

**INDUSTRIAL  
VENTILATION  
DESIGN  
GUIDEBOOK**



# INDUSTRIAL VENTILATION DESIGN GUIDEBOOK

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## ■ ACKNOWLEDGMENTS

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Special thanks are due to the patience and determination of the contributors who tirelessly prepared drafts and redrafts, attended meetings and more meetings, and reviewed proofs, more proofs, and then the final proofs. It has been a pleasure to work with all members of the professional team at Academic Press toward the common goal of publishing this book on schedule.

The editors acknowledge the significant contributions by Esko Virtanen of TEKES during all stages of this project. Also, we would like to acknowledge the exceptional work and long hours by Kalevi Pöntinen at the Helsinki University of Technology, who has been the overall coordinator for the communications between the editors, contributors, and the publishing team.

Two organizations that have supplied the fundamental building blocks and supporting organizations for this vision of publishing the first edition of the *Design Guidebook* are the Helsinki University of Technology and COST. Special thanks are due to these organizations. A brief introduction to these two organizations is presented below.



TEKNILLINEN KORKEAKOULU  
TEKNISKA HÖGSKOLAN  
HELSINKI UNIVERSITY OF TECHNOLOGY

### **Helsinki University of Technology**

The Helsinki University of Technology (HUT) is the oldest and largest university of technology in Finland, dating back to the nineteenth century. In 1849, the Helsinki Technical School was founded, marking the beginning of organized technical education in Finland. In 1872 the school became the Helsinki Polytechnic School and in 1879 the Helsinki Polytechnical Institute. In 1908 the name was changed to the Helsinki University of Technology, and thus the teaching of technology at the university level began in Finland. In the 1950s and 1960s new premises were built to house the University of Technology in Otaniemi and the university moved from Helsinki to the neighboring city of Espoo. HUT includes 12 faculties, 9 separate institutes, and 15 degree programs.

The Laboratory of Applied Thermodynamics has had a significant involvement in industrial ventilation activities since the inception of the national Finnish industrial ventilation technology program INVENT 1988. One of the first projects was the Design and Dimensioning Criteria for Industrial Ventilation. The laboratory is a proposer and coordinator for the European COST Action G3, “Industrial Ventilation” (1996–2003), and the Network of Industrial Ventilation, INVENTNET (2000–2002). The main interests of the laboratory are new technical solutions for energy conversion and equipment and to provide comprehensive education in the field of thermal engineering. The present research areas of the Laboratory of Applied Thermodynamics are fuel cells and hydrogen technology, experimental fluid dynamics using laser Doppler anemometry, new and innovative energy production methods, technical and chemical thermodynamics, modern heat pumps and heat exchangers, low-emission combustion technologies, industrial ventilation (INVENT), and computational fluid dynamics (FINFLO).

The Laboratory of Applied Thermodynamics provides comprehensive education in the field of energy engineering. The students, mostly in applied thermodynamics, have profound theoretical and practical bases in energy conversion processes and equipment. They master the basic mathematical and physical principles of energy physics and are then capable of specializing in a wide range of different technical applications of energy engineering. The main fields of education cover technical and chemical thermodynamics, heat and power generation processes and equipment, renewable energy production methods, heat and mass transfer, heat exchangers, and fluid mechanics. Some of the research project results are also included in subsequent education. The calculation of thermodynamic equilibrium of thermochemical systems can be done using computer programs such as ELCHEM and HSC, which are based on the laboratory’s own research work. The education of computational fluid dynamics is strongly connected with the FINFLO research project team.



## **COST**

Founded in 1971, COST is an intergovernmental framework for European cooperation in the field of scientific and technical research, allowing the coordination of nationally funded research on a European level. COST actions cover basic and precompetitive research as well as activities of public utility.

The goal of COST is to ensure that Europe holds a strong position in the field of scientific and technical research for peaceful purposes, by increasing European cooperation and interaction in this field. Ease of access for institutions from nonmember countries also makes COST a successful tool for tackling topics of a truly global nature.

To emphasize that the initiative came from the scientists and technical experts themselves and from those with a direct interest in furthering international collaboration, the founding fathers of COST opted for a flexible and pragmatic approach. COST activities have in the past paved the way for community activities, and its flexibility allows COST actions to be used as a testing and exploratory field for emerging topics.

The member countries participate on an “à la carte” principle, and activities are launched using a “bottom-up” approach. One of its main features is its built-in flexibility. This concept clearly meets a growing demand, and in addition, it complements the community programs.

COST has a geographical scope beyond the EU, and most of the Central and Eastern European countries are members. COST also welcomes the participation of interested institutions from non-COST-member states without any geographical restriction.

COST has developed into one of the largest frameworks for research cooperation in Europe and is a valuable mechanism for coordinating national research activities in Europe. Today it has almost 200 actions and involves nearly 30,000 scientists from 32 European member countries and more than 50 participating institutions from 11 nonmember countries.

Among these is COST Action G3 on industrial ventilation. This action was launched in 1996 and comprises to date more than 60 experts from fourteen COST countries and from institutions of four nonmember countries. Its main objective, as stipulated in the Memorandum of Understanding of the action, is to “produce a basis for a Design Guidebook by a multidisciplinary approach based on gathering the expert knowledge which exists internationally, further developing it and making it available for the designers.”

The present volume is tangible proof of the success of COST Action G3. Thanks to the early fulfillment of this objective, possible further developments, and the quality of the team of experts gathered throughout Europe and beyond, this action, initially scheduled to terminate by the end of 2001, was prolonged until April 2003 by the Committee of Senior Officials of COST.

*Franck CHARMAISON*  
*Scientific Secretary*  
*COST Urban Civil Engineering*

## ABOUT THE EDITORS

### **Howard D. Goodfellow, Ph.D., P.Eng.**

Howard D. Goodfellow is Vice President of Stantec Global Technologies Ltd. Stantec is a Canadian professional services firm providing knowledge-based solutions for infrastructure and facilities. Stantec sells and markets Goodfellow EFSOP™ (*Expert Furnace System Optimization Process*), an award-winning software and hardware technology system. Goodfellow EFSOP™ uses online off-gas chemistry measurements from industrial combustion processes for closed-loop control for process optimization.



The company he founded in 1986, Goodfellow Consultants Inc., received the 1992 Canada Award for Business Excellence (CABE) in the environment field for the development of a computer program for the design of specialized industrial ventilation systems. Dr. Goodfellow is a recognized expert in the ventilation, air pollution control, and air quality areas.

He graduated with a Ph.D. from the Department of Chemical Engineering and Applied Chemistry at the University of Toronto and has been responsible for specialized consulting and engineering design services for over 1000 industrial and government clients in the environmental field.

He is an Adjunct Associate Professor in the Department of Chemical Engineering and Applied Chemistry at the University of Toronto, where he teaches a graduate course in ventilation and conducts research and development in the ventilation and indoor air quality field. Dr. Goodfellow was awarded the 2T5 Meritorious Service Medal of the Engineering Alumni Association of the University of Toronto. The award was for his outstanding contributions as an engineer, teacher, researcher, author, and administrator in the field of ventilation and occupational health at the University of Toronto, with global recognition for achievements in the advancement of environmental consulting. Professor Goodfellow also teaches a Mine Ventilation and Occupational Health course at the University of Toronto in the Lassonde Mineral Engineering Programme. Dr. Goodfellow has presented numerous courses internationally in the clean air technology field, both for industrial clients and at conferences and seminars, and he has presented and/or published over 100 technical papers.

Dr. Goodfellow has worked with TEKES and the INVENT team in Finland since 1993. He spent three months (April–June 1997) lecturing at the Helsinki University of Technology, initiating research projects in the ventilation field, and working with Finnish experts in the planning stages of the *Design Guidebook*.

**Esko Tähti, Ms, S. Eng.**

Esko Tähti is Managing Director of Suomen Talotekniikan Kehityskeskus Oy (TAKE, Finnish Development Centre for Building Services, Ltd.). The company is owned by Finnish associations and companies in the business area of building services. The company is established to accomplish R&D projects in the field of building services.

The company was founded in 1991 and started its activities in 1996 when Esko Tähti became its managing director. TAKE's scope of activities includes the whole area of building services. Its other major projects have been in the area of energy use in buildings, life cycle economy, water services, indoor air control, clustering, and IT technologies and automation.

One of the first projects has been the *Design Guidebook*, the “bible” of industrial ventilation. The project has been administrated by the COST secretariat. Esko Tähti has been Chairman of the Management Committee together with Helsinki University of Technology Professor Markku Lampinen and researcher Kalevi Pöntinen.

Esko Tähti graduated in 1967 from the Helsinki University of Technology Laboratory of Applied Thermodynamics. He has been working in different positions in the Finnish companies Metso (Valmet Paper Machines), ABB, and Nokia and also in the Ministry of Environment and Helsinki University of Technology. He has held various positions within Finnish organizations in the area of building services, acting as teacher, researcher, author, and administrator. One important role has been in international projects, especially at the European level and as a contact person for Russian scientists in the area of industrial ventilation. Esko Tähti was also the coordinator of the Finnish technology program INVENT for the period 1991–1996. This program initiated this handbook during an international brainstorming session at Zurich in 1995.



## PREFACE

The primary goal of the *Industrial Ventilation Design Guidebook* is to develop a systematic approach to the design of air technology systems based on current scientific research and engineering knowledge on a global basis. There is no internationally accepted handbook available that describes the basic theories and science behind the technical solutions for industrial air technology. Our objective has been to develop a much-needed scientific reference book that covers the whole field of industrial air technology based on validated and updated technology from leading scientists, engineers, and researchers worldwide. This preface outlines why there is a need for a reference handbook, how this goal has been achieved, what has been achieved, and the intended audience for this book.

Rapid changes in process and manufacturing industries and demands for improved workplace environments have placed new demands on the design of advanced industrial ventilation systems. These systems must be more tightly integrated with processes and building service systems. The optimization step requires new design tools and technological innovations. The challenges are not only for technical solutions but also for new technical standards and policy actions to support the technological progress. In many industries the objective is not only to comply with legal standards, but to minimize health risks as much as possible. These objectives require the design team to work closely with the end users to specify target levels or energy consumption levels. The *Industrial Ventilation Design Guidebook* is a compilation of the current knowledge base in the industrial air technology field into a systematic and integrated handbook.

The question may be asked, “How has the goal of publishing the handbook been achieved?” Many factors have contributed to this goal. For those of us who have worked in the industrial ventilation field for several years, there was a recognition that an international guidebook based on the best scientific knowledge on the subject of industrial ventilation would be an essential first step to raise the level of industrial ventilation worldwide. An important step was the organizing of the first International Conference on Ventilation for Contaminant Control in Toronto in 1985. This conference was attended by over 300 delegates. Over 80 scientific papers in the field of industrial ventilation (research and development and applications) were presented at the

conference. Subsequent international conferences have been held every three years. The complete list follows:

Ventilation '85	Toronto, Canada
Ventilation '88	London, UK
Ventilation '91	Cincinnati, Ohio, USA
Ventilation '94	Stockholm, Sweden
Ventilation '97	Ottawa, Canada
Ventilation 2000	Helsinki, Finland
Ventilation 2003	Sapporo, Japan

To date, there have been more than 1500 attendees and more than 500 technical papers or presentations delivered at these conferences. A critical mass of researchers, engineers, and scientists developed through the INVENT program in Finland, which started in 1991. These activities have expanded to include scientists, engineers, and practitioners from some 18 countries as part of the COST Action Program.

The *Industrial Ventilation Design Guidebook* is the first comprehensive, definitive handbook to cover all aspects of air technology on a worldwide basis. The structure of the 16 chapters is as follows:

1. Industrial Air Technology—Description
2. Terminology
3. Design Methodology of Industrial Air Technology
4. Physical Fundamentals
5. Physiological and Toxicological Considerations
6. Target Levels
7. Principles of Air and Contaminant Movement Inside and Around Buildings
8. Room Air Conditioning
9. Air Handling Processes
10. Local Ventilation
11. Design with Modeling Techniques
12. Experimental Techniques
13. Gas Cleaning Technology
14. Pneumatic Conveying
15. Environmental Assessment Tools
16. Economic Aspects

The book is intended for engineers, scientists, seniors at the university level, and graduate students who have a fundamental understanding of the concept of fluid flow, thermodynamics, and heat transfer. The handbook bridges the disciplines of engineering and occupational health and safety (industrial hygiene). The book can be used as a textbook, a scientific reference for researchers, and a fundamental handbook for practitioners in the industrial air technology field.

This international handbook will be updated regularly in order to meet our objective of including the most current scientific knowledge on a global basis. The plan is to also publish additional volumes to cover systems and

equipment and guidelines for specific industrial applications based on leading-edge concepts of design methodology and target levels.

In closing, we are reminded of a statement by the renowned Albert Einstein: “If we did all the things that we are capable of doing, we would literally astound ourselves.” The publication of this first edition of *Industrial Ventilation Design Guidebook* is an astounding event. The opportunity to be editors of this handbook has been a truly exciting and satisfying experience. It has been a unique opportunity and a pleasure to collaborate with our international friends on this journey.

*H. D. Goodfellow*  
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