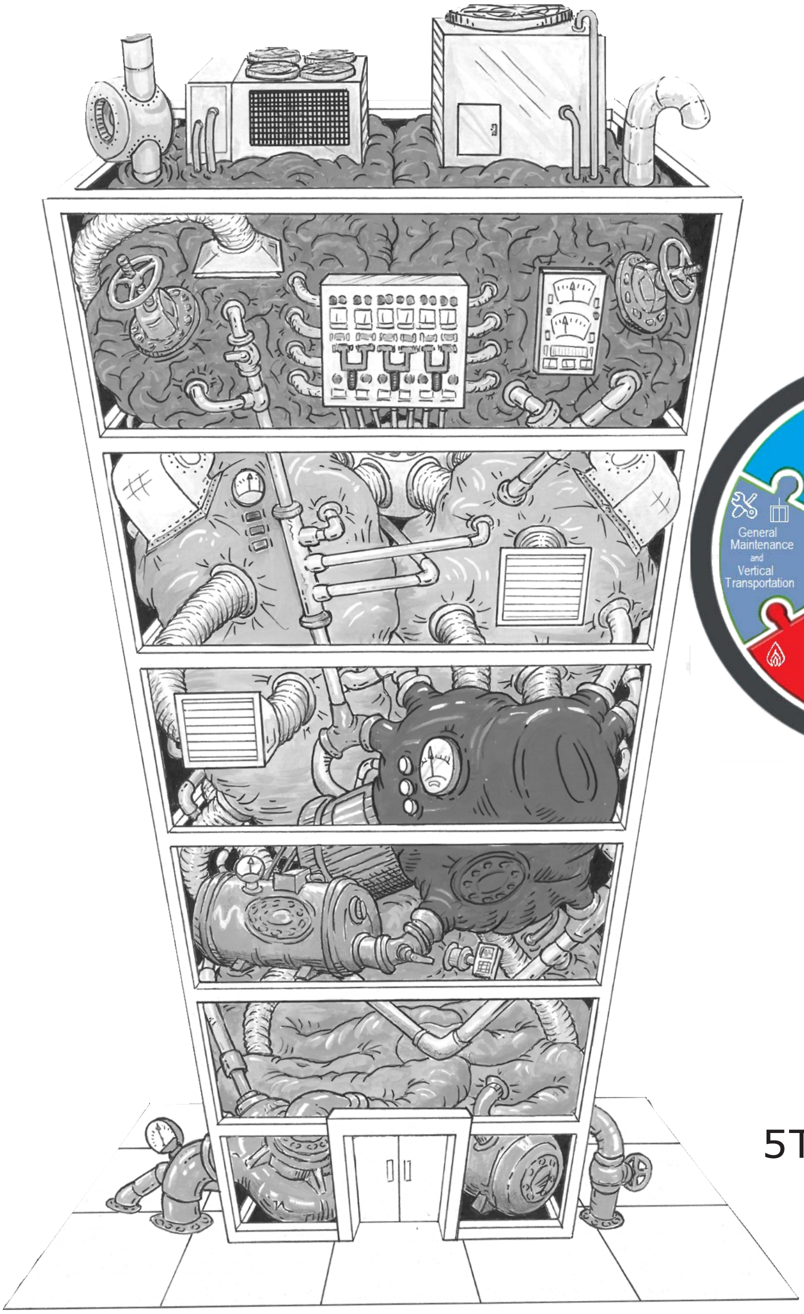

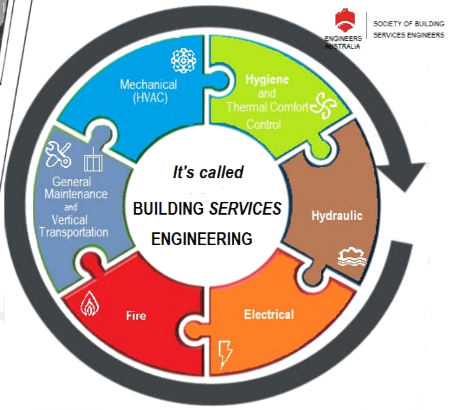

PARLOUR
5TH EDITION

Building Services 5th Edition

Engineering for Architects and Building Design Professionals
A guide to integrated design
Parlour, Richard Patrick

Covering: -
- **Integrated design**
- **Air conditioning**
- **Vertical transport**
- **Electrical power**
- **Fire protection**
- **Water supply**

For all involved in commercial building design who need an overview of mechanical and electrical services, without getting too involved in the engineering details, this book answers the questions: -
- Why are these service systems required?
- What equipment must be installed?
- How much plant room and facade space needs to be allocated?
- What are the implications on the total building's design?

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What was new in Edition 4

Up to date guidance for non-engineering specialists to participate in the building services early design process.

- Integrated design is expanded to guide the reader through the essential stages of client consultation, feasibility and selection of the design criteria, regulation compliance, the principal early 'big picture' issues.
- Subsequent chapters provide updated overview of systems and equipment required for air conditioning, vertical transport, electrical power, fire protection and water supply.
- The practical worked examples complete the book.

What is new in Edition 5 (2023)

Update of building regulatory framework,
change of indexing references in National Construction Code 2022,
inclusion of Battery Electric Vehicle charging issues within building enclosures.

Acknowledgments

The author of the initial (1994-2000) editions, the late Dr R P Parlour had been engaged in the design of mechanical engineering building services for over 30 years, both in Australia and the UK and was senior lecturer in the School of Architecture at University of New South Wales, Australia.

Edition 4 was updated, expanded and edited by Alan Obrart, with the assistance of technical editor Vince Aherne, and peer review by: Chris Finegan AECOM, Dr David Leifer BOND UNIVERSITY, Peter McLean LIGHTING, Lester Partridge AECOM, Grant Potter ACOR, and technical contributors: Steve Hennessy and PC Thomas.

Edition 5 was updated and edited by Ian Childs

Alan Obrart, B.Sc; B.E; CPEng; NER (Building Services Mechanical) Grad Dip Building Surveys Assessment, F.IEAust; M.AIRAH M.ASHRAE Aff .CIBSE, has been involved in design, and documentation of mechanical services for over 40 years, principal of Obrart & Co Pty Ltd, and was Adjunct Associate Professor, Faculty of Architecture, Design and Planning at the University of Sydney.

Ian Childs, F.IPEA; Comp.IEAust; M.FPAA; M.SFS; M.SBSE; M.AIES; Aff.AFA; NAM; ESM; NEM. has been a representative of institutional property owners with standards australia technical committees since 1993 involved in drafting and developing standards associated with building services and then principal of a building services and compliance practice.

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Preface to Edition 5

WHO SHOULD USE THIS BOOK

This book is all about the engineering services commonly installed in new and refurbished commercial buildings. The information provided will be useful to both students and building professionals; architects, builders, consulting engineers, property and facilities managers and surveyors, in fact anyone associated with the building industry who needs a broad overview of the impact these services have on building design, without getting too involved in the engineering details.

EARLY DESIGN

The aim is to assist non-engineering specialists and commercial property and building industry professionals to participate in and understand early design processes and decisions for Air conditioning, heating, ventilating, electrical power, vertical transport, fire protection and water supply are covered, all of which can require significant space and affect other components of the total design.

The very early stage is, without doubt, the most critical period of the entire building design process. This is a time when all members of the design team need to get a realistic feel for what the finished building will look like. A reasonably accurate, though approximate, prediction of the end result is an essential basis for early decision making on which future detailed design is based.

INTEGRATED DESIGN

Integrated design collaboration harnesses the talents and insights of all participants to optimise design efficiency through all phases of a project allowing all design team members to realize their full potential and expand the value of the services they provide throughout the project lifecycle.

The intuitive design procedure carried out during the early stage in a professional office is "integrated design". In the office, mutual understanding between the several design team members is necessary, which professional architects and engineers acquire based on practical experience and integrated discussion. As a project progresses through feasibility towards construction design 'charrettes' or similar are often held to facilitate continued integration of design inputs.

A similar overview is necessary for students but this is unfortunately unavailable and highlights a serious flaw in academic studio design. In fact, there is a general lack of understanding of the large amount of space needed for services installation by both student and professional architects and other non-engineering members of the design team. A rational allocation of space is essential and, without due consideration, building designs can be fantastic in the true sense of the word. Such an understanding of building services is essential, whether in the professional office or academic studio in order to provide a firm basis for spatial planning and architectural expression.

The first chapter of this book provides an overview of the basic engineering design criteria regarding space, costs, mandatory and market drivers of design. Subsequent chapters cover those services which have significant space requirements within the building envelope. Chapters are structured to provide (a) the engineering principles and associated information on system design, suitable for a course of lectures, and (b) a design guide suitable for integrated design in the studio. Data are approximate with an accuracy consistent with that required at the early design stage.

Much of the information given in this book is based on the original author's experience and updated by a peer review panel of subject experts for this edition. Successful application of the information provided needs to be backed up by a measure of common sense but, if used in context, it will be a valuable aid to building design, whether in the studio or the professional office.

The intention is to address the principal questions normally raised at the early design stage, i.e.:

- What are the comfort expectations and requirements of building users?
- How is Safety in Design being incorporated?
- What is the justification for air conditioning?
- Which system is appropriate and what equipment is needed?
- What are the costs, energy, and indoor environment implications of different system types?
- How much plant room space is required?
- When are escalators more appropriate than moving walks?
- What are the likely regulation impacts, insurance and risk profiles?
- What are the issues surrounding environmental effects?
- What specialized requirements are necessary in a building for Battery Electric Vehicle Charging?
- What building data must be provided by designers, installers and certifiers?
- Is the development to address introduced occupancy issues (hazards, etc)?

These questions and many others are addressed in this book however, real, precise answers depend on factors such as budgetary allowances, the owner's financial criteria, property cycles, equipment availability and the finer points of engineering, all of which are beyond the scope of this book.

After many years as a consulting engineer the original author joined the School of Architecture at the University of New South Wales. This provided an opportunity to bring together the practical undocumented engineering knowledge accumulated over many years' experience in design offices both in Australia and the U.K. This sort of information is commonly used by professional engineers for assessing the feasibility of alternative proposals and represents a source of information for those who need to know but haven't the time or the inclination to get too involved.

There are a number of mechanical engineering design guides currently available but, in general, they cover the fine details of practical design and are intended mainly for professional engineers with years of experience. This book serves a complimentary purpose since it provides a necessary link between engineer and all non-engineering members of the design team. The information and data presented should be useful in most parts of the world since it is based on the constraints, criteria and the underlying spirit of commonly accepted design.

Heating, ventilating and air conditioning of buildings is a highly innovative and changeable industry that incorporates frequent technology shifts however the fundamentals, as discussed in this book, generally remain the same; comfort must be balanced against cost, functionality balanced against space restraints, complexity balanced against operator skills level and local technical capacity.

EDITORS NOTE TO THE READERS

To: Academics and Teachers,

Parlour is a living book, in a field of constant change, please provide the editor, with whatever feedback you think is appropriate for future improvement.

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Table of Contents

1. Overview

1.1. Integrated Design - all services

The design of building services systems for modern commercial buildings has become very complex. Not so long ago, the mechanical, electrical, and other services were fairly basic and could be readily understood by all those involved in the building's design. The engineering design process was mainly deductive, based on trial and error and past experience, with required technical information available from relatively simple design guides. In most cases, the building's design architect played a very predominant role, having overall control and coordination of most of the details associated with the total building design.

This scenario has changed since the development of modern building methods, high-tech building facade options and complex specialised engineering building services such as air conditioning, high speed lifts, fire and smoke protection, automatic computerised building monitoring and control systems, as well as complex security and communication and information technology systems. Computer software programs are now readily available to the consultant engineer which provide the precise engineering information required for optimal equipment selection and operation. Building energy simulation and energy consumption analyses are now very important and these can be carried out quickly and more accurately than earlier manual methods. As a result, the relatively large design safety factors, which were required in the past, are no longer necessary or acceptable to meet current regulatory minimum standards such as the National Construction Code and market criteria such as NABERS and Green Star building rating tools. The result is that modern buildings are more accurately designed and hence more cost effective but require a much greater degree of technical knowledge.

Other building services systems such as security, energy monitoring and emergency evacuation also require similar expertise. As a consequence, the architect has a different role to play with regard to design integration and coordination. Most large buildings are now designed by a coordinated 'design team' consisting of an architect and several engineering consultants, including ESD (environmentally sustainable design) experts, and WHS expertise; with each member being responsible for the detailed design of a particular part of the total design, but with the entire group responsible for integrating the individual parts into a whole building design solution.

Experience has shown that the effectiveness and quality of the completed building depends very much on the degree of mutual cooperation by the design team and how well the various components of the design have been brought together into an integrated whole. Modern software tools including Building Information Modelling (BIM) and virtual building analysis can facilitate the integration process. The processes followed to commission the building and its associated services are also essential to its ongoing performance.

The value of 'integrated' building design (also called integrated project delivery or IPD) is generally widely accepted. It depends on each team member having 'in-depth' knowledge of one component or discipline plus a realistic overview of the techniques, potential problems and constraints of the other team members/ disciplines. Mutual understanding and empathy is necessary between architect, structural, mechanical, electrical, hydraulic, acoustic engineers, project manager and quantity surveyor in order to achieve the best or optimum end result for the available resources. This book is intended to promote this aim.

1.2. The Building Design Stages

All building projects must be designed in accordance with the client's brief and overall budget constraints. Unlimited resources are never available, regardless of whether the client is private or public, and the projected cost of the building must be estimated (as accurately as possible) progressively from the very beginning of the commission. Cost estimates at the beginning of the project are partly based on experience and partly on educated or informed guesses. At any stage they are normally given on the basis of 'not more than but may be less than that provided estimate'.

In practice, it would be unwise to press ahead enthusiastically with detailed design on the assumption that an exciting building services scheme can always be adequately funded. In order to maintain an orderly design procedure, and a happy client, the total process is normally divided into three separate and progressive stages.

1.2.1. Feasibility Stage

The early, so-called, Feasibility stage is the most critical part of the design and hence should be given particular consideration. In practice, it is always more difficult to make a realistic inspired guess, based on approximate information, than one based on detailed designs. In most projects, feasibility estimates are required, within just a few days of starting the project, to ensure that costs will be within an acceptable range (say plus 0%, minus 15%). This means that the contracted final cost will be no greater than, and hopefully, less by as much as 15% of that estimated. The client can then decide, with some confidence, whether the project is economically viable or not.

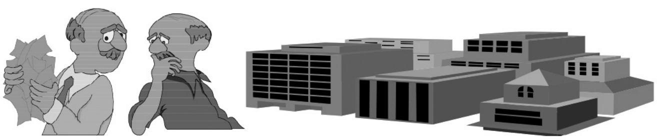
1.2.2. Preliminary Stage

Only after the design has been shown to be 'feasible' does work proceed to the next, so-called, Preliminary stage, which may cover a period of maybe a few weeks, resulting in preliminary drawings on which cost estimates can be based using more accurate information. After 'preliminary' approval of costs, the design can then proceed to the final detailed design stage.

1.2.3. Detailed design stage

It is during the so-called Detailed stage that accurate working drawings and specifications are prepared for final costing by a Quantity Surveyor. The detailed design stage can take several months or years, depending on the complexity and size of the project and include details required for development approval, building approval, building certification and statutory authority submission.

It is commonly recognised that design decisions made during the 'feasibility' stage are crucial since they tend to become 'locked-in' and form the basis for much subsequent work even though they may not be the best. This is also the most appropriate time for the team to investigate any major alternatives, based on the best approximate information available. Critical to this process is to fully understand the client's requirements for all areas of the project. Remember that the goal is to provide and deliver to the client requirement and perceived usage. It must be "fit for purpose" and provide a safe occupation.



Is the project feasible?

During the 'preliminary' and 'detailed' design stages, the various engineering problems can normally be analysed and solved using straightforward methods, based on well-established engineering data.

The use of "BIM" technology may be extremely useful to guide the detail process from design and construction through to ongoing building management.

The accuracy of the general design data in this book is intended to be about plus 0% minus 15%, i.e. consistent with that normally required for the feasibility and preliminary stages and is appropriate for all the team, particularly the architect. Precise technical design is best left to the mechanical engineering consultants.

This is also the stage where "Safety in Design" must be incorporated into the project for construction operations and post construction occupancy operations as defined.

1.2.4. Academic Studio Design

From a student architect's viewpoint, spatial planning in the design studio corresponds closely to the work carried out in the design office during the 'feasibility' and 'preliminary' stages. In both the studio and professional office a major effort is required to assess the proper location and arrangement of space within the project building. Allocation must cover that required for all human activities including that required for the installation and servicing of the mechanical and electrical plant. This relates to the practical 'buildability' and 'maintainability' considerations for the proposed scheme and the space that needs to be allocated to accommodate the building services can be a significant proportion of the total.

The 'integrated' design process is just as necessary in the academic studio as in the professional office. It requires the student to have an overall understanding of what building services are needed, a realistic estimate of the space required for each and its proper location within the building enclosure. Only then, can studio design be considered as a realistic answer to the design brief.

It is unnecessary for the architecture student to determine any precise details of the equipment to be installed but he/ she must be aware of the following:

- What performance outcomes does the client require for all areas of the building?
- What are the legislative requirements for development and construction. Planning Authority, National Construction Code and Referenced Standards.
- What are the regulation and market constraints, including the grade of services (e.g. Property Council of Australia guidelines), Commonwealth and State Government leasing and usage requirements, Green Star sustainability and NABERS criteria?
- What building services are actually required?
- How much space is needed for their proper installation?
- Where is this space best located within the building enclosure?

A break-down of the space requirements for such a typical office, as a percentage of the total volume is:

Service system	**Volume**
Mechanical	10%
Hydraulics	1%
Fire Protection	1%
Vertical Transport	3%
Electric Power	1%
Ceiling voids	10%
Total	**26% of the total volume**

For a relatively simple high rise office building, about a quarter of the building's total volume is required for services (refer to the Worked Example 4 at the end of this book). A greater amount would be required in a more heavily serviced building such as a laboratory or hospital. Note the large percentage (10%) of ceiling void space which may be needed to accommodate the ducts, lights, smoke detection, warning and evacuation systems, and associated pipes and cables at each floor. In high-rise building design, considerable effort takes place in order to minimise the vertical depth of the ceiling void space, in order to optimise the total useable area or number of floors. There are alternative ways of providing for horizontal services as discussed later in this book.

1.2.5. Plant Room Location

The plant rooms required for each service have particular requirements and need to be located in accordance with the criteria discussed in the following chapters. For many commercial high-rise buildings, a major plant room is commonly located at the top of a building in order to provide for the large supply of fresh air required and outdoor access for heat exchangers. Plant room space located above the top occupied floor normally has no or limited rental value but building regulations allow this space to be used for plant rooms (and it is discounted from the building effective height). In some cases, a single large plant room may not be appropriate and it can be more effective to have a number of smaller plant rooms located adjacent to the individual air-conditioned areas served.

Electric lift motor rooms are normally located at the highest point in the building but there are alternatives as discussed later. Sufficient over-run must be provided above the top floor served. The lifts may not have a requirement to have a stop at the plant room level, and the over-run may be accommodated within the air conditioning plant room height.

Electrical sub-stations are usually best located near the ground level in order to facilitate the removal of the very heavy transformers for maintenance. However, in some very high rise buildings substations may be required at an elevated level in the building. The main switch-room would normally be located fairly close to the sub-station.

Other than for building services; the building facade may require a roof mounted building maintenance unit (BMU) requiring significant roof space with dedicated parked location and interfacing with the facade.

1.3. Cost of Building Services

For an average quality high-rise office building, the approximate capital cost of the various services components as a percentage of the total building cost are: -

- **Mechanical (10%)** - Covering air conditioning, heating, and ventilating.
- **Hydraulic (2%)** - Covering DCW, DHW, sewerage, and waste plumbing.
- **Fire protection (2%)** - Covering detection and extinguishing systems.
- **Vertical transport (8%)** - Covering lifts, escalators and dumb-waiters.
- **Electrical (4%)** - Covering lighting, power, and emergency stand-by.
- **Management (1%)** - Covering communications, security, and monitoring.

In total, this represents about 27% of the total building cost. The percentage for a more heavily serviced building could be much greater. Architectural design and engineering consulting services can account for 5 to 15% of the construction cost depending oncomplexity.

A 'preliminary' cost estimate of each of these services may be made, based on past experience of only similar buildings, using typical $ per square metre of serviced floor area, relative to the proposed type of system to be actually installed.

The difficulty of presenting cost estimates in terms of normalised values such as $/sqm GFA or $/system capacity is that the diversity of commercial building quality and level of performance in combination with the individual range of mechanical and electrical systems and their respective controls, makes the range of quantification too wide to be of practical use with the data available in Australia. ***This is the reason for only presenting data as a % of build cost***, as the build cost tends to keep the services costs in proportion across the diversity of services performance and quality.

1.4. Mandatory and Market Requirements

The mechanical and electrical services that are actually required for the building are either mandatory or market driven.

- **Mandatory:** In this case the service must be installed in order to comply with the statutory requirements of the National Construction Code [NCC/BCA] (previously known as the Building Code of Australia with Vol.1 being for Apartments, Hotel, Commercial, Retail, Storage & Carparks, Factories & Laboratories, Assembly & Healthcare and Vol.2 for detached dwelling hoses and non-occupied structures) in conjunction with any other requirements of Federal or State regulation, Local Councils, Industrial Awards, Government Acts, Ordinances and Byelaws. The overall intent of the installation is specified by the relevant statutory regulation. These generally relate to minimum requirements for outdoor air ventilation, sanitary facilities, fire and smoke segregation, fire egress, fire control, smoke detection and emergency lighting, alarm and warning systems, but can also address neighbourhood amenity issues such noise or air pollution.
- **Market driven:** In this case the decision to install a particular service is based on an assessment of its **economic benefit**. Whether it can be justified or not depends on the current economic climate, the building owner's investment philosophy, and the occupant's expectations of comfort, safety and working efficiency. These considerations depend greatly on the type of building and its location. Whether the building is to be assessed under building grading and rating schemes such as the Property Council of Australia building grading, Green Building Council of Australia Green Star sustainability star ratings and Government NABERS energy, water, IAQ and waste star ratings is also a market driven decision.

For example, a modern commercial office block in the CBD would almost certainly be fully air conditioned whereas a similar building, in a different location might not be. Justification also depends on whether the client is a developer or an owner/occupier. A developer would normally be more concerned with the initial capital cost whereas an owner/occupier would take a longer term view of capital costs versus total annual owning costs or the full building life cycle costs of construction, operation and maintenance, and even demolition or decommission may be included. High-quality, low-maintenance, energy efficient building services generally require more space accommodation and represent a higher capital cost, but they are easier and cheaper to operate and maintain.

Any building service system, whether mandatory or market driven must comply with the requirements of the BCA and other relevant Australian Standards and applicable Codes of Practice. The quality (and hence cost) of the equipment to be installed should be consistent with the general quality of the building and the total funds available. Any equipment installed additional to the mandatory requirements is a market decision for the client and some of these considerations are covered in the various chapters of this book.

In general, the following applies to building services:

- **Air conditioning –** Fresh air ventilation is mandatory in all occupied buildings. Heating is mandatory in most commercial, trade and public buildings, but not in domestic dwellings. Summer-time cooling and dehumidification by air conditioning is generally market driven and requires justification in all types of building.

- **Vertical transport** – Emergency lifts are mandatory in buildings higher than 25m and those used for multi-storey health care. The number and quality of other passenger lifts, escalators etc. is market driven and requires justification.
- **Electrical power** – Emergency lighting is mandatory in buildings higher than 12m. The extent and quality of the electrical power distribution system is market driven.
- **Fire protection** – These services are generally mandatory, and their extent depends on the type and size of building. In some cases, there could be a market driven justification for installing a fire protection service even though not mandatory. The BCA requirements for fighting fire inside and outside the building, the need for smoke detectors, internal hydrants, external hydrants, hose reels and sprinklers are covered later in this book.
- **Water supply** – The extent and quality of water supply systems are generally market driven.
- **Sanitary facilities** – These facilities are mandatory, and their minimum extent depends on the type and size of building.

1.5. Integrated Project Delivery - all services

Integrated design collaboration harnesses the talents and insights of all project participants to optimise design efficiency through all phases of a project allowing all design team members to realise their full potential and expand the value of the services they provide throughout the project lifecycle. Integrating the design of building services, including HVAC, into an integrated building design and delivery process means that HVAC must be considered at all design and implementation stages of a building project.

In the first instance there is a direct relationship between building architecture, and building cooling and heating loads and the integration of both passive and active solutions for HVAC. Early design decisions such as building orientation to sun and prevailing wind, building shape and massing, the level and type of fenestration, facade materials and methods of construction all have a significant effect on heating, cooling and ventilation systems. The less shade that the glazing has, the less thermal resistant the materials are, the leakier the façade is, the bigger the need for HVAC and the more difficult it is to stabilise and control indoor environment quality.

Building physics requires detailed consideration of the materials used and the methods of installation of the individual fabric elements. Design choices can influence the thermal properties of the structure which influences heat flow and thermal storage and the level of sealing or permeability of the building fabric which influences infiltration of outdoor air and exfiltration of indoor air and affects the controllability of indoor airflows. Integrating the architectural design and materials choices with the building's HVAC needs at the early design stages can provide optimised energy efficient buildings.

Integrated project delivery requires early communication between design professionals on a range of HVAC related architectural issues including spatial requirements for plant and distribution systems, structural requirements for plant weight and service penetrations, and access arrangements for both the initial installation and ongoing maintenance. Early collaboration between architects, structural engineers, services designers, fire engineers, builders and building operators in the design process helps to provide integrated solutions with a whole-of-life perspective.

Often HVAC services can be provided by hybrid and mixed mode solutions. Combining architectural passive solutions such as labyrinth cooling or atrium natural ventilation with mechanical systems that operate only some of the time can provide low cost and robust building solutions and resilient buildings.

Modern design tools such as building simulation and Building Information Modelling (BIM) lend themselves well to integrated project delivery. Designs can be shared more easily within the design team and changes can be tracked and controlled which reduces rework time for all. Integrating project delivery with BIM produces a range of efficiencies within the building delivery process as leveraging these design tools forces participants into greater collaboration that was historically the case. Leveraging BIM tools correctly means that all designers work from the same BIM "Model" and that information is carried through the construction process into the operation and maintenance phase of the building life-cycle all the way through to decommissioning, retrofit and refurbishment.

1.6. Whole of Building Life Time Costs - all services

The initial capital outlay in building procurement is usually clearly defined and is often a key factor influencing the choice between alternative assets. There are, however, other future costs that should also be considered if the best outcome is to be achieved. The process of identifying and documenting all the costs involved over the life of an asset is known as life-cycle costing (LCC). It is important that the design team focus on minimising the whole of building life time costs and the need to consider future costs associated with the building, including maintenance, operational and energy costs associated with the long-term use of the asset. Often the lowest capital cost solution represents the highest operational costs and a balance needs to be struck.

1.7. Commissioning - all services

Commissioning is a comprehensive process for the planning, delivery, and verification of buildings and their systems. Commissioning involves peer review, quality control and risk management; it assures all building systems perform interactively according to the design, specification, and owners' operational needs. Commissioning means integration meetings, system surveys and tests, resolving issues, documenting the process, and verifying and reporting at each stage. Effective commissioning requires the following fundamental principles to be incorporated:

- •Determine the project performance requirements.
- •Plan the commissioning process.
- •Complete commissioning in accordance with the plan.
- •Document compliance and acceptance.

The commissioning of building systems fulfils three roles:

1 Set up and test systems to ensure they will operate reliably, and as the designer intended, to provide the specified internal comfort conditions;
2 Record system settings and base operating attributes or data (e.g. airflow's, water flows, temperatures etc.) to verify system performance and provide documentation for future reference; and
3 Provide handover briefing and or training for building system maintainers and operators.

For regulatory compliance the commissioning and testing of building services is required for certification and would typically follow the three steps below for a typical high-rise commercial building:

Step one – commissioning phase

- Verify that the installation complies with the approved plans and specifications.
- Carry out commissioning of individual installations by the contractor.
- Document commissioning data and results (baseline data).
- Inspection and report by relevant consultant.
- Independent certification by commissioning manager.

Step two – verification phase

- Inspection of installations by the approving authority.
- Witness of tests by the approving authority.
- Integrated testing of complete installations/whole-building testing.
- Fault rectification and re-certification.
- Reinspection and testing.

Step three – sign off phase

- Labelling, identification, signage, tactical fire plans, etc. are in place
- Submission of test reports, component information, as built drawings, commissioning reports, consultant reports and independent certificates to the approving authority.
- Inspection and report by the fire engineer.
- Witness that on site documents are provided.
- Final approval leading to project sign off.
- All must be provided in the vetted and principal approved "Operations & Maintenance Manual" (O&MM) prior to the provision of the Occupation Certificate.

The discovery of poor quality or non-compliant installations can lead to litigation and practitioners can be disciplined for any inappropriate actions by the relevant State/Territory Regulatory Authority.

To meet increasing performance requirements and environmental and energy standards building systems have become more complex and interdependent, and increasingly integrated with the building's physics and the occupant's behaviour. To deliver the required performance outcomes buildings and their systems must now be commissioned with a more sophisticated and integrated approach which includes post occupancy evaluation and an extension of the time and focus of commissioning to help fine-tune the building as it moves into its operational phase.

1.8. Post Occupancy Interventions - all services

1.8.1. Post Occupancy Evaluation

Post occupancy evaluation means evaluating the actual performance of the building after a significant period of normal occupation has passed. Evaluations generally concentrate on the two critical areas of the operating performance data of the building systems, and the occupant satisfaction level.

Evaluation activities include surveying occupants regarding their comfort and satisfaction levels and checking set points and schedules to determine system energy and water consumption, maintenance needs and costs, data logs for key performance indicators and the like. Building operators, tenants, occupants, and maintenance providers should all be included in the survey. Periodic evaluation sheets can be issued to determine if there are any new or emerging issues within the building and its systems.

During the post occupancy period, it is important to maintain a log of tenant complaints to determine where problems exist. This can be monitored and addressed by the building tuning team.

1.8.2. Building Tuning

Building tuning is a systematic approach to identifying and correcting building system problems and maintaining an optimised system performance. Seasonal testing, data monitoring, performance trending, condition monitoring, and proactive maintenance techniques are employed to identify systems or plant that may require attention. Initial building tuning is carried out as part of the initial building commissioning process. Ongoing building tuning is also carried out to ensure continued optimised performance and maintain optimum outcomes. Building tuning can include:

- Establishment and monitoring of energy use benchmarks.
- Establishment and monitoring of water use benchmarks.
- Establishment and monitoring of non-resource benchmarks such as complaints or maintenance calls.
- Energy tracking and evaluating key performance indicator data trend logs.
- Preventative and predictive maintenance techniques.
- System optimisation techniques.

1.8.3. Recommissioning - all services

Recommissioning is the commissioning of existing buildings and systems that have already been through the commissioning process. These systems are generally tested using the same methods and focus as was used in the original commissioning process. Recomissioning is not intended to be a repeat of the entire commissioning process; rather it is a review of the building and system performance to ensure that the original criteria are currently being achieved. This may require a review or repeat of some of the original commissioning test methodology.

1.8.4. Retrocommissioning - all services

Retrocommissioning applies to buildings that have never been commissioned and buildings or systems that have been significantly updated or altered.

Retrocommissioning is not always applied to the whole building. Particular plant or systems may be the focus depending on the project objectives. Systems are generally tested using test methods and procedures developed specifically for the project.

1.9. Property Standards, Client Expectations and Building Use

Various organisations including the Property Council of Australia (PCA) and the Australia Property Institute (API) produce property standards to assist with grading and valuing commercial property.

The PCA standards include a grading system for commercial office space. This grading system, while voluntary, is almost always reflected in the rents a building manages to command.

Some of the criteria used in grading a building include the following:

- Access – all commercial, retail, healthcare and assembly developments must make provision for the impaired.
- Environmental - the top three grades must have high environmental credentials such as Green Star ratings. This means all new buildings must be submitted for environmental ratings to be graded at all.
- Configuration or size - to gain Premium grade the building must be bigger than specified minimum areas in Sydney or Melbourne and other CBDs. A-grade buildings must be bigger than specified minimum areas and the floor plate also has to be a given size.
- Mechanical - this relates to air conditioning, tenant equipment and building intelligence systems - premium and A-grade buildings must have full building management control systems (BMCS).
- Lifts - premium and A-grade buildings must have lifts.
- Building management – premium and A-grade buildings must have management on- site for buildings larger than specified minimum areas.
- Security – (with CCTV systems necessary to gain premium, A-, or B-grade) amenities (change rooms and showers in premium and A grades), and
- Parking - which must include a carpark and loading docks or delivery bays for premium or A-grade buildings.

The result is that premium grade buildings are landmarks with expansive views or outlook, ample natural lighting, prestige lobby and finishes, high quality access from an attractive street setting and are subjected to premium maintenance procedures.

A-grade buildings are high quality with good views, outlook and natural light, good quality access from an attractive street setting and high quality maintenance.

C- and D-grade buildings can earn higher grades if they are refurbished according to the criteria listed in the guide.

The API standards outline a set of principles for good valuation practice that are accessible and useful to valuation users and others interested in valuation.

1.10. Building Controls

1.10.1. Controls for Building Services

Controls and control systems are fundamental to how a building works and how individual building systems or services operate. The rapid development of digital controls and the information technology revolution has changed all aspects of how modern buildings and their systems work. Professionals, managers and technicians within the building industry may find it difficult to stay up to date with the latest functionality and capability of digital and computerised controls systems.

Building management and control systems (BMCS) are not items that can be taken out of a box and plugged into a building. Rather they are the brain of the building that must be connected to all of the senses (sensors and monitors) and all of the muscles (equipment, motors, actuators), before the BMCS is considered truly formed. These systems play a fundamental role in the buildings operational performance.

1.10.2. Integrated Controls for Smart Buildings

Modern buildings are made up of multiple networks and individual control systems for HVAC, lighting, electrical, lifts, CCTV, fire, telecommunication, information technology and access control. With the technology currently available, there are opportunities to integrate these control systems onto a common network, operating system, and/or data gathering platform.

There is also an increasing convergence between building control systems and building IT systems. This convergence opens up opportunities to integrate building and HVAC control systems with other business-oriented software such as Computerised Maintenance Management Systems, Building Information Models, financial management systems and the like. Issues to consider regarding systems integration include at what level to integrate, how to achieve integration, and the potential benefits and risks associated with integration.

1.11. Regulations for Buildings

1.11.1. Building Regulations

When Federation of Australia occurred in 1901, the Constitution was formed and agreed to by the six States at the time. The Federal Government gained specified powers under the Constitution such as national defence, taxes (income tax came later), foreign policy and international affairs. The States retained all other powers. These state powers included, law and order (police force), roads and transport and amongst other things, building control.

Initially the State and Territory Governments shifted the responsibilities of building control to the local Councils, via Council by laws and rules. However, as the varying rules and by laws became confusing between municipal boundaries the State Governments systemically 'unified' these laws into a standard law with Councils still providing the enforcement facility.

A 'law' at either Federal or State/Territory level can only be enforceable through the introduction of an Act of Parliament. In the case of building control, a law is enforceable via an Act of State/Territory Parliament.

Three (3) factors govern building control:

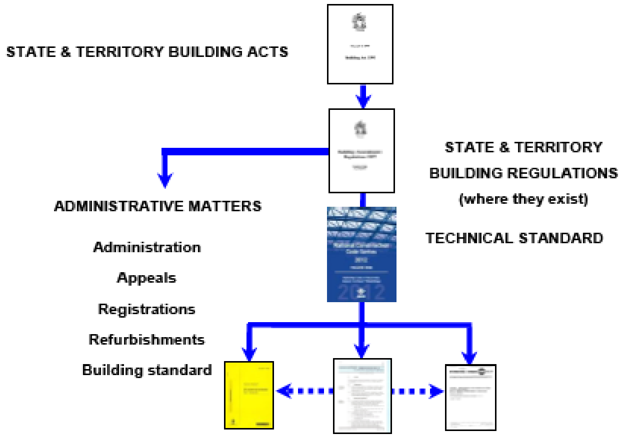
- The law (Act);
- Administration (Regulations); and
- The actual requirements (codes and standards).

1.11.2. State and Territory Building Controls

Generally, all jurisdictions (State and Territories) require a staged development and building approval progress. Generic state and territory building controls comprise of the law (Act) and administration (regulations).

The Act outlines what is required and the Regulations specifies the detail of what is required.

For example, if the Act that says that a mechanical services design must be prepared by a licensed, registered or accredited practitioner, it is the Regulations that describe the types of practitioners and the requirements applicable to each category. The Act and Regulations are specific to each state however the actual detailed requirements are largely uniform and harmonised by reference to the National Construction Code (NCC) which contains the Australian building and plumbing codes. NCC requirements ensure that buildings are structurally sound, able to provide the basic living necessities (e.g. toilets, bathrooms and kitchens), ventilated to provide adequate air quality and control objectionable odours, and keep occupants and others safe from various hazards such as fire and smoke risks or microbiological disease risks.



The usual stages for commercial development are (each individual state and building Act needs to be referenced for specific detail):

- Development approval from local council;
- Building or construction approval, from local council or accredited private certifier; and
- Compliance, completion or occupancy approval from local council or private certifier.

From a services perspective the NCC requirements in the following areas must be addressed.

1.11.3. NCC as the Minimum Standard

It is important to understand that the intent of this document is to "enable the achievement of a nationally consistent minimum necessary standard of relevant safety, health and amenity and sustainability."

This means the NCC has no role in property or contents projection - other than safe guarding the occupants, emergency services, personnel and neighbours. If the building and contents needs to be preserved for commercial, functional or other reasons, construction and services may have to be included, in addition to the minimum NCC requirements e.g. many WHS mandated requirements are not mentioned in the NCC.

1.11.4. NCC System of Building Classification

The key to understanding and application of the NCC/BCA set of documents is to identify the appropriate classification for a building – refer to part A3 of NCC Volume One, for example, an office building (see detail in section 5.1.4) is a "class 5" building.

The building classification, along with the effective height are the principal linkages leading to fire safety requirements for normal commercial buildings to which designers of structure and services must provide compliant design.

1.11.5. Performance Based Building Regulations

The NCC regulations are "performance based". In order to satisfy the requirements of the NCC the building and its services can meet the "deemed to satisfy" specification in the NCC via associated referenced standards, or meet the performance requirements as quantified in the NCC with methodology as described in Part A0 Application, see A0.4 to A0.10.

Volume 1 (Residential houses)

- Part G2 Heating appliances, fireplaces, chimneys and flues
- Part J5: Air conditioning and ventilation systems

Volume 2 (Commercial and high rise residential)

- Part C1 Fire resistance and stability - Fire hazard properties;
- Part C3 Protection of openings - Openings for service installations;
- Part E1 Firefighting equipment - Fire control centres;
- Part E2 Smoke hazard management -Smoke and fire control;
- Part F2 Sanitary and other facilities - Microbial (Legionella) control;
- Part F4 Light and ventilation - Ventilation of rooms, carparks and kitchen local exhaust;
- Part G3 Atrium construction - Smoke control;
- Part I1 Equipment and safety installations – Essential services;
- Part J5 Air-conditioning and ventilation systems – Heating, cooling, air conditioning and ventilation systems.

The core standards that HVAC systems are most commonly designed to, and certified against, include AS/NZS 1668.1 (Fire and smoke control) and AS 1668.2 (Mechanical ventilation), AS/NZS 3666.1 (Microbial control) and AS 4254.1/.2 (Ductwork). The Australian wiring rules (AS/NZS 3000) and the plumbing codes (AS/NZS 3500) are also important standards for the industry. The NCC references more than 90 standards and many of those reference standards themselves have secondary references (which must be applied, including year versions, even though not necessarily directly referenced by the NCC). These technical documents form the regulatory architecture under which building services design professionals operate.

1.12. Regulations for Building Services

1.12.1. Mechanical and Electrical Services Regulations

A range of legislation and regulation is applicable to HVAC&R (heating, ventilation, air conditioning and refrigeration) and technical service providers must familiarise themselves with all the legal and procedural requirements of the jurisdiction in which they operate. Applicable regulated areas include, building and planning, public health, WHS/ Occupational Health and Safety (OH&S), environmental controls, or other legislation including requirements relevant to the provision of access to systems for maintenance and the delivery of essential service maintenance.

The building services industry operates under the following regulatory requirements and regimes:

- Building regulations - NCC requirements and various state based administration systems.
- Planning regulations - local government-based planning or development consent conditions.
- Environmental regulations - Ozone/SGG regulations, environmental noise and air pollution.
- Energy regulations - Commercial Building Disclosure and MEPS/GEMS.
- Electrical regulations – AS/NZS 3000 and appliance/equipment electrical safety standards.
- Plumbing regulations - Including NCC Volume 3, AS 3500 series, and sewage acts etc.
- Licensing regulations - for refrigerant handling through the Australian Refrigeration Council.
- Health regulations - Indoor air quality, microbial control, WHS/OH&S regulations.
- Safety regulations - Essential services, inspection, testing and maintenance.

1.12.2. Planning Regulations and Building Services

There are a range of planning regulations, imposed by state or local government in addition to building regulations that can impact on HVAC&R. For example, some localities include controls on roof colour (cool/white roofs), roof mounted plant, location restrictions, restrictions on specific refrigerants (ammonia or hydrocarbons) as well as noise controls (cannot disadvantage neighbors) and other environmental controls.

1.12.3. Essential Safety Maintenance Regulations

Most States and Territories have regulations applying to essential services maintenance and from a building services perspective this includes:

- Smoke and thermal detection systems;
- Emergency warning and communication systems;
- Fire and smoke control systems;
- Fire and smoke dampers installed on air distribution systems;
- Hydrants, hose reels, fire mains, pump sets, and static water supplies;
- Sprinkler systems;
- Emergency lighting and illuminated exit directional signs;
- Lifts (including emergency lifts).

Fire safety aspects of HVAC and ventilation based smoke control systems must be inspected and tested annually to ensure compliance. Australian Standard AS 1735.2 (Lifts) AS 1851 (fire protection), AS/NZS 2293.2 (emergency lighting) and AS/NZS 3009 (Emergency Power Generator) defines maintenance of Essential Fire Safety Measures and ongoing certification that Fire Safety Services work properly at the time of commissioning and every year after. The Four elements of maintenance are:

- **Inspection:** Visual examination to establish correct settings, physical condition or fitness for purpose.

- **Test:** Confirmation of correct function or performance of a component or system
- **Maintenance:** (Preventative Maintenance) Actions including lubrication, cleaning, adjustment and replacement of component at a predetermined frequency to minimize the incidence of breakdown.
- **Survey:** Visual inspection to identify if fire protection systems or equipment have been altered, damaged or compromised.
- **Report:** These are coupled with records to be kept and reports to be made and culminating in the issue of a final condition report with such records being retained at site and auditable. Many states require annual sign-off that this work has been completed and designers need to provide adequate access to plant and equipment to ensure that the ongoing certification can be readily carried out

1.12.4. Building Services Health-based Regulations

The other area of HVAC&R maintenance that is regulated by states and territory administrations is maintenance regimes for microbial control. The most common sources for biological contaminants in HVAC systems are the outdoor air and the return air. Other sources of biological contaminants result from water ingress, excessive moisture, excessive condensation or the infiltration of nutrients (dust) onto HVAC component surfaces. Whenever there is enough moisture and nutrients, biological contaminants can thrive.

Present-day research on microbiological aspects of indoor air quality tends to concentrate on fungi. Fungi produce a variety of compounds, and all are potentially antigenic and allergenic. In most cases, sensitization to antigens (and allergens) occurs via the airborne route. Two types of disease that are caused by airborne fungal antigens are allergic disease (asthma and rhinitis) and hypersensitivity pneumonitis.

The main problem with bacteria in HVAC systems occurs when there is stagnant water. Blocked drain pipes or pans and biofilm formation on cooling coils and condensate pans are major sources of bacterial contamination. Airborne bacteria are generally transmitted to building occupants when they inhale aerosolised water or particulates. Legionella, Pseudomonas, Salmonella and Enterobacteria are all gram negative bacteria.

Aerosolisation of Legionella from cooling towers can cause Legionnaires' disease so Legionella presents a significant health hazard for the industry. Legionnaires' disease is a respiratory illness which affects the lung and which may resolve without specific treatment. On the other hand, cases may be severe and pneumonia may be accompanied by involvement of multiple organs usually brain, kidneys, liver and bowel giving rise to symptoms of mental confusion, renal and liver failure and diarrhoea. Legionnaires' disease can be fatal.

The risk associated with that hazard may vary widely from insignificant (as in Legionella presence in rivers, rainwater and the like) to substantial (as in water supplied to baby humidicribs, misters in supermarkets and cooling water systems that generate aerosol). About 300 cases of Legionnaires' disease in Australia are notified each year. The number of cases is apparently increasing but this is probably due to improved medical diagnostics rather than to greater prevalence. Based on several epidemiological studies it appears the true number of cases is probably ten times this rate as many cases go unnoticed or are sub-clinical, i.e. the patient is barely aware of the infection, and it does not lead to illness.

Most States and Territories have health based legislation and regulations intended to control the occurrence of Legionellosis in the built environment. The Public Health and Wellbeing Act 2008 (PHWA) in Victoria and the Public and Environmental Health (Legionella) Regulations 2008 in South Australia New South Wales has the Public Health Act and Regulations with all of these regulating the design, operation and maintenance of cooling towers and cooling water systems., Western Australia, Tasmania and the ACT also have health legislation in this area while Queensland regulations operate under workplace health and safety legislation.

Food regulations cover appropriate storage temperatures for foods as well as requirements for the construction and operation maintenance and cleaning provision of food premises (see AS 4674 Construction & fitout of food premises). Restaurant kitchens for example are an ideal environment for mould growth, fatty or oily build up, and dirty duct work.

Food premises, fixtures, fittings, equipment and transport vehicles are required to be designed and constructed to be cleaned and, where necessary, sanitised. Premises are required to be provided with the necessary services of water, waste disposal, light, ventilation, cleaning and personal hygiene facilities, storage space and access to toilets.

1.13. Energy Based Regulations

1.13.1. Commercial Building Disclosure

The Commercial Building Disclosure (CBD) scheme is a national program designed to improve the energy efficiency of Australia's large office buildings by requiring certain owners and tenants to disclose the actual energy performance of the office space at the time of sale or lease. The current CBD program was developed by the Australian, state and territory governments under the National Strategy on Energy Efficiency. The CBD program is delivered by the Australian Government and established by the Building Energy Efficiency Disclosure (BEED) Act 2010.

Commercial Building Disclosure, at the time of publication, applied to net lettable areas of 2,000 m^2 or more and to:

- Building owners who are selling or leasing office space, and
- Tenants who are subleasing part of their office tenancy.

Under the CBD program, owners or lessors of office space of 2,000 m^2 or more are required to disclose an up-to-date (less than one-year-old) Building Energy Efficiency Certificate (BEEC) if they wish to sell, lease or sublease that space. The star rating communicated on a BEEC will be a NABERS Energy rating – either a base building rating or whole building rating if a base building rating is not possible. The NABERS Energy rating that must be disclosed on the BEEC cannot take into account any Green Power purchases.

1.13.2. NABERS Ratings

NABERS (the National Australian Built Environment Rating System) is a government developed tool that can be used to measure and compare the environmental performance of a building against its market peers. NABERS provides an accurate, comparable measure of a building's performance rated against a set of benchmarks developed using national building performance data.

NABERS tools rate the measured operational energy and water efficiency, indoor environmental quality and waste recovery characteristics of the building or site. Performance is listed on a 6-star scale, with 3 stars representing average performance. A 6-star rating demonstrates market leading performance, while a 1-star rating means the building is performing well below average market practice and has considerable scope for improvement.

1.13.3. Minimum Energy Performance Standards

Governments in Australia and New Zealand work cooperatively through the Equipment Energy Efficiency (E3) Program, to increase the energy efficiency of new appliances and equipment which are supplied into the market. The aim of the E3 program is to increase the average energy efficiency of equipment sold, increasing energy productivity and therefore competitiveness, reducing energy bills for consumers, and reducing greenhouse and other environmental emissions.

Minimum Energy Performance Standards (MEPS) programs are mandatory in Australia and New Zealand. MEPS are enforced by state government legislation and regulations in Australia (called GEMS) and national regulations in New Zealand applicable to the relevant Australian or Australia/New Zealand Standards. In addition to the MEPS program single phase non-ducted air conditioners for household use are required to carry an energy label in Australia and New Zealand.

For air conditioners, the measure of energy efficiency is the Energy Efficiency Ratio (EER) for cooling and the Coefficient of Performance (COP) for heating. The EER and COP are defined as the capacity output divided by the power input based upon the tested power input and the tested capacity output when tested in accordance with AS/NZS 3823.

1.14. WHS Regulation

WHS/OH&S regulations include the management of risks in the provision and maintenance of safe plant and structures. Work Health and Safety/Occupational Health and Safety regulations have a big impact on the HVAC&R industry which itself has a big impact on the WHS of others. People are generally not aware of the impacts the HVAC&R industry has on the WHS of others. In addition, the specific requirements of WHS legislation and regulation, and particularly compliance methods, are not well understood by practitioners within the HVAC&R industry

WHS impacts and responsibilities in the area of HVAC&R building services industry include:

- Indoor Air Quality including the provision of adequate mechanical ventilation where required for buildings and the hygienic maintenance of all HVAC&R systems.
- Fire and smoke control including the design and installation of fire protection measures within HVAC, smoke control systems and essential system ongoing testing and maintenance.
- Cold chain/Food processing including the design, installation and maintenance of refrigeration systems throughout the food supply chain, farm to plate.
- Energy and the environment including the energy consumption of building HVAC and the correct and safe management of environmentally harmful substances.

Specific WHS issues and challenges that the HVAC&R industry practitioners encounter in their work, in addition to the general duties assumed by employers and supervisors, include:

- Safety in design requirements and the WHS duties of equipment and system designers and suppliers, including pressure vessels in refrigeration systems and boilers.
- General safety in the construction and plant maintenance industries, e.g. safe work method statements. Construction sites and equipment plantrooms are our workplaces.
- Working with toxic or flammable substances, e.g. safe use, handling and storage of the refrigerants used in air conditioning and refrigeration systems.
- Working in confined spaces, e.g. servicing plant in concealed basements, ceilings, roof spaces and inside cooling towers, large boilers, large tanks etc.
- Working at height, e.g. servicing roof-mounted plant.
- Working from elevated platforms, e.g. servicing roof-integrated high level fans.
- Working with dangerous plant, e.g. large boilers or gas-fired electricity generators.

WHS regulations impose duties on designers, manufacturers, importers and suppliers of plant, in order to ensure health and safety in respect of subsequent use of plant. It imposes duties on people that commission plant or structures to comply with designer or manufacturer information, and relevant health and safety instructions in doing so. It imposes complementary duties on people with management and control responsibility of plant, as well as imposing a range of additional control measures for specific types of plant. It provides for the registration of plant and plant designs, and imposes additional duties in respect of plant and plant designs that are required to be registered.

1.15. Environmental Regulations

1.15.1. Regulations on Environmental Protection

Regulations controlling air conditioner, diesel generator, co-gen and gas engine noise, air and water pollution are common in most jurisdictions. Typically, regulations are developed at state government level and administered by local councils.

- AS 2107 Acoustics - Recommended design sound levels and reverberation times for building interiors
- AS 1055 Acoustics - Description and measurement of environmental noise - General procedures
- EPA Acts and regulations (varies by state and territory).

1.15.2. Regulations on Ozone Protection and SGG

The Ozone Protection and Synthetic Greenhouse Gas Management Act 1989 (modified in 1995) was established to meet Australia's obligations under the Vienna Convention and the Montreal Protocol and later to include Australia's obligations under the Kyoto Protocol. These protocols aim to bring countries around the world together with the common goal of reducing the use of Ozone Depleting Substances (ODS), which deplete the world's protective ozone layer, and synthetic greenhouse gases (SGG) which have a high Global Warming Potential (GWP).

Many substances used as refrigerants, the working fluids for vapour compression based refrigeration and air conditioning systems, are ODS or SGGs which have a high GWP. The Regulations contain provisions to authorise people who have proven themselves competent and qualified to obtain a licence which allows them to work with refrigerant and refrigeration and air conditioning equipment. The licensing scheme is administered by the Australian Refrigeration Council (ARC) on behalf of the Department of Environment.

Ozone depleting refrigerants (CFC and HCFC) have been phased-out and SGG refrigerants which have a high GWP are going to be controlled and phased-down in the near future. It is because of this that the industry is transitioning to low GWP refrigerants including natural refrigerants and fourth generation synthetic refrigerants (HFO).

1.15.3. Green Star Environmental Ratings

The Green Building Council of Australia launched the 'Green Star environmental rating system' for buildings in 2003. Green Star rating tools help the property industry to reduce the environmental impact of buildings, improve occupant health and productivity and achieve real cost savings, while showcasing innovation in sustainable building practices.

Green Star rating tools are currently available for a variety of building sectors, including commercial offices, retail centres, schools and universities, multi-unit residential buildings, industrial facilities and public buildings. Rating tools can be applied to the design, construction, interior fit-out, and operating performance of buildings. Rating tools can also be applied to precincts or communities.

1.16. Facilities Management Considerations

1.16.1. Maintenance Issues

Facility managers are the professionals that operate buildings that architects and engineers design. Buildings consume significantly more resources over their life time than is expended in their construction. Whilst it is the designers job to provide the most efficient and effective plant, it is the facility managers job to provide the services to end users at an acceptance level of quality and availability. This objective can only be achieved when designers of services and equipment installation have maintenance as a major criterion.

1.16.2. Strategic Issues

There are two aspects to the facility managers' role; strategic and operational. Because business decisions can be made much quicker than real estate can respond, it is necessary to look ahead at the purpose of the facility and how it contributes to the user organisation's mission. There is also the issue of planning the long term but inevitable replacement of fabric, plant and equipment that is subject to wear and tear. This might involve establishing a sinking fund to accumulate the necessary finance.

1.16.3. Operational Issues

The operational issues are those that involve day to day running including observance of statutory obligations of building ownership. Annual fire safety, pressure vessels, lifts require annual inspections, documentation and certification. Cooling tower and air handling systems require assessments, checking and treatment necessary to prevent the development of legionella.

It is presumed that the services engineer and architect have considered the question of access for the maintenance technicians to the plants and equipment. Not only must the technicians be able to access any of the plant, ducts, pipes and cables, but there must also be adequate space for their equipment and tools. The positioning of plantrooms and the ability to remove and replace major items of equipment, such as chillers, motors and air handling units, might require cranage, access to large openings in the envelope through which to pass the equipment, or for access by fork lift trucks or similar. Heavy pieces of equipment should be able to be lowered onto the back of a truck.

1.16.4. Knowledge Transfer

The major operational costs are utility bills, repairs and maintenance (R&M), cleaning and security. It is essential to transfer the design intent as necessary operational knowledge to the staff who will be in charge of the buildings operation. This means a comprehensive set of as built drawings, hopefully in electronic 3D + form (BIM), a description of the way in which the building was designed to operate, commissioning settings and maintenance manuals. It is particularly important to explain how the controls systems are intended to work and an understanding of what the operator should not attempt without professional advice.

In NSW, the EP&A Act'79 cl.6.27 has mandated that an Occupation Certificate may not be issued until the building owner has been provided with a building manual which they have reviewed and approved. We understand that this clause has been ignored by inept Principal Certifiers to date.

1.17. Repairs and Maintenance

1.17.1. Maintenance Costs

The Australian Tax Office allows 2.5% of the capital cost of a building used to generate income to be depreciated. That is, there is recognition that wear and tear takes place and requires and investment of 2.5% of the construction costs to be expended annually to keep it in pristine condition. However, few organisations spend as much as 1.75%.

In order to keep track of maintenance it is first necessary for the facility manager to have an asset register. This is a list of all items of plant that require maintenance and have details that include a unique identification code or number, make and model number, date of purchase, date of expiry if warranty, power rating (where appropriate), capacities, economic/service life expectancy and other relevant information. Most organisations will have an 'asset register' but this has usually been set up by the finance department in a structure designed for other reasons and is unsuited to aid FM operations.

This is complimented by a condition register that ought to distinguish between at least three categories; operational, awaiting services and non-operational. This database should include the histories of past maintenance particularly the date of last service and the name of the service contractor.

There should also be a schedule of maintenance tasks that each asset requires and the frequencies at which these activities should be carried out. Such actions might be daily, weekly, monthly, annually, or be based on time run.

1.17.2. Preventative Maintenance

Maintenance is managed by organising planned or programmed maintenance and having provision and capacity to deal with emergency maintenance as and when it arises. Programmed maintenance, particularly statutory requirement - follows from the list of maintenance tasks alluded to above. These tasks when programmed into a calendar allow an appropriate budget to be estimated and capital replacements foreseen. The maintenance programme should include not only for plant and equipment, but also for building fabric. i.e. check on flashings and waterproofing; repainting, etc. The programme might provide for checking 10% of the fabric every year, in a ten-year cycle.

Usually, particularly for government agencies that are concerned with due process, maintenance contracts are sent out to three sources for tendering. The facility manager would do well to include realistic and measurable Service Level Agreements (SLA's) that reward good performance and penalise bad. (This can be linked to ISO 9000 quality assurance procedures). There is also consideration for non-government organisations to periodically 'go to the market' to check that they are obtaining value for money. It is important that the contractor keeps records and data and lodges it with the facility manager and, it is added to the condition register.

1.17.3. Condition Based Maintenance

An effective variation of programmed maintenance is a condition based maintenance. Here, equipment is regularly inspected, but maintenance initiated only after its performance has dropped to a pre-defined level. Examples of conditioned based maintenance include chemical analysis of oil to monitor the build-up of metallic particles to provide details of rates of wear; vibration analysis to determine the wear on bearings; thermal tomography of electric circuits to identify hot spots, etc.

Obviously, emergency maintenance is happenchance and can only be predictable after time by statistics of occurrence in any one building. Emergency maintenance that has a safety implication has to be dealt with immediately.

1.18. Defining the Building Services

1.18.1. Project Operating Requirements -all services

The owner or client is responsible for defining the overall functional requirements of their building. The Project Operating Requirements (POR) is a document that clearly outlines the operational and performance requirements for systems and building. The POR is typically developed by the owner to allow the architect and services consultants to design and develop a building that meet the requirements detailed by the owner. It is advantageous for the owner to seek advice from their facility management team to help incorporate building critical requirements that will assist the building in meeting any performance targets.

The information typically outlined in the POR would include:

- Building location, size and classification (including multiple classifications).
- Occupancy numbers, population type, hours of occupancy, type of activity.

- Thermal Comfort (operating temperatures and humidity limits) for each area.
- Acoustic performance – both internal and external.
- Lighting requirements – both natural and artificial.
- Equipment loads and processes within the building.
- Specialist operations i.e. Laboratories, Maintenance areas, and similar.
- Maintenance policy for the building.
- Sustainability schemes the design is to be assessed against.
- Energy efficiency and any energy rating schemes the design is to conform to.
- Control and operational efficiency requirements.
- Monitoring and reporting requirements.
- Performance targets.
- Verification and acceptance criteria.
- Record keeping requirements.
- Maintenance and building tuning requirements.
- Project Timeline Program.

The level of detail in the POR will vary according to the size and complexity of the building, the owners or client needs, the contractual structure for the project, and the experience of the design team. The POR is a live document and should be reviewed by operation and maintenance personnel at least annually and whenever changes are made to the building or systems.

1.18.2. Basis of Design (BOD) - all services

Once the POR has been issued to the building and system designers and the design has been developed, the Basis of Design (BOD) document, a detailed narrative outlining the strategies employed for system function and measurable outcomes, is developed by the designers. It is important at this stage to incorporate lessons learnt from previous projects to ensure the building design is as practical and functional as possible, whilst maintaining cost targets.

The project specifications usually detail by what standard the project is to be built to, however limited emphasis is usually placed on how the building is to be operated. In-depth operating strategies should be included in the BOD to ensure the design and operational intent is understood by the system builders, commissioning engineers and facility management staff.

It is important that the designers approach the design process with a "whole building" operational and performance strategy in mind to assist with design integration.

The clearer the intent in the BOD and the strategies detailed within it, the better the building will be setup, commissioned and tuned. The information typically required in a BOD document would include:

- Building details, occupancy, population, usage (from project operating requirements).
- IAQ requirements (outdoor air quantities, filtration, air contaminant monitoring, contaminant minimisation strategies, innovative IAQ strategies).
- Legislated requirements - BCA, Australian Standards, Codes of practice.
- Indoor/Outdoor design conditions for summer/winter.
- Load calculations and assumptions and defined by location climatic conditions.
- System concepts and design schematics.
- Ventilation requirements and designs.
- Noise levels within the various areas in the building, and levels not to be exceeded at the boundaries.

- Equipment capacity and minimum performance.
- Detailed sequence of control and control routines for all modes of operation.
- Metering and monitoring and the planned break up on what is to be metered and sub-metered.
- Utility reporting requirements.
- Sustainability strategies.
- Performance targets.
- Verification and acceptance criteria.
- Maintenance and building tuning requirements.
- Project Timeline Program.

1.18.3. Client Brief/Reverse Brief - all services

Briefing is difficult to do well and has a major impact on the final building product. Briefing essentially determines how designers are going to spend their time and what outcomes they are going to try and achieve. Designers should provide a reverse brief to clarify client needs before they start work and to make sure clients are happy with their interpretation of the deliverables, scope, timeframes and costs. It's good project management and good for the client/ agency relationship too.

In the reverse brief three things happen. The first is that the client being briefed can check their understanding of the direction being taken. Secondly, the client gains clarity for perhaps the first time about what the implications of their own requirements actually are, and may revise them as a result. Thirdly, it provides an opportunity to ensure alignment across the entire design team.

Reverse briefs should move the thinking on, not merely replicate the client brief in more detailed or interesting language.

A design brief establishes clear expectations between a client and the design team. A design brief is not a 'one size fits all' because building projects can vary so much. The brief should cover

- **Due date for completion:** if there are any dependencies which make a particular start and end date critical make sure you communicate these to a designer. You may need to negotiate with the designer depending on how in-demand they are and the complexity of the project. The due date for completion is when you expect to have the final, approved design in your hand, ready for use.
- **Review date/s:** there should be at least one client review to ensure the design meets client expectations. You can also specify completion dates of other key stages.
- **Budget:** provide an idea of how much money you plan to spend. This enables the designer to be realistic when they provide options.
- **Key objectives:** the main business benefits of getting this design successfully delivered.
- **Regulatory issues:** note any regulations which will impact the design e.g. NCC requirements.)
- **Scope:** (detailed list of everything the project is expected to deliver.)
- **Not in scope:** (use this section to specify design elements that are out of scope
- **Purpose and function:** To be able to provide a workable design, the designer needs to know what the building is supposed to be able to do, who will be using it and in what circumstances. This information needs to be spelled out clearly for the designer.
- **Design Project plan:** List the project milestones, what is needed to complete them and who is responsible.)
- **Measures of success:** (how will you ensure the design is appropriate for your objectives and audience e.g. will you show samples to your potential customers, run surveys etc.)

1.19. Ventilation Choices - Natural or Mechanical

The provision of fresh outdoor air to indoor spaces is necessary for human respiration, dilution or removal of airborne contaminants, correct operation of combustion appliances, thermal comfort and smoke clearance. Ventilation can be either natural or mechanical or a combination of the two.

A possible definition for natural ventilation could be "ventilation that depends on the naturally occurring agencies of wind and temperature difference to cause air movement between the inside and outside of a building, between enclosures within a building and within enclosures".

In simple terms ventilation air is provided through openings of a particular size and distribution in the external facade of a building. Air moves in and out of these openings and circulates throughout the space being ventilated through naturally occurring forces (wind and stack effects). In some buildings it is the natural porosity of the building envelope combined with openable windows that are relied on to provide ventilation. In other buildings natural ventilation systems can be complex, engineered and controllable. The minimum requirements that need to be achieved to naturally ventilate a building are set by the NCC. Where a building cannot meet these minimum requirements regulations require it to be mechanically ventilated.

Mechanical ventilation could be defined as "ventilation that depends on fans and other air movement devices to cause air movement between the inside and outside of a building, between enclosures within a building and within enclosures". In simple terms air is pumped to where it is required to go.

Hybrid ventilation uses both natural and mechanical ventilation, or features of both, in an integrated system. Natural and mechanical ventilation forces can be combined or operated separately, with the system operating mode varying depending on the ambient conditions and resulting opportunity at any given time. Control systems for hybrids can be quite complex or can be as simple as mechanical ventilation cut out switches when natural ventilation devices are opened.

Mixed mode ventilation systems are similar to hybrids as they use a combination of the two ventilation systems but there is generally a greater independence of operation and control between the natural/mechanical systems (i.e. two separate systems with control integration only).

Ventilation and air infiltration are expressed in terms of a volumetric flow rate, L/s or m^3/s. Sometimes the volumetric flow rate is divided by the number of occupants to give a flow rate for each occupant, i.e. L/s. person. Natural ventilation requirements are often expressed as a percentage (of floor area) of fixed or openable openings requirement.

The selection of a ventilation system is largely up to the designer once the requirements for building regulations have been satisfied.

Building regulations are based on the assumption that natural ventilation will be the first choice for building ventilation and where the specified minimum criteria for natural ventilation cannot be achieved then mechanical ventilation is permitted as an acceptable substitute.

Deemed-to-satisfy mechanical ventilation systems must comply with the mandatory requirements of AS 1668.2 which contains several options for mechanical ventilation; primarily dilution ventilation by supply or exhaust and also local exhaust for contaminant removal. These options are to be applied to buildings to control indoor air contaminants to acceptable levels.

Requirements for natural ventilation are outlined in a few simple rules contained directly in the technical provisions of the NCC.

1.20. Resilience and Redundancy in Design

Resilience of a system or building refers to the ability of the building or system to continue to operate after a failure has occurred, it is a relative not an absolute term. Redundancy refers to duplication of components; it is an absolute term.

Redundancy supports resilience, the more redundancy in the separate components of a system, the higher the resilience will be. A system with no redundant components has no resilience.

N+1 redundancy is a form of resilience that ensures system availability in the event of component failure. Components (N) have at least one independent backup component (+1). The level of resilience is referred to as active/passive or standby as backup components do not actively participate within the system during normal operation.

One way to achieve resiliency within HVAC is by employing redundant systems, but resilient systems, do not necessarily provide redundancy.

A major focus on mechanical and electrical services resilience is disaster proofing including the ability of systems to operate during fire for emergency services, storms and floods. Issues such as roof-mounted or basement mounted plant need to be considered.

A good example of poor design is locating a main electrical switchroom in a below ground area where there is the likelihood of disruption by flooding of the switchroom, this occurred in buildings in Brisbane CBD and Sydney CBD when the cities were overcome by storm and tempest.

BUILDING SERVICES

ENGINEERING FOR ARCHITECTS & BUILDING DESIGN PROFESSIONALS

A GUIDE TO INTEGRATED DESIGN

This book is primarily intended as a text and design guide for architects, building design professionals and students, in fact anyone involved in the building industry who needs a realistic overview of large building services without getting too involved in the engineering details. The information and approximate data provided are an essential basis for integrated building design.

Originally authored by the late Dr. Pardour with updating by Alan Obrart and then current revisions and additions by Ian Childs (editor and copyright owner), principal of
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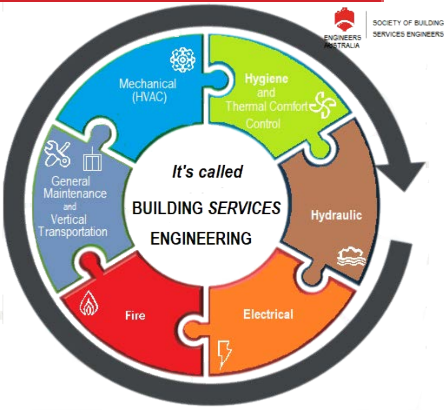
EDITORS NOTE TO THE READERS



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