A practical guide to

HVAC Building Services Calculations

By Gay Lawrence Race and Sally Mitchell

BSRIA Guide 30/2003
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ACKNOWLEDGEMENTS

BSRIA would like to thank the following sponsors for their contributions to this Guide:

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The research project was undertaken under the guidance of a project steering group drawn from industry representatives and BSRIA staff. The steering group contributors were:

Fulcrum Consulting	Andrew Ford, representing DTI
Independent chair	Bryan Franklin
CIBSE	Hywel Davies
ACE	Jeremy Croxson
Bovis	Jean-Louis Auguste
Crown House Engineering	Susan Hone-Brookes
ESTTL	Tony Barton
FaberMaunsell	Quinten Babcock
	Ant Wilson
Hoare Lea	Graham Cossons
	Les Mackenzie
	Terry Wyatt
HVCA	Derrick Newson
	Bob Towse
N G Bailey	Ken Sargeant
	Roland Edkins
South Bank University	Martin Ratcliffe
Troup Bywaters & Anders	David Arnold (representing CIBSE)
W S Atkins	Adrian Defalco
	Steve Platt

Gay Lawrence Race and Sally Mitchell contributed from BSRIA.

This publication has been produced by BSRIA as part of a contract placed by the Department of Trade & Industry. The contract was let under the Partners in Innovation programme, which provides part funding of collaborative research. Any views expressed in it are not necessarily those of the Department.

The authors have sought to incorporate the views of the steering group, but final editorial control of this document rested with BSRIA.

©BSRIA 70186 June 2003 ISBN 0 86022 618 2 Printed by The Chameleon Press Ltd.

PREFACE

This publication provides practical, easy to follow methodologies for a range of calculations used in the design of heating ventilating and air conditioning building services systems.

The calculation sheets are presented in four sections covering:

- Heating loads and plant
- Cooling loads and plant
- Water flow distribution systems
- Air flow distribution systems

The calculation sheets provide practical guidance including design watchpoints, design tips and rules of thumb, and are intended to aid the design process and reduce errors. The guidance is based primarily on data and procedures contained within the *CIBSE Guides*, together with other sources such as *Building Regulations*, with clear cross-referencing provided to data sources.

This publication is intended primarily to help junior design engineers, working within a structured and supervised training framework, by providing assistance in completing the basic calculations needed to define operating conditions for systems, size distribution systems and to specify required duties for plant and equipment. It is not the purpose of this guide to identify the most appropriate system for a particular application. Such decisions require knowledge, experience and analysis of the application.

This guidance is also not intended to be exhaustive or definitive. It will be necessary for users to exercise their own professional judgement, or obtain further advice from senior engineers within their organisation when deciding whether to abide by or depart from the guide. The calculation sheets are relevant to many design applications, but cannot be fully comprehensive or cover every possible design scenario. Every design project is different and has differing needs, and it is the professional duty of the responsible design engineer to consider fully all design requirements. Designers should exercise professional judgement to decide relevant factors and establish the most appropriate data sources and methodologies to use for a particular application.

Designers must be aware of their contractual obligations and ensure that these are met. Following this guidance - or any other guidance - does not preclude or imply compliance with those obligations. Similarly, it is the duty of the designer to ensure compliance with all relevant legislation and regulations.

It is hoped that design practices and individual designers will be encouraged to share knowledge and experience by extending and adding to the design watchpoints and design tips, and disseminating this work within their organisations. BSRIA would be pleased to receive any such contributions for incorporation into any future revisions of this publication to provide wider industry sharing of such knowledge.

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INTRODUCTION

BSRIA has been researching into the design process and design methodology in the building services industry since the mid 1990's. This has produced guidance on the use of engineering design margins[1], feedback to design[2] and quality control systems for detailed technical design[3]. The overall aim has been to develop systematic guidance for the industry that would contribute to greater consistency in design and to an overall raising of design standards.

The studies have involved considerable discussions with industrial partners on their current and future needs, and several visits to the design offices of a number of industrial contributors to the projects. A majority of those organisations consulted said that a lack of formal design guidance and inadequate recording of calculations was a major barrier to quality improvement in design. Many also felt that standardised formal procedures would help improve the quality of design outputs.

BSRIA's research also revealed that there is a lack of standardisation in design procedures, both between companies and between individuals. Many companies have developed their own design guidance and approaches to calculation procedures, leading to considerable diversity within the industry. This can make it difficult to cross-check work done by others, which could lead to differences in system design parameters and sizes, and even calculation and design errors. There are many specific examples of design errors and issues that should have been considered during design calculations and have led, (or could have led) to operational problems or subsequent litigation[4], including:

- Omission of HEPA filter resistance from fan-pressure calculations, requiring subsequent fan motor replacement which then required additional silencing
- Omission of duct sizes and flows from drawings, leading to incorrect sizes being installed
- Incorrect pipe and pump sizing for a constant temperature heating circuit, necessitating replacement of system distribution network
- No allowance for pipework expansion on a heating mains.

Although there is considerable design guidance and data available to inform the design process much of it is intended for use by experienced engineers, who have fulfilled a programme of education and training and have design experience. For example, while the design guides published by the Chartered Institution of Building Services Engineers (CIBSE)[5] provide essential design data for building services engineers, they are intended for use by experienced engineers, and therefore do not always show how to design in detail by giving every necessary calculation step. They also do not show how different calculation routines link together to build up the design process.

Research has also shown that many employers are currently finding it difficult to recruit design engineers with appropriate building services skills and experience, which necessitates recruiting and retraining engineers from other disciplines.[6] Output from building services courses is currently falling,[7] which implies there will be no short term improvement in this situation.

These recruits, with no building services training or experience, will require close supervision and considerable training which can place a heavy burden on company resources.

While there is no substitute for an appropriate quality control framework and adequate supervision by qualified senior staff, good training resources and technical support can provide an invaluable adjunct to company training provision.

Aim

As a result of all these factors many of the leading organisations involved in education and training in the building services industry, including BSRIA, CIBSE, ESTTL and HVCA and a number of industrial contributors embarked on this project to develop simple and clear guidance on building services calculation procedures that would be applicable across the industry.

Objectives

The resulting guidance is intended to be suitable as an in-company learning resource, in order to improve quality and communication within the design process. This should reduce the risk of design calculation errors and omissions, simplify the task of calculation checks and improve the overall efficiency of the design process.

A comprehensive review of current building services design practice and calculation procedures was carried out in consultation with the industry. This was closely linked to current industry design guides and reference material in order to develop this good practice guidance for building services calculation procedures, including:

- An overview of the building services design process;
- Flowcharts of key calculation sequences;
- Practical procedures and calculation sheets covering 30 key building services calculation design topics;
- Clear cross-referencing to the CIBSE Guide and other appropriate reference sources.

The calculation sheets provide an overview of each procedure, with guidance on design information, inputs and outputs, design tips and watchpoints and worked examples, to aid the design process and reduce errors. They are supplemented with illustrations and guidance on how to use appropriate tables, figures and design information correctly.

Intended users

This guidance is intended for practising building services design engineers, and will be particularly relevant to junior engineers and students on building services courses. Junior engineers would be expected to use it under supervision, (for example within a formal company training scheme) as part of their practical design work. Students can use it within the taught framework or industrial training component of their course, guided by course tutors as appropriate. The guidance should also encourage clear recording and referencing of calculation procedures which will aid quality assurance requirements and allow simpler and easier in-house checking of design work.

The guidance complements the CIBSE Guides, in particular Guide A covering design data, Guide B1 covering heating, Guide B2 covering ventilation and air conditioning, Guide B3 covering ductwork, and Guide C covering reference data. It especially complements the CIBSE Concise Guide[8] a companion volume showing the use and practical application of commonly used design data from other CIBSE Guides.

The Practical Guide to Building Services calculations also closely complements the BSRIA Guide: Design Checks for HVAC – a quality control framework for building services engineers[3]. This provides good practice guidance for building services technical procedures and design management, including design guidance sheets for 60 key design topics and check sheets that can be used in project quality assurance procedures.

New entrants to building services may find it helpful to read the overview information given in the BSRIA illustrated guides volumes 1 and 2.[9]

THE BUILDING SERVICES DESIGN PROCESS

Calculation procedures are a necessary component of design but it is important to see them in the context of the whole design process. Decisions made as part of initial design and during the calculation procedures will affect system design, installation, operation and control.

The BSRIA publication *Design Checks for HVAC – a quality control framework for building services engineers*[3], provides a useful and relevant discussion of the building services design process. As part of this work, a detailed analysis of design procedures and tasks was carried out for building services design and a simple linear model of the building services design process derived was derived as shown. This gives a single design sequence, from statement of need, through problem analysis, synthesis and evaluation to final solution and enables design tasks to be clearly linked to both preceding and succeeding actions. Some primary feedback loops are shown, but in practice there are often feedback loops between all tasks and even within specific tasks.

This work also mapped the building services design process, both as a sequence of design tasks and as a series of topics that make up the design process. This detailed map of the process is shown opposite. The map is shown as a linear view of design, (with iteration and intermediate feedback omitted) in the form of an Ishikawa or fishbone diagram. The process originates from the client's need on the left with various branches feeding into the main design line to eventually reach design completion and design feedback. The map may be of particular benefit to junior engineers as it will enable them to put their contribution to the whole design process in context. When engineers carry out load calculations or pipe sizing, it is easy to forget that this is part of a larger process with consequences for impact on future system installation, operation and control.