Industrial Air Pollution Handbook

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Preface

This book has been planned to provide information which will be of value to all who are concerned with surveys of general pollution of the air in urban and rural areas, and to those who are involved in reducing to a realistic minimum the emission of air pollutants from industrial processes.

It would be an advantage if there were internationally accepted methods and standards for the measurement of air pollution, so that a sound comparison of all results could be made. That is not the position at present, though there are moves in that direction; nevertheless, this book will have a greater relevance outside, as well as inside, the UK.

There is a comprehensive chapter on the effects of air pollution on human health, on plants and animals, and on materials, while another chapter deals with the existing legislation. However, the major part of the book deals with methods of reduction of the emission of pollutants, so far as is practicable on the basis of present knowledge and experience. As it is impossible in one volume to deal with the total range of industries, it has been necessary to be selective, but we have ensured that all important methods of emission reduction have been covered.

The editor has written three chapters and parts of three others, and the remainder have been written by authors who are experts in the subjects they cover. The editor expresses his appreciation of their work in preparing their contributions and thanks them for their cooperation throughout the life of the project.

ALBERT PARKER
November 1977

The editor

Albert Parker, CBE, BSc(Hons), MSc (Manchester), DSc (Birmingham), FRIC, FIChemE, FIWater Pollution Control, Hon FIGasE, Hon FInst Fuel, Hon FIPubHlthEng, Hon Mbr Coke Oven Managers' Assoc, Life Vice-President RSHlth, Hon FAmerPubHealth Assoc.

The editor became Graduate Scholar and Beyer Research Fellow of Manchester University. He was then a Lecturer at Birmingham University, and subsequently officer in charge of a team on development work and research for a joint committee of the Institution of Gas Engineers and the Fuel Department of Leeds University on methods of manufacture of gas and the treatment and disposal of gas liquor effluents. Afterwards, he became Assistant Director and later Director of Water Pollution Research in the former Government Department of Scientific and Industrial Research, and then Director of Fuel Research and Air Pollution Research in the same Government Department. On leaving Government Service, he established a practice as a Consultant Chemical Engineer on a variety of scientific and technical problems in Britain and several other countries.

During the Second World War he was Lieutenant-Colonel in charge of a group of British and American scientists, all in military uniform, advising the American Army during their advance through and beyond the Ruhr on certain facets of the German production of synthetic fuels for German aircraft, tanks, etc.

From 1951 to 1964, he was Honorary Secretary of British National Committee of World Energy Conference. He prepared and presented documents on world energy resources for the World Energy Conference in Melbourne, Australia, in 1962 and for the Conference in Moscow in 1968.

He was Honorary Editor IChemE 1937–45 and Vice-President 1941–3. From 1953 until 1955 he was President of the Fuel Luncheon Club, London, and from 1955 until 1956 Chairman of the Council of RSH, of which he is now Life Vice-President. He was Honorary Secretary of the British National Committee of the World Energy Conference 1951–64 and Chairman of the Committees guiding the production of the sixth and seventh editions of Technical Data on Fuel. He was President of the National Society for Clean Air from 1963 to 1965, and is now Honorary Vice-President.

He was awarded the Osborne Reynolds Medal IChemE, 1941, the Melchett Medal Inst Fuel, 1955, the Telford Premium, 1942, and the Chadwick Medal, 1955, of the Inst. Civil Eng. for papers on water pollution and on air pollution. He gave the Thomas Hawksley Lecture IMechE, 1949. He gave the Mitchell Memorial Lecture and was awarded the Gold Medal of the Stoke-on-Trent Assn of Engineers in 1956. He gave the Cantor Lectures of the Roy. Soc. Arts, 1960. He was Chairman of the Expert Committee of WHO on Air Pollution, 1958, and was given a Clean Air Award of the Nat. Soc. for Clean Air, 1973.

Contributors

1. The editor.
2. Part 1. Marjorie Clifton, MD, and Sir Charles Stuart-Harris, CBE, MD, DSc, FRCP, Professor at University of Sheffield Medical School.
   Part 2. L. H. P. Jones, PhD (Melbourne), BAgrSc, FRACI, FRIC, FIBiol, and D. W. Cowling, MIBiol, both of Grassland Research Institute, Hurley, Maidenhead, Berkshire.
   Part 3. The editor.
3. Part 1. The editor.
   Part 2. Pamela M. Bryant, BSc, FRIC, Senior Environmental Adviser to the National Radiological Protection Board, Harwell. President, UK Society for Radiological Protection 1977–78.
4. S. R. Craxford, ISO, MA(Oxon), DPhil, Consultant.
5. The late G. Spurr, BSc(Hons), FInstP, FRMetS, was on the staff of the Environmental and General Studies Section, Central Electricity Generating Board, London.
6. K. P. Grubb, BSc(Eng), MICE, Senior Assistant Civil Engineer, Central Electricity Generating Board, London.
7. J. Bettelheim, CEng, DiplEng, CSc(Prague), FIChemE, Research Officer, B. H. M. Billinge, PhD, BSc, Group Leader, and W. S. Kyte, CEng, MA(Cantab), PhD, FIChemE, Research Officer, all of Research Laboratories, Central Electricity Generating Board, Leatherhead, Surrey.
8. K. Darby, Managing Director of Lodge-Cottrell Ltd, Birmingham.
9. J. Bettelheim, CEng, DiplEng, CSc(Prague), FIChemE, Research Officer, and B. H. M. Billinge, PhD, BSc, Group Leader, both of Research Laboratories, Central Electricity Generating Board, Leatherhead, Surrey.
10. A. A. Barrett, CEng, FIMechE, Plant Engineering Department of the Generation Development of the Construction Division of the Central Electricity Generating Board, Cheltenham, Gloucestershire.
11. Pamela M. Bryant, BSc, FRIC, Senior Environmental Adviser to the National Radiological Protection Board, Harwell.

12. Part 1. G. E. Hall, CChem, MSc, MRIC, Senior Technical Officer, Head of Member Services, British Carbonization Research Association, Wingerworth, Chesterfield, Derbyshire.
    Part 2. The editor.
13. M. T. Westaway, PhD, FInstPet, Environmental Studies, and G. J. Brockis, BSc, FInstPet, Head of Environmental Sudies, both of BP Research Centre, Sunbury on Thames, Middlesex.
14. G. E. Speight, MBE, BSc, FRIC, AssocMet, FIM, formerly Manager, Environmental Pollution Control, Head Office, British Steel Corporation, London.
15. A. K. Barbour, CChem, PhD, BSc, FRIC, of R.T.Z. Services Ltd, Bristol, J. F. Castle, CEng, FIChemE, MInstF, of R.T.Z. Consultants, London, and S. E. Woods, DPhil, FRS, of R.T.Z. Services Ltd, Bristol,
16. B. C. Spall, MA, DPhil(Oxon), Chief Chemist, Levington Research, Levington, Ipswich, Suffolk of the Fertilizer Division of Fisons Ltd.
17. R. J. Gates, CEng, MA, MIMechE, Chief Engineer, Rugby Portland Cement Co. Ltd, Rugby.
18. E. Rowden, MBE, BSc, ARCS, DIC, FRIC, FICeram, Consultant on Air Pollution Problems to the British Ceramic Research Association, Penkhull, Stoke-on-Trent.
19. The editor.
20. The late H. B. Johnson, BSc, FIEE, was a Partner in Merz and McLellan, Consulting Engineers, and J. M. Burnett, BA, MIEE, an Associate in Merz and McLellan, London and Newcastle upon Tyne.
21. The editor.
22. R. A. Haslett, PhD, BSc, Ricardo, Consulting Engineers, Shoreham by Sea, Sussex.

Units and conversion factors

TABLE 1

Basic SI units

Quantity	Name of unit	Unit symbol
length	metre	m
mass	kilogram	kg
time	second	s
electric current	ampère	A
thermodynamic temperature	degree Kelvin	K
luminous intensity	candela	cd

TABLE 2

Some derived SI units with special names

Physical quantity	SI unit	Unit symbol
force	newton	N = kg m s^{-2}
work, energy, quantity of heat	joule	J = N m
power	watt	W = J s^{-1}
electric charge	coulomb	C = A s
electrical potential	volt	V = W A^{-1}
electric capacitance	farad	F = A s V^{-1}
electric resistance	ohm	Ω = V A^{-1}
frequency	hertz	Hz = s^{-1}
magnetic flux	weber	Wb = V s
magnetic flux density	tesla	T = Wb m^{-2}
inductance	henry	H = V s A^{-1}
luminous flux	lumen	lm = cd sr
illumination	lux	lx = lm m^{-2}

TABLE 3

Some additional derived SI units

Physical quantity	SI unit	Unit symbol
area	square metre	m^2
volume	cubic metre	m^3
mass density	kilogramme per cubic metre	$kg\ m^{-3}$
velocity	metre per second	$m\ s^{-1}$
angular velocity	radian per second	$rad\ s^{-1}$
acceleration	metre per second squared	$m\ s^{-2}$
angular acceleration	radian per second squared	$rad\ s^{-2}$
pressure	newton per square metre	$N\ m^{-2}$
surface tension	newton per metre	$N\ m^{-1}$
dynamic viscosity	newton second per metre squared	$Ns\ m^{-2}$
kinematic viscosity diffusion coefficient	metre squared per second	$m^2\ s^{-1}$
thermal conductivity	watt per metre degree Kelvin	$W\ m^{-1}\ K^{-1}$
electric field strength	volt per metre	$V\ m^{-1}$
magnetic field strength	ampere per metre	$A\ m^{-1}$
luminance	candela per square metre	$cd\ m^{-2}$

TABLE 4

Multiples and sub-multiples of units

Factor by which the unit is multiplied		Prefix	Symbol
1 000 000 000 000	10^{12}	tera	T
1 000 000 000	10^{9}	giga	G
1 000 000	10^{6}	mega	M
1 000	10^{3}	kilo	k
100	10^{2}	hecto	h
10	10^{1}	deca	da
0 1	10^{-1}	deci	d
0 01	10^{-2}	centi	c
0 001	10^{-3}	milli	m
0 000 001	10^{-6}	micro	μ
0 000 000 001	10^{-9}	nano	n
0 000 000 000 001	10^{-12}	pico	p
0 000 000 000 000 001	10^{-15}	femto	f
0 000 000 000 000 000 001	10^{-18}	atto	a

Much of the useful technical literature available, particularly that published in the UK and the USA, gives quantitative data in units that are neither metric nor SI. Eventually, technical literature will use metric and SI units. In some instances it will mean modifications in units used in certain items of legislation. There are some differences in the units that have been and are still used in the UK and the US. In Tables 5–17 conversion factors are given likely to be useful to readers of this book.

TABLE 5

Comparison of some UK and US units

UK	US
1 yard = 0·914398 m	1 yard = 0·914402 m
1 lb = 0·453 592 338 kg	1 lb = 0·453 592 427 7 kg
1 lb = 16 oz = 7000 grain	1 lb = 16 oz = 7000 grain
1 cwt = 112 lb	1 short cwt = 100 lb
1 ton = 20 cwt = 2240 lb	1 short ton = 20 short cwt = 2000 lb
1 gal is the volume occupied by 10 lb of distilled water at 62°F, i.e. 4·545 96 l	1 gal is 3·785 33 l which = 0·832 680 UK gallon

TABLE 6

Miscellaneous relationships between units

1 mi = 1760 yd = 5280 ft = 1·609 344 km
1 in^2 = 6·4516 cm^2
1 acre = 4840 yd^2
1 lb = 7000 grain 1 US barrel = 42 US gallons
1 mb = 1000 dyn cm^{-2}
1 hp = 550 ft lbf s^{-1}
1 cheval vapeur = 75 kgf·m s^{-1}
1 therm = 10^5 British thermal units
1 thermie = 10^6 15° C calories

TABLE 7

Length

	cm	m	in	ft	yd
1 cm	1	0·01	0·393 701	0·032 808 4	0·010 936 1
1 m	100	1	39·370 1	3·280 84	1·093 61
1 in	2·54	0·025 4	1	0·083 333 3	0·027 777 8
1 ft	30·48	0·304 8	12	1	0·333 333
1 yd	91·44	0·914 4	36	3	1

1 km = 0·621 371 mi
1 micron (μ) = 1 micrometre (μm) = 10^{-6} m = 10^{-3} mm
1 angstrom (Å) = 0·000 1 micron = 10^{-7} mm

TABLE 8

Area

	m^2	in^2	ft^2	yd^2
1 m^2	1	1550·00	10·763 9	1·195 99
1 in^2	0·000 645 16	1	0·006 944 44	0·000 771 605
1 ft^2	0·092 903 0	144	1	0·111 111
1 yd^2	0·836 127	1296	9	1

1 hectare = 10 000 m^2 = 2·471 05 acres
1 mi^2 = 640 acres = 258·999 hectares

TABLE 9

Volume

	l	in³	UK gal	US gal
1 l	1	61·025 5	0·219 976	0·264 178
1 in³	0·016 386 6	1	0·003 604 65	0·004 328 98
1 UK gal	4·545 96	277·42	1	1·200 94
1 US gal	3·785 33	231·00	0·832 680 1	1

	m³	yd³	UK gal	US gal	US barrel
1 m³	1	1·307 95	219·969	264·170	6·289 76
1 yd³	0·764 555	1	168·179	201·973	4·808 88
1 UK gal	0·004 546 09	0·005 946 07	1	1·200 94	0·028 593 8
1 US gal	0·003 785 43	0·004 951 15	0·832 680	1	0·023 809 5
1 US barrel	0·158 988	0·207 948	34·972 6	42	1

TABLE 10

Mass

	kg	grain	oz	lb
1 kg	1	15 432·4	35·274 0	2·204 62
1 grain	0·000 064 798 9	1	0·002 285 71	0·000 142 857
1 oz (avoirdupois)	0·028 349 5	437·5	1	0·062 5
1 lb	0·453 592 37	7000	16	1

	kg	tonne	ton	sh tn
1 kg	1	0·001	0·000 984 207	0·001 102 31
1 tonne (1000 kg)	1000	1	0·984 207	1·102 31
1 ton (2240 lb)	1016·05	1·016 05	1	1·12
1 short ton (2000 lb)	907·185	0·907 185	0·892 857	1

TABLE 11

Force

	dyn	gf	pdl	lbf
1 dyn	1	0·001 019 72	$72·3301 \times 10^{-6}$	$2·248\,09 \times 10^{-6}$
1 gf	980·665	1	0·070 931 6	0·002 204 62
1 pdl	13 825·5	14·098 1	1	0·031 081 0
1 lbf	444 822	453·592	32·174 0	1

TABLE 12

Pressure

	mb	kgf cm^{-2}	pdl ft^{-2}
1 mb	1	$1{\cdot}019\,72 \times 10^{-3}$	67·196 9
1 kgf cm^{-2}	980·665	1	65 897·6
1 pdl ft^{-2}	0·014 881 6	$15{\cdot}175\,0 \times 10^{-6}$	1
1 lbf ft^{-2}	0·478 803	$0{\cdot}488\,243 \times 10^{-3}$	32·174 0
1 tonf ft^{-2}	1 072·52	1·093 66	72 069·9

	lbf ft^{2}	tonf ft^{-2}
1 mb	2·008 54	$0{\cdot}932\,385 \times 10^{-3}$
1 kgf cm^{-2}	2048·16	0·914 358
1 pdl ft^{-2}	0·031 081 0	$13{\cdot}875\,4 \times 10^{-6}$
1 lbf ft^{-2}	1	$0{\cdot}446\,429 \times 10^{-3}$
1 tonf ft^{-2}	2240	1

TABLE 13

Pressure

	mb	atm	kgf cm^{-2}
1 mb	1	$0{\cdot}986\,923 \times 10^{-3}$	$1{\cdot}019\,72 \times 10^{-3}$
1 standard atmosphere	1 013·25	1	1·033 23
1 kgf cm^{-2}	980·665	0·967 841	1
1 torr	1·333 22	$1{\cdot}315\,79 \times 10^{-3}$	$1{\cdot}359\,51 \times 10^{-3}$
1 barometric inch of mercury	33·863 9	0·033 421 1	0·034 531 6

	torr	in Hg
1 mb	0·750 062	0·029 530
1 standard atmosphere	760	29·921 3
1 kgf cm^{-2}	735·559	28·959
1 torr	1	0·039 370 1
1 barometric inch of mercury	25·4	1

TABLE 14

Pressure

	mb	kgf m^{-2}	lbf ft^{-2}	mmHg
1 mb	1	10·197 2	2·088 54	0·750 062
1 kgf m^{-2}	0·098 066 5	1	0·204 816	0·073 555 9
1 lbf ft^{-2}	0·478 803	4·882 43	1	0·359 131
1 barometric millimetre of mercury	1·333 22	13·595 1	2·784 5	1

TABLE 15

Power

	W	kgf m s^{-1}	ft lbf s^{-1}	hp
1 W	1	0·101 972	0·737 562	$1{\cdot}341\,02 \times 10^{-3}$
1 kgf m s^{-1}	9·806 65	1	7·233 01	0·013 150 9
1 ft lbf s^{-1}	1·355 82	0·138 255	1	$1{\cdot}818\,18 \times 10^{-3}$
1 hp	745·700	76·040 2	550	1

1 W = 3·412 14 Btu h^{-1}; 1 Btu h^{-1} = 0·293 071 W
1 kW = 0·947 817 Btu s^{-1}; 1 Btu s^{-1} = 1·055 06 kW

TABLE 16

Heat, work and energy

	j	kcal	Chu
1 J = 1 W s = 10^7 erg	1	$0{\cdot}238\,846 \times 10^{-3}$	$0{\cdot}526\,565 \times 10^{-3}$
1 kcal	4 186·8	1	2·204 62
1 Centigrade heat unit (Celsius heat unit)	1 899·10	0·453 592	1
1 British thermal unit	1 055·06	0·251 996	0·555 556
1 kgf m	9·806 65	$2{\cdot}342\,28 \times 10^{-3}$	$5{\cdot}163\,84 \times 10^{-3}$
1 ft lbf	1·355 82	$0{\cdot}323\,832 \times 10^{-3}$	$0{\cdot}713\,928 \times 10^{-3}$

	Btu	kgf m	ft lbf
1 J = 1 W s = 10^7 erg	$0{\cdot}957\,817 \times 10^{-3}$	0·101 972	0·737 562
1 kcal	3·968 32	426·935	3 088·03
1 Centigrade heat unit (Celsius heat unit)	1·8	193·655	1 400·71
1 British thermal unit	1	107·586	778·169
1 kgf m	$9{\cdot}294\,91 \times 10^{-3}$	1	7·233 01
1 ft lbf	$1{\cdot}285\,07 \times 10^{-3}$	0·138 255	1

TABLE 17

Heat, work and energy

	kJ	kcal	Btu
1 kJ	1	0·238 846	0·947 817
1 kcal	4 186·8	1	3·968 32
1 British thermal unit	1 055·06	0·251 996	1
1 therm	$1{\cdot}055\,06 \times 10^5$	$0{\cdot}251\,996 \times 10^5$	10^5
1 kWh	3 600	859 845	3 412·14
1 hp h	2 684·52	641·186	2 544·43

	therm	kWh	hp h
1 kJ	$0{\cdot}947\,817 \times 10^{-5}$	$2{\cdot}777\,78 \times 10^{-4}$	$3{\cdot}725\,06 \times 10^{-4}$
1 kcal	$3{\cdot}968\,32 \times 10^{-6}$	0·001 163	$1{\cdot}559\,61 \times 10^{-3}$
1 British thermal unit	10^{-5}	$2{\cdot}930\,71 \times 10^{-4}$	$3{\cdot}930\,15 \times 10^{-4}$
1 therm	1	29·3071	39·301 5
1 kWh	0·034 121 4	1	1·341 02
1 hp h	0·025 444 3	0·745 700	1

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