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"Air Pollution Control Technology Handbook", Second Edition

By Karl B. Schnelle Jr., Russell F. Dunn (Vanderbilt University, Nashville, Tennessee, USA) and Mary Ellen Ternes (Crowe and Dunlevy, Oklahoma, USA), CRC Press, Boca Raton, USA, 2016, 429 + xxvi pages, ISBN 9781138747661, £60.00, US$79.95

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Introduction

When the first edition of this book by Karl B. Schnelle and Charles A. Brown was published (1) some 16 years ago, there were a number of texts available that covered various aspects of pollution emissions and their control, including "Practical Handbook of Environmental Control" by Conrad P. Straub (2) that gave in tabular form a huge amount of easily accessed relevant data, and the monumental text by B. J. Finlayson-Pitts and J. N. Pitts (3). Schnelle and Brown's book was a guide focusing on the sources of air pollutants, their measurement and the control of pollutants from industrial plants.

The second edition of the "Air Pollution Control Technology Handbook" retains the original senior author, K. B. Schnelle (now Emeritus Professor at Vanderbilt University, Nashville, Tennessee, USA), joined by Professor R. F. Dunn from the same university and Mary Ellen Ternes, a Vanderbilt graduate now an environmental lawyer. Like the first edition, the present book has 24 chapters with related titles and the same general layout with a focus on the situation in the USA.

US Air Quality Legislation

The first short chapter (12 pages) 'Historical Overview of the Development of Clean Air Regulations' gives a historical overview of the US clean air regulations and is similar to that in the first edition with a small difference being that the references, instead of being at the end of the chapter, are now collected together in a separate section before the index at the end of the book. The larger second chapter (25 pages) entitled 'Clean Air Act' delineates the development of the US legislation. Tabular information has been updated to February 2015 and some more recent references are included. These two chapters provide a particularly readable and useful source for those wanting to gain insight into the way US air quality legislation has developed over several decades, resulting in major air quality improvements in many urban areas.

Air Emission Permits and Atmospheric Pollutant Modelling

The third chapter 'Air Permits for New Sources' (12 pages) explains the procedures necessary when an air permit is required before the construction of plant in the USA that adds or modifies a source of

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pollution. It goes through the procedural elements and details them for applications that include secondary emissions and the primary emissions rates, although only one additional reference is given compared with the first edition. The next chapter (13 pages) called 'Atmospheric Diffusion Modelling for Prevention of Significant Deterioration Permit Regulations and Regional Haze' highlights the need for appropriately tall stacks which, while not preventing emissions from entering the atmosphere, do reduce ground level pollution to low enough concentrations so as not to be harmful around the source. The approach is qualitative and nonmathematical in outlining atmospheric diffusion models and reference is made to several computer models, particularly those available through the US Environmental Protection Agency (EPA) Air Quality Modelling Group. Strangely the original two references in this chapter were not extended or updated.

Pollutant Monitoring

The fifth chapter (8 pages) deals with 'Source Testing' by which is meant determining the concentration and/or quantity of pollutant at its source, for example a stack. Sampling techniques are covered in some detail and the following chapter (18 pages) 'Ambient Air Quality and Continuous Emissions Monitoring' includes details of the federal reference analytical methods for a wide range of pollutants and the calibration of continuous measurement procedures. No additional references were added to the two of the first edition.

Financial Aspects of Environmental Compliance

The short seventh chapter (7 pages) called 'Cost Estimating' is concerned with financial aspects of air pollution control and, for instance, examines the ways of determining the trade-offs between capital and operating costs. Chapter 8 (11 pages) 'Process Design and the Strategy of Process Design' outlines the decisions involved in the choice, design and implementation of pollution control processes. Illustrative examples are taken from the first edition, one of which is the elimination of brown NOx plume from a stack with the chosen control being a packed counter-flow absorption tower. Although this illustrates various intended points the nature of the chemistries involved are not considered nor are today's difficulties and costs associated with transport and disposal of spent absorption solution. As a result unless there are special reasons for not doing so, catalytic ammonia selective catalytic reduction (SCR) is now usually chosen for such NOx control requirements and this efficient process enables modern very low NOx emissions standards to be achieved. Catalytic ammonia SCR technology is briefly discussed later in the book (pages 280–281).

The ninth chapter (9 pages) returns to financial considerations and is called 'Profitability and Engineering Economics' which in separate short sections deals with profitability analysis, effect of depreciation, capital investment and total product cost.

Pollutant Removal Processes

Chapter 10 (8 pages) gives an introduction to control of gaseous pollutants with a focus on volatile organic compounds (VOCs) and their stripping and absorption. Little is said about VOC catalytic oxidation that is commonly used to meet stringent emissions standards today, although later in the book under 'Catalytic Incineration' (pages 235–237) this topic is discussed. Chapter 11 deals with 'Adsorption for Hazardous Air Pollutants and Volatile Organic Compounds Control' (58 pages). This is a major improvement over the corresponding shorter chapter (42 pages) in the first edition that when it appeared was dated and did not consider more efficient tower packings but concentrated on older types such as saddles, the use of which would result in considerably oversized and costly towers that could be improved by the use of modern packings. The present chapter includes more recent generations of mass transfer packings that allow for much more practical and far less costly tower designs. A wide variety of modern structured metal packing devices are illustrated.

The twelfth 35 page chapter considers 'Absorption for Hazardous Air Pollutants and Volatile Organic Compounds Control' using solid absorbents such as activated carbons, activated aluminas, silica gels and molecular sieves (zeolites). Their operational advantages and disadvantages are detailed before examining ways of predicting breakthrough times and the necessary *in situ* regeneration methods available in different situations if charges are not to be replaced.

Chapter 13 'Thermal Oxidation for Volatile Organic Compounds Control' in 17 pages considers three thermal oxidation processors and each is addressed in turn: thermal oxidation (flares), thermal oxidation and incineration and catalytic

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oxidation, with most space given to various types of flaring. Only a couple of pages are given to 'Catalytic Incineration' although its use is common today. The important role of heat recuperation in many situations is stressed. While the following rather longer Chapter 14 looks at the 'Control of Volatile Organic Compounds and Hazardous Air Pollutants by Condensation' in 20 pages, that might be thought more appropriately placed before the previous chapter because of the relative removal efficiencies of the processes involved. Indeed condensation is often the preliminary process for removing high levels of volatile organic compounds with the advantage of recovering what might be valuable material, followed by one of the processes discussed in the earlier chapter which can eliminate organics to the desired low levels. Like the first edition, this chapter has two appendices: one on the derivation of the area model for a mixture condensing from a gas and the second giving the calculation method or 'algorithm'.

The short (8 pages) Chapter 15 'Control of Organic Compounds and Hazardous Air Pollutants by Biofiltration' is in some ways a gas analogue of reed bed treatment of effluent waters. Here process gas is passed through a moist porous bed of material containing microorganisms (fungi, bacteria and actinomycetes) fed with oxygen and suitable nutrients maintained at an appropriate temperature and pH. When operated correctly good performance can be obtained that is competitive with alternative technologies. The four page Chapter 16 entitled 'Membrane Separation' has been lengthened compared with the first edition but still cites only rather old references. What is covered is useful but could have been beneficially expanded. The advantages, such as recovery of a pollutant in a fairly concentrated stream that is also possible with some processes previously discussed in Chapter 12, could have been highlighted, and indeed the present short chapter could well have been cognated into the earlier one.

NOx and SOx Pollutant Removal

Chapter 17 'NOx Control' has 13 pages, and as in the first edition nitrous oxide (N_2O) is included in the term NOx although it usually refers to molecules containing one nitrogen and one or more oxygen atoms and generally is not meant to include N_2O (4). Combustion processes account for most of the atmospheric NOx with highway vehicles and other transportation being major contributors. The interesting graph of NOx emissions from various sources starting in 1970 only extends to 1997, as in the first edition, and it is a pity so much relevant more up-to-date information was not included. The lowering of NOx from a variety of burner technologies is covered before flue gas treatment techniques are considered. Selective noncatalytic reduction, selective catalytic reduction, ozone oxidation prior to absorption of the nitric acid so formed (**Scheme I**), catalytic oxidation and absorption of the resulting NO_2 in alkaline solution, and finally oxidation in a corona induced plasma are all discussed. Given the significance of NOx emissions from highway vehicles and other transportation sources and the efficient catalytic systems available to control them it is curious they were not considered in the context of relevance to treating NOx emissions from other sources.

$$NO + O_3 \rightarrow NO_2 + O_2$$

$$2NO_2 + O_3 \rightarrow N_2O_5 + O_2$$

$$N_2O_5 + H_2O \rightarrow 2HNO_3$$

Scheme I

Chapter 18 'Control of SOx' has 20 pages and like the first edition relies much on the 1998 paper by Charles Brown (5). The most significant sulfur emission into the atmosphere is sulfur dioxide that is produced in many combustion processes, often at levels higher than the corresponding NOx, with a major source being coal fired power stations. When oxidised to sulfur trioxide (SO_3) its reaction with water leads to formation of sulfuric acid often formed as fine nanoparticles. There is an interesting graph showing sulfur dioxide emission trends from various sources that starts from 1970 but only extends to 1997; so missing almost two decades of key data. Several acid gas removal processes are discussed including the calcium-based process that involves partial aerial oxidation of first-formed calcium sulfite to very stable calcium sulfate (**Scheme II**). This process is widely used in coal-based power stations. More expensive sodium-based processes using sodium carbonate or hydroxide are then considered but in all of these situations disposal of spent solution or solid is required that can be expensive today. Problems associated with the oxidation of sulfur dioxide to sulfur trioxide and thence in the presence

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of water to sulfuric mist are discussed, but not the deliberate conversion to sulfuric acid when large amounts of sulfur dioxide are available. Here the clean-up costs are offset by a commercially saleable product.

$$SO_2 + Ca(OH)_2 \rightarrow CaSO_3 + H_2O$$

$$2CaSO_3 + O_2 \rightarrow 2CaSO_4$$

Scheme II

Particulate Pollutant Removal from Gas Streams

Particulate matter (PM) emissions down to nanoparticle sizes similar to those of bacteria and virus particles have in recent years attracted growing attention because of their serious health implications. Chapter 19 on 'Fundamentals of Particulate Control' has 10 pages and usefully covers some of the basic concepts in this area but does not include the various particle measuring techniques nor emphasise the current importance of nanoparticle control.

'Hood and Ductwork Design', covered in the 14 page Chapter 20, as its title suggests, deals with the removal of pollutants from specific environments, and like the first edition provides a useful guide to design a variety of hood types and the importance of smooth bends in ducting to prevent erosion when high velocity particles are present. Cyclones are widely used for removal of relatively large particles from process gas streams, and in recent years related technology has been employed in domestic vacuum cleaners. Chapter 21 entitled 'Cyclone Design' provides an overview of their design and applications in 11 pages. After outlining fundamental operating principles typical dimensions are given with details such as pressure-drop, before the theoretical collection efficiency limitations are derived that correspond to internal gas rates of between 50 and 100 feet per second.

Wet scrubbing usually involves spraying a mist of water into a gas stream containing PM so as to increase particle size *via* one or more mechanisms to facilitate their removal trapped in liquid. Chapter 22 deals with the 'Design and Application of Wet Scrubbers' in 26 pages. With traditional micron-sized particles removal efficiency decreases with particle size and normally wet scrubbing is employed for removing particles above about a micron in size. As well as providing particulate control, wet scrubbing can also selectively remove certain gaseous components so serving a dual function. Mechanisms of particle growth in a mist of liquid are reviewed before outlining different types of wet scrubbers and the key factors needed for their design and implementation. Although there was some rearranging of the material from the first edition, it remains effectively the same in the new edition and there is no significant updating of the text or references.

Filtration of particles from a dry gas stream and especially from an air stream is frequently done using a variety of porous materials including 'ceramic candles', paper cartridges and fabric bags. On the large scale fabric bags are convenient to operate, shake and empty with the important attraction of being cost effective and traditionally units having several bags are called 'baghouses'. Chapter 23 called 'Filtration and Baghouses' in its 23 pages discusses some of the fundamentals of filtration and bag fabric properties, before turning to factors such as pressure drop during use and the effect of removing the collected filter cake. The modes of bag failure include fibre weakening during use caused by flexing or chemical attack. Their design should provide high geometric surface and for optimal performance often a fresh bag is first treated with large particles to encourage the development of a filter cake on the surface to prevent entraining small particles within the fabric that leads to high pressure drop. The last section on design theory is an addition over that in the first edition and includes factors such as the number of compartments as well as an example of a baghouse design.

Like elsewhere in the book, the final Chapter 24 called 'Electrostatic Precipitators' closely follows that in the first edition without updating the now rather old references or highlighting the relevance of any recent developments. Notwithstanding this the coverage in 15 pages of this important technology for removal of PM is very useful. In an electrostatic precipitator a potential of several tens of kilovolts is applied to thin wires spaced a few inches apart that run through holes in collector plates. The applied potential is sufficient to form a corona around the wires without flash-over or sparking, and ions from the corona collide with larger particles thus charging them so they migrate to the oppositely charged collecting plate surfaces where they are retained until deliberately removed. More important for smaller particles is diffusion charging where a charge is acquired by particles moving in a sufficiently high potential gradient. The nature and particularly the resistivity of the particles concerned

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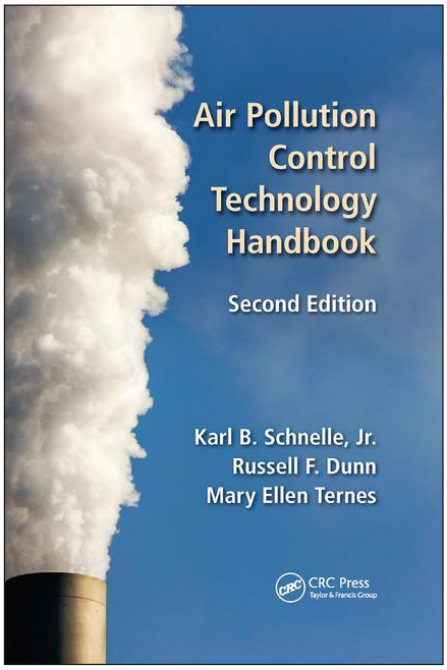
is important for efficient electrostatic precipitation, and for example flue gas from power plants burning low sulfur coal has to be conditioned by introducing into the gas small amounts of sulfuric acid or its precursor sulfur trioxide. A range of additives have been used in different situations.

References and Index

As mentioned previously rather than have references listed at the end of each chapter as in the first edition, in the second edition they are collected together in eleven pages before a useful general index which occupies a similar number of pages.

Conclusions

The second edition of the "Air Pollution Control Technology Handbook" closely follows the outline and content of the first edition, with some updates in several places. The updated review of the Clean Air Act is well done and a notable feature is in the much enlarged Chapter 11 on the use of packed towers for absorption of volatile organic compounds that now includes modern metal structured tower packing designs. Overall this book provides a useful general reference for chemical engineers and others involved with the control of pollution emissions from industrial plants and as such it should be available in appropriate libraries.



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The Reviewer

Martyn Twigg retired as Johnson Matthey's Chief Scientist in 2010. Since retiring Martyn has maintained research activities with several universities in the UK and overseas, and has honorary positions at some. His consulting business is thriving with work in a variety of areas many of which are providing new and exciting challenges, additionally novel catalytic systems have been developed and put into production.

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