Chemical Engineers' Handbook

FIFTH EDITION

Prepared by a staff of specialists
under the editorial direction of

Robert H. Perry

Consultant

Cecil H. Chilton

Senior Advisor
Battelle Memorial Institute

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List of Contributors

V. H. Abadie, M.S.M.E., *Project Manager, Brown & Root, Inc. (Expansion Turbines)*

Michael M. Abbott, Ph.D., *Research Associate, Fluid, Chemical, and Thermal Processes Division, Rensselaer Polytechnic Institute. (Electrochemical Cells)*

George E. Alves, M.S., *Chemical Engineer, E.I. du Pont de Nemours & Co. (Fluid and Particle Mechanics)*

Charles M. Ambler, B.S.Ch.E., *Director of Chemical Engineering, Pennwalt Corp. (Centrifuges)*

Robert C. Amero, B.S., *Staff Engineer, Gulf Research and Development Co. (Liquid Fuels, Combustion)*

William F. Ames, *Professor, Department of Mechanics and Hydraulics, University of Iowa. (Mathematics)*

B. O. Ayers, Ph.D., *Systems Research Department, Applied Automation, Inc. (Process Control)*

Eno Bagnoli, M.S., *Senior Research Specialist, E.I. du Pont de Nemours & Co. (Psychrometry)*

H. Carl Bauman, B.S., *Manager, Administrative Services Department, American Cyanamid Co. (Cost and Profitability Estimation)*

Kenneth J. Bell, Ph.D., *Professor, Department of Chemical Engineering, Oklahoma State University. (Thermal Design of Heat Exchangers, Condensers, Reboilers)*

Richard C. Bennett, B.S. Ch.E., *Manager, Crystallizer Department, Whiting Corp. (Crystallization from Solution, Crystallization Apparatus)*

Benjamin Block, M.S., *Project Engineer, Abbott Laboratories. (Batch Distillation)*

Donald F. Boucher, Ph.D., *Chemical Engineer, E.I. du Pont de Nemours & Co. (Fluid and Particle Mechanics)*

E. T. Briddell, M.S., *Senior Staff Engineer, Advanced Management Methods Department, Sun Oil Company. (Process Simulation)*

J. A. Brink, Ph.D., *Development Director, Monsanto Enviro-Chem Systems, Inc. (Phase Separation)*

Robert J. Brison, B.Sc., *Senior Process Engineer, Parsons-Jurden Corp. (Flotation)*

William J. Bronkala, B.S., *Staff Consultant, Mineral Services, Inc. (Dense Media and Magnetic Separation)*

C. Edward Capes, Ph.D., *Associate Research Officer, National Research Council (Canada). (Size Enlargement)*

Cecil H. Chilton, M.S., *Senior Advisor, Battelle Memorial Institute. (Mathematical Tables)*

Robert F. Conley, Ph.D., *Manager of Basic Research, Georgia Kaolin Co. (Stirred and Vibratory Media Mills)*

William C. Corder, M.S., *Senior Research Chemical Engineer, Battelle Memorial Institute. (Sublimation)*

Richard C. Corey, B.S., *Senior Staff Scientist, U.S. Bureau of Mines. (Solid Fuels; Combustion)*

Conrad F. Cornell, B.S.Ch.E., *Assistant to Vice President, Envirotech Corp. (Gravity Sedimentation Operations)*

Donald A. Dahlstrom, Ph.D., *Vice President, Envirotech Corp. (Gravity Sedimentation Operations)*

William P. Dyrenforth, D.E., *Senior Vice-President, Carpco Research and Engineering, Inc. (Electrostatic Separation)*

Robert C. Emmett, B.S.Ch.E., *Senior Research Engineer, Envirotech Corp. (Gravity Sedimentation Operations)*

Richard B. Engdahl, M.S., *Fellow, Battelle Memorial Institute. (Solid Wastes, Air Pollution, Incinerators)*

John H. Erbar, Ph.D., *Professor, School of Chemical Engineering, Oklahoma State University. (Process Simulation)*

Charles E. Ernst, *Chief Engineer, Johns Manville Sales Corp. (Thermal Insulation)*

Frank L. Evans, Jr., B.S.M.E., L.L.B., *Editor, Hydrocarbon Processing, Gulf Publishing Co. (Process Machinery Drives)*

J. R. Fair, Ph.D., *Engineering Director, Monsanto Co. (Liquid-Gas Systems)*

R. K. Finn, Ph.D., *Professor, Department of Chemical Engineering, Cornell University. (Separation Processes Based Primarily on Action in a Field)*

Bryant Fitch, M.S., *Chief Scientist, Dorr-Oliver Inc. (Classification)*

E. N. Fuller, Ph.D., *Systems Research Department, Applied Automation, Inc. (Process Control)*

Frank H. Fuller, M.S., *Consultant, E.I. du Pont de Nemours & Co. (Air Conditioning)*

W. R. Gambill, B.S.Ch.E., *Research Engineer, Oak Ridge National Laboratory, Union Carbide Nuclear Co. (Prediction and Correlation of Physical Properties)*

Raymond P. Genereaux, Ch.E., *Chemical Engineer (Retired), E.I. du Pont de Nemours & Co. (Transport and Storage of Fluids)*

W. M. Goldberger, D.Ch.E., *Chief, Minerals and Metallurgical Processing, Battelle Memorial Institute. (Liquid-Liquid and Solid-Solid Systems)*

Joseph B. Gray, Ph.D., *Senior Consultant, E.I. du Pont de Nemours & Co. (Agitation of Low-viscosity Particle Suspensions)*

C. Fred Gurnham, D. Eng. Sc., *President, Gurnham and Associates, Inc. (Expression)*

Joseph D. Henry, Jr., Ph.D., *Assistant Professor, Department of Chemical Engineering, University of West Virginia. (Miscellaneous Separation Processes, Crystallization from the Melt)*

K. C. D. Hickman, Ph.D., *Technical Director, Aquastills, Inc. (Molecular Distillation)*

Nevin K. Hiester, Ph.D., *Director, Materials Laboratory, Stanford Research Institute. (Adsorption and Ion Exchange)*

Arthur E. Hoerl, M.A., *Associate Professor, Department of Statistics and Computer Science, University of Delaware. (Mathematics)*

Richard L. Hoglund, M.S., *Chemical Engineer, Union Carbide Corp. (Diffusional Separation Processes)*

Arthur D. Holt, *Consultant, The Jeffrey Manufacturing Co. (Thermal Design for Solids Processing, Heat Exchangers for Solids)*

Hoyt C. Hottel, S.M., *Professor Emeritus, Department of Chemical Engineering, Massachusetts Institute of Technology. (Radiation)*

Stephen J. Janovac, B.S., *District Sales Manager, W.S. Tyler, Inc. (Screening)*

Eric Jenett, M.S.Ch.E., *Manager Process Engineering, Brown & Root, Inc. (Power Recovery from Liquid Streams)*

D. A. Jewett, B.S., *Systems Research Department, Applied Automation, Inc. (Process Control)*

A. I. Johnson, Ph.D., *Dean of Engineering Science, University of Western Ontario. (Dynamic Simulation)*

Victor J. Johnson, B.S., *Chief, Cryogenic Technical Services, National Bureau of Standards. (Cryogenic Processes)*

Louise H. Jones, Ph.D., *Assistant Professor, Department of Statistics and Computer Science, University of Delaware. (Mathematics)*

Brian H. Kaye, Ph.D., *Professor of Physics and Director of Institute for Fine Particles Research, Laurentian University. (Particle Analysis)*

Gerhard Klein, M.S., *Research Engineer, Sea Water Conversion Laboratory, University of California. (Adsorption and Ion Exchange)*

James G. Knudsen, Ph.D., *Associate Dean of Engineering and Professor of Chemical Engineering, Oregon State University. (Heat Transmission)*

D. W. Lane, Ph.D., *Systems Research Department, Applied Automation, Inc. (Process Control)*

A. Legsdin, M.S., *Professor of Mineral Dressing, University of Missouri. (Jigging and Tabling)*

Robert Lemlich, Ph.D., *Professor, Department of Chemical Engineering, University of Cincinnati. (Adsorptive Bubble Separation Methods)*

Norman N. Li, Sc.D., *Senior Research Engineer, Esso Research and Engineering Co. (Membrane Processes)*

Peter E. Liley, Ph.D., *Thermophysical Properties Research Center and School of Mechanical Engineering, Purdue University. (Physical and Chemical Data)*

Kuang-Hui Lin, Ph.D., *Research Staff, Oak Ridge National Laboratory, Union Carbide Nuclear Co. (Reaction Kinetics, Reactor Design)*

R. B. Long, Ph.D., *Scientific Advisor, Esso Research and Engineering Co. (Membrane Processes)*

Robert L. Lucas, B.S., *Senior Consultant, E.I. du Pont de Nemours & Co. (Gas-Solids Separations)*

R. N. Maddox, Ph.D., *Head, Department of Chemical Engineering, Oklahoma State University. (Absorption)*

Paul Y. McCormick, B.S., *Consultant, E.I. du Pont de Nemours & Co. (Drying)*

R. D. McCoy, Ph.D., *Systems Research Department, Applied Automation Inc. (Process Control)*

John J. McKetta, Ph.D., *Dean, College of Engineering, University of Texas. (Dimensional Analysis)*

Eugene J. Mezey, Ph.D., *Senior Chemist, Battelle Memorial Institute. (Electric Heating)*

A. W. Michalson, B.S.Min.E., *Regional Marketing Representative, Westinghouse Electric Corp. (Ion Exchange and Adsorption Equipment)*

E. C. Miller, A.B., *Technical Assistant to Director of Systems Research, Applied Automation, Inc. (Process Control)*

Shelby A. Miller, Ph.D., *Director of the Center for Educational Affairs, Argonne National Laboratory. (Liquid-Solid Systems)*

Elmer S. Monroe, Jr., M.M.E., *Senior Consultant, E.I. du Pont de Nemours & Co. (Combustion, Fired Process Equipment)*

Eldon R. Morgan, M.S., *Office Manager, Denver Equipment Division of Joy Manufacturing Co. (Solids Sampling)*

R. S. Moser, B.S., *Systems Research Department, Applied Automation, Inc. (Process Control)*

B. O. Myers, Ph.D., *Systems Research Department, Applied Automation Inc. (Process Control)*

Louie A. Nady, Ph.D., *Chemical Engineer, Stauffer Chemical Co. (Separation Processes Based Primarily on Action in a Field, Electrophoresis)*

John Newman, Ph.D., *Professor, Department of Chemical Engineering, University of California. (Separations Based Primarily on Action in a Field, Electrochemical Theory)*

Robert W. Nolan, *Senior Consultant (Retired), E. I. du Pont de Nemours & Co. (Storage and Process Vessels)*

Robert B. Norden, B.S.Ch.E., *Managing Editor (Engineering), Chemical Engineering. (Materials of Construction)*

Robert W. Norris, B.S., *Senior Consultant, E. I. du Pont de Nemours & Co. (Evaporative Cooling, Refrigeration)*

F. T. Ogle, Ed. M., *Systems Research Department, Applied Automation, Inc. (Process Control)*

James Y. Oldshue, Ph.D., *Vice President, Mixing Equipment Co. (Agitation of Low-viscosity Particle Suspensions)*

Carl R. Olsen, M.S.E.E., *Fellow Engineer, Westinghouse Electric Corp. (Electric Motors)*

Philip P. O'Neill, M.S., *Section Supervisor, E. I. du Pont de Nemours & Co. (Pumping of Liquids and Gases)*

T. J. Pemberton, Ph.D., *Systems Research Department, Applied Automation, Inc. (Process Contol)*

W. R. Penney, Ph.D., *Engineering Specialist, Monsanto Co. (Gas-in-Liquid Dispersions)*

Wolfgang B. Pietsch, Ph.D., *Director, Hutt Gmbh. (Compaction)*

Harold F. Porter, B.S., *Principal Consultant, E. I. du Pont de Nemours & Co. (Gas-Solid Systems)*

John E. Powers, Ph.D., *Professor, Department of Chemical Engineering, University of Michigan. (Crystallization from the Melt)*

R. K. Prabhudesai, Ph.D., *Principal Chemical Engineer, The Coca-Cola Co. (Leaching)*

Abbott A. Putnam, B.M.E., *Fellow, Battelle Memorial Institute. (Heat Transport)*

W. G. Ragains, M.S., *Systems Research Department, Applied Automation, Inc. (Process Control)*

Grantges J. Raymus, M.S., M.E., *Managing Consultant, Union Carbide Corp. (Handling of Bulk and Packaged Solids)*

William T. Reid, B.S., *Senior Fellow (Retired), Battelle Memorial Institute. (Heat Generation and Transport)*

R. C. Richardson, Ph.D., *Systems Research Department, Applied Automation, Inc. (Process Control)*

O. E. Ririe, B.S., *Systems Research Department, Applied Automation, Inc. (Process Control)*

Elliot J. Roberts, Ph.D., *Scientific Consultant, Dorr-Oliver Inc. (Classification)*

Lawrence A. Roe, M.S., *Manager, Inorganic Research and Development, R.T. Vanderbilt Co. (Spiral Concentration)*

Frank L. Rubin, B.Ch.E., *Sales Engineer, Adamson Co. (Heat-transfer Equipment)*

R. A. Sanford, B.S., *Systems Research Department, Applied Automation, Inc. (Process Control)*

Adel F. Sarofim, Sc.D., *Associate Professor, Department of Chemical Engineering, Massachusetts Institute of Technology. (Radiation)*

Florian Schwarzkopf, Dr. Ing., *Vice-president for Product Development, Kennedy Van Saun Corp. (Fertilizer Grinding)*

Joseph Sheehan, B.S.M.E., *Contract Engineer, Combustion Engineering Inc. (Pulverizers)*

I. H. Silberberg, Ph.D., *Lecturer, Department of Petroleum Engineering and Assistant Director Texas Petroleum Research Committee, University of Texas. (Dimensional Analysis)*

Charles E. Silverblatt, M.S.Ch.E., *Director, Industrial Processing Research and Development, Envirotech Corp. (Gravity Sedimentation Operations)*

Eugene M. Simons, Ph.D., *Fellow, Battelle Memorial Institute. (Nuclear Heat Sources)*

Buford D. Smith, Ph.D., *Professor, Department of Chemical Engineering, Washington University. (Distillation)*

Julian C. Smith, Ch.E., *Professor, Department of Chemical Engineering, Cornell University. (Centrifuges, Selection of a Solids-Liquid Separator)*

Robert B. Smith, B.M.E., *Technical Advisor, Battelle Memorial Institute. (Gaseous Fuels, Combustion)*

Richard H. Snow, Ph.D., *Senior Engineer, IIT Research Institute. (Size Reduction and Size Enlargement)*

K. S. Spiegler, Ph.D., *Professor, Sea Water Conversion Laboratory, University of California. (Separation Processes Based Primarily on Action in A Field)*

F. C. Standiford, M.S., *President, W. L. Badger Associates, Inc. (Thermal Design of Evaporators, Evaporator Equipment)*

H. W. Staten, M.S., *Systems Research Department, Applied Automation, Inc. (Process Control)*

H. Steen-Johnsen, M.S.M.E., *Chief Staff Engineer, Elliott Co. (Steam Turbines)*

D. E. Steinmeyer, M.S., *Engineering Specialist, Monsanto Co. (Liquid-in-Gas Dispersions)*

W. S. Stewart, Ph.D., *Systems Research Department, Applied Automation, Inc. (Process Control)*

Edward H. Steymann, B.S., *Associate Editor, Chemical Engineering. (Handling of Bulk and Packaged Solids)*

avid Stuhlbarg, Ch.E., *Project Engineer, Procon Inc. (Thermal Design of Tank Coils, Tank il Equipment)*

David E. Stutz, B.S.E.E., *Senior Engineer, Battelle Memorial Institute. (Electric Heating)*

David B. Todd, Ph.D., *Technical Director, Baker Perkins Inc. (Paste and Viscous-material Mixing)*

E. D. Tolin, M.S., *Systems Research Department, Applied Automation, Inc. (Process Control)*

Robert E. Treybal, Ph.D., *Chairman, Department of Chemical Engineering, University of Rhode Island. (Liquid Extraction, Liquid-Liquid Systems)*

Vincent W. Uhl, Ph.D., *Chairman, Department of Chemical Engineering, University of Virginia. (Agitated Vessels)*

H. C. Van Ness, D.Eng., *Chairman, Fluid, Chemical, and Thermal Processes Division, Rensselaer Polytechnic Institute. (Thermodynamics)*

Theodore Vermeulen, Ph.D., *Professor, Department of Chemical Engineering, University of California. (Adsorption and Ion Exchange Electrophoresis)*

Edward Von Halle, Ph.D., *Chemical Engineer, Union Carbide Corp. (Diffusional Separation Processes)*

James B. Weaver, M.S., *Vice President, ICI America, Inc. (Cost and Profitability Estimation)*

William D. Webb, *Senior Design Consultant, E.I. du Pont de Nemours & Co. (Process Plant Piping)*

Sherman S. Weidenbaum, Ph.D., *Research Professor, Department of Physical and Ocean Sciences, United States Coast Guard Academy. (Solid-Solid Mixing)*

David F. Wells, B.S., *Senior Consultant, E.I. du Pont de Nemours & Co. (Fluidized-bed Systems)*

Arthur W. Westerberg, Ph.D., *Assistant Professor, Department of Chemical Engineering, University of Florida. (Machine Simulation)*

T. C. Wherry, B.S., *Vice-President, Applied Automation, Inc. (Process Control)*

Preface to
the Fifth Edition

It is obvious that the practice of chemical engineering has benefited greatly from the continuing explosion of scientific and engineering knowledge. The result is not only a tremendous increase in the depth of our understanding but also a much wider geographic application of it. No longer are the benefits (and challenging problems) limited to a few industrial nations. It is now a necessity world-wide that the chemical process industries, as well as others, carry out their missions in the most efficient and economic manner possible. Conservative exploitation of the world's resources is an obligation which all professions, and especially our own, must shoulder willingly. With this in mind while revising a basic reference work, the editors have made available to the profession the latest and best information regarding design techniques and equipment performance. To do this required a complete rewriting of the Handbook. Each section has been extensively revised, and for most sections this meant starting with a completely new approach to the topic in question. A patchwork revision was not possible. This is not to say that we do not acknowledge the debts we owe to those who contributed to prior editions. It is instead a recognition that engineering practice has become more firmly based on scientific principles as opposed to depending on empirical accumulation of facts. This edition reflects this in each section. It was our intent, though, not to neglect empiricism where such data lead quickly to the most economic design. The test we have applied has been pragmatic—which approach will, now and in the immediate future, lead to sound efficient design?

An abbreviated summary of the additions and changes made in this edition follows.

SECTION-BY-SECTION SUMMARY OF CHANGES
AND ADDITIONS IN THE 5TH EDITION

Section 1. Mathematical Tables Emphasis during this revision was on incorporation of conversion to SI units, including newtons, watts, and joules as well as the more common units of length and weight. The latest accepted values of fundamental constants have been listed. A new nomograph for solving growth-rate problems is presented.

Section 2. Mathematics New subsections have been added which describe various optimization techniques and modern computer process-simulation methods in some detail.

Section 3. Physical and Chemical Properties Thermodynamic diagrams for the superheat region have been added for a variety of compounds, while retaining tabular data for saturation conditions. Extensive new tables are included for the transport properties of many compounds. The subsection dealing with correlation and prediction of physical properties has been thoroughly updated.

Section 4. Thermodynamics This subsection has been completely rewritten. Thermodynamic functions for PVT systems are defined for both constant and variable composition. Solution thermodynamics and electrochemical cells are much more thoroughly treated than was the case in the fourth edition. Procedures for the evaluation of thermodynamic properties from equations of state are presented.

Reaction Kinetics and Reactor Design Extensive revision has resulted in much more emphasis upon application of fundamentals to reactor design, including interpretation of laboratory and pilot-plant data and also scale-up methods. An extensive list of references is included on a topic-by-topic basis.

Section 5. Fluid and Particle Mechanics Thorough updating has resulted in new material on turbine meters, anemometers, and quadrant-edge flowmeters. There is an entirely new subsection on mass flowmeters. Extensive new material has been added for two-phase systems with regard to metering and flow-pattern prediction. New material on particle dynamics includes information on free-fall orientation of particles, effects of particle concentration on hindered settling, and the dynamics of liquid drops suspended in liquids.

Section 6. Transport and Storage of Fluids New material is added for in-line vertical pumps, ANSI horizontal single-stage pumps, and vacuum systems. Non-metallic pipe and pipe linings are described. The 1972 ANSI pressure piping code is reflected in design procedures for piping systems. Vessel design has been updated to reflect ASME Code changes. Recent cost data are included for vessels as well as for pumps and compressors.

Section 7. Solids Transport and Storage The subsection dealing with conveying bulk solids has been expanded to include new material on pneumatic and screw conveying, including sizing and cost information. The bulk-storage subsection now includes the Jenicke method of bin design which takes into account factors affecting material flow in storage vessels. New subsections on weighing and packaging solids are included, as well as new material on the transportation of solids, with dimensions given for typical highway trailers and railroad cars.

Section 8. Size Reduction and Size Enlargement The description of the theoretical aspects of grinding has been revised. The discussion of the selection of equipment for specific applications in line with current practice and availability has been rewritten and reorganized.

Section 9. Heat Generation and Transport Entirely new or revised tabular material for solid fuels (coal, metallurgical coke, pitch, and petroleum coke and chars) is presented. The subsection on liquid fuels has been rewritten to include a discussion of basic fuel chemistry, and there are new tabular data on physical, thermal, and chemical properties. Similarly the subsection on combustion now emphasizes up-to-date tabular and graphical data.

Section 10. Heat Transmission This section's discussion of fundamentals has been revised, especially the subsection dealing with radiation. A detailed heat-exchanger design method has been included, and new material is presented on the processing of divided solids.

Section 11. Heat-transfer Equipment This section now includes a new subsection on thermal insulation and another on seawater evaporators. There is new material on tube layouts. The explanation of heat exchanger codes has been updated.

Section 12. Psychrometry, Evaporative Cooling, Air Conditioning, and Refrigeration This section no longer includes material on drying, thus permitting a more cohesive format. Extensive revision was made in the refrigeration subsection to include equipment selection guides, new data on brines, and information on steam jet refrigeration.

Section 13. Distillation   Coverage of phase equilibrium has been extended with respect to gas-phase non-ideality corrections, verification of data accuracy, and equations for prediction and correlation of activity coefficients. Short-cut design methods for continuous and batch distillation are treated in detail. Various multicomponent, multistage distillation design procedures are analyzed for effectiveness in differing situations.

Section 14. Gas Absorption   Up-to-date calculation techniques have been included for rigorous stepwise analysis of multicomponent systems accounting for heat and material balances as well as the rate of mass transfer.

Section 15. Liquid Extraction   This material is now presented in a separate section. New items include: a greatly expanded treatment of phase equilibria with tabular data for 278 ternary systems, a predictive method for equilibria utilizing activity coefficients, descriptions of double-solvent (fractional) extraction and direct-contact heat exchange between liquids, and a new and improved chart of the Kremser equation.

Section 16. Adsorption and Ion Exchange   Much of this section has been rewritten to facilitate fixed-bed design. Regenerative heat storage is treated, and multicomponent sorption is covered extensively. The underlying material on physical properties and equilibrium calculations has been thoroughly revised. Operations with other than fixed beds (batch, stage, and countercurrent) are analyzed.

Section 17. Miscellaneous Separation Processes   The crystallization subsection has been expanded to include a parallel treatment of crystallization from solution and melt. A subsection on adsorptive bubble separations, foam fractionation, and solvent sublimation has been added. The discussion of dialysis has been expanded to include liquid permeation, gas permeation, and reverse osmosis. The material on gaseous diffusion now also includes thermal, pressure, and mass diffusional separation processes. Separations based on action in an electrical field have been expanded to include electrophoresis and electromatography as well as electrodialysis.

Section 18. Gas-Liquid Systems   This section has been completely rewritten to reflect advances in the science and art of liquid-gas contactor design, and to include recent performance and cost data. Methods for sizing plate and packed towers have been updated, and the performance of newer contacting devices (such as valve trays) is analyzed. New developments in atomization, fogging, and bubble (gas-sparged) contactors have been included. Particular attention has been given to phase separation in keeping with current interest in pollution abatement.

Section 19. Liquid-Solid Systems   A subsection devoted to crystallization equipment, adsorption equipment, and selection of a solids-liquid separator has been added. The material on paste mixing and leaching equipment has been completely rewritten. Descriptions of equipment performance for agitation, ion exchange, gravity sedimentation, filtration, centrifugation, and expression have been extensively updated.

Section 20. Gas-Solid Systems   The material treating drying and fluidized solids equipment has been updated. In view of current environmental problems, a major emphasis in the section is now on particulate solids scrubbers, dust and mist collection, and electrostatic precipitators. Granular-bed gas filters are discussed, using new material.

Section 21. Liquid-Liquid and Solid-Solid Systems   For liquid-liquid systems, the treatment of agitated vessel performance has been completely rewritten to include information on droplet coalescence and formation, scale-up, and intra-stage recycle. The description of differential contact equipment now includes analysis of the effects of axial dispersion for all major equipment types. New extractors (such as Quadronics, Delaval, Treybal, Fenske-Long, Graesser) are described. For solid-solid systems, in addition to an extensive updating of performance and cost data, there are new subsections on spiral concentration and heavy media concentration.

Section 22. Process Control   This section has been rewritten to emphasize the principles of automatic control of processes rather than present a catalogue of applications. New material has been added on fundamentals, the application of computers, analysis of control problems, and the management of control projects and systems.

Section 23. Materials of Construction   The material dealing with the causes of corrosion and techniques for combating it has been completely rewritten, as has the discussion of corrosion-testing methods. Revised and new data are presented concerning the properties of materials of construction, especially those metal alloys and non-metallic materials recently introduced.

Section 24. Process Machinery Drives   This is a completely new section dealing with the selection of motors, steam and gas turbines, gas engines, expansion turbines, and liquid power-recovery turbines.

Section 25. Cost and Profitability Estimation   There is new material in this section dealing with foreign cost data and analysis. A subsection on risk analysis in the evaluation of projects has been added.

One hundred and thirty-five contributors spent several years producing the fifth edition of this Handbook. They represent many engineering and scientific disciplines and they work in a broad range of industrial, academic, and consulting institutions. The editors-in-chief believe that their efforts have produced a book which is an important contribution to the current literature of the profession and is a fitting successor to previous editions of this work. The editors-in-chief owe a great deal, if not everything, to the dedication and diligence with which contributors made their expertise available. Our thanks to them and the organizations they serve is whole-hearted and sincere. We are confident that others in our profession will join us in an appreciation of their efforts.

The untimely death of Cecil Chilton shortly before publication is a tragedy for all his professional colleagues, but perhaps more than most, I will miss his friendship and professional wisdom. To whatever extent this edition fulfills its purpose, we are in great debt to him.

Robert H. Perry

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For the detailed contents of any section, consult the title page of that section.
See also the alphabetical index in the back of this handbook.

Mathematical Tables

BY

Cecil H. Chilton, M.S., *Senior Advisor, Columbus Laboratories, Battelle Memorial Institute; Member, American Institute of Chemical Engineers, American Association of Cost Engineers, American Society for Engineering Education.*

MATHEMATICAL TABLES

Table 1-1. Five-place Common Logarithms of Numbers

100-170

No.	L	0	1	2	3	4	5	6	7	8	9
100	00	000	043	087	130	173	217	260	303	346	3u9
101		432	475	518	561	604	647	689	732	775	817
102		860	903	945	988	*030	*072	•115	•157	•199	•242
103	01	284	326	368	410	452	494	536	578	620	662
104		703	745	787	828	870	912	953	995	*036	*078
105	02	119	160	202	243	284	325	366	408	449	490
106		531	572	612	653	694	735	776	816	857	898
107		938	979	*019	*060	*100	•141	•181	•222	•262	•302
108	03	342	383	423	463	503	543	583	623	663	703
109		743	782	822	862	902	941	981•	*021	*060	*100
110	04	139	179	218	258	297	336	376	415	454	493
111		532	571	610	650	689	727	766	805	844	883
112		922	961	999	*038	*077	•115	•154	•192	•231	•269
113	05	308	346	385	423	461	500	538	576	614	652
114		690	729	767	805	843	881	918	956	994	*032
115	06	070	108	145	183	221	258	296	333	371	408
116		446	483	521	558	595	633	670	707	744	781
117		819	856	893	930	967	*004	*041	*078	•115	•151
118	07	188	225	262	298	335	372	408	445	482	518
119		555	591	628	664	700	737	773	809	846	882
120	08	918	954	990	*027	*063	*099	•135	•171	•207	•243
121		279	314	350	386	422	458	493	529	565	600
122		636	672	707	743	778	814	849	884	920	955
123		991	*026	*061	*096	•132	•167	•202	•237	•272	•307
124	09	342	377	412	447	482	517	552	587	621	656
125		691	726	760	795	830	864	899	934	968	*003
126	10	037	072	106	140	175	209	243	278	312	346
127		380	415	449	483	517	551	585	619	653	687
128		721	755	789	823	857	890	924	958	992	*025
129	11	059	093	126	160	193	227	261	294	327	361
130		394	428	461	494	528	561	594	628	661	694
131		727	760	793	826	860	893	926	959	992	*024
132	12	057	090	123	156	189	222	254	287	320	353
133		385	418	450	483	516	548	581	613	646	678
134		710	743	775	808	840	872	905	937	969	*001
135	13	033	066	098	130	162	194	226	258	290	322
136		354	386	418	450	481	513	545	577	609	640
137		672	704	735	767	799	830	862	893	925	956
138		988	*019	*051	*082	•114	•145	•176	•208	•239	•270
139	14	301	333	364	395	426	457	489	520	551	582
140		613	644	675	706	737	768	799	829	860	891
141		922	953	983	*014	*045	*076	•106	•137	•168	•198
142	15	229	259	290	320	351	381	412	442	473	503
143		534	564	594	625	655	685	715	746	776	806
144		836	866	897	927	957	987	*017	*047	*077	•107
145	16	137	167	197	227	256	286	316	346	376	406
146		435	465	495	524	554	584	613	643	673	702
147		732	761	791	820	850	879	909	938	967	997
148	17	026	056	085	114	143	173	202	231	260	289
149		319	348	377	406	435	464	493	522	551	580
150	17	609	638	667	696	725	754	782	811	840	869
151		898	926	955	984	*013	*041	*070	*099	•127	•156
152	18	184	213	241	270	299	327	355	384	412	441
153		469	498	526	554	583	611	639	667	696	724
154		752	780	808	837	865	893	921	949	977	*005
155	19	033	061	089	117	145	173	201	229	257	285
156		312	340	368	396	424	451	479	507	535	562
157		590	618	645	673	700	728	756	783	811	838
158		866	893	921	948	976	*003	*030	*058	*085	•112
159	20	140	167	194	222	249	276	303	330	358	385
160		412	439	466	493	520	548	575	602	629	656
161		683	710	737	763	790	817	844	871	898	925
162		952	978	*005	*032	*059	*085	•112	•139	•165	•192
163	21	219	245	272	299	325	352	378	405	431	458
164		484	511	537	564	590	617	643	669	696	722
165		748	775	801	827	854	880	906	932	958	985
166	22	011	037	063	089	115	141	168	194	220	246
167		272	298	324	350	376	401	427	453	479	505
168		531	557	583	608	634	660	686	712	737	763
169		789	814	840	866	891	917	943	968	994	*019
170	23	045	070	096	121	147	172	198	223	249	274
No.	L	0	1	2	3	4	5	6	7	8	9

Proportional parts

	44	43	42
1	4.4	4.3	4.2
2	8.8	8.6	8.4
3	13.2	12.9	12.6
4	17.6	17.2	16.8
5	22.0	21.5	21.0
6	26.4	25.8	25.2
7	30.8	30.1	29.4
8	35.2	34.4	33.6
9	39.6	38.7	37.8

	41	40	39
1	4.1	4.0	3.9
2	8.2	8.0	7.8
3	12.3	12.0	11.7
4	16.4	16.0	15.6
5	20.5	20.0	19.5
6	24.6	24.0	23.4
7	28.7	28.0	27.3
8	32.8	32.0	31.2
9	36.9	36.0	35.1

	38	37	36
1	3.8	3.7	3.6
2	7.6	7.4	7.2
3	11.4	11.1	10.8
4	15.2	14.8	14.4
5	19.0	18.5	18.0
6	22.8	22.2	21.6
7	26.6	25.9	25.2
8	30.4	29.6	28.8
9	34.2	33.3	32.4

	35	34	33
1	3.5	3.4	3.3
2	7.0	6.8	6.6
3	10.5	10.2	9.9
4	14.0	13.6	13.2
5	17.5	17.0	16.5
6	21.0	20.4	19.8
7	24.5	23.8	23.1
8	28.0	27.2	26.4
9	31.5	30.6	29.7

	32	31	30
1	3.2	3.1	3.0
2	6.4	6.2	6.0
3	9.6	9.3	9.0
4	12.8	12.4	12.0
5	16.0	15.5	15.0
6	19.2	18.6	18.0
7	22.4	21.7	21.0
8	25.6	24.8	24.0
9	28.8	27.9	27.0

	29	28
1	2.9	2.8
2	5.8	5.6
3	8.7	8.4
4	11.6	11.2
5	14.5	14.0
6	17.4	16.8
7	20.3	19.6
8	23.2	22.4
9	26.1	25.2

	27	26
1	2.7	2.6
2	5.4	5.2
3	8.1	7.8
4	10.8	10.4
5	13.5	13.0
6	16.2	15.6
7	18.9	18.2
8	21.6	20.8
9	24.3	23.4

° Indicates change in the first two decimal places.

Table 1-1. Five-place Common Logarithms of Numbers—(Continued)

170–240

No.	L	0	1	2	3	4	5	6	7	8	9
170	23	045	070	096	121	147	172	198	223	249	274
171		300	325	350	376	401	426	452	477	502	528
172		553	578	603	629	654	679	704	729	754	776
173		805	830	855	880	905	930	955	980	*005	*030
174	24	055	080	105	130	155	180	204	229	254	279
175		304	329	353	378	403	428	452	477	502	527
176		551	576	601	625	650	674	699	724	748	773
177		797	822	846	871	895	920	944	969	993	*018
178	25	042	066	091	115	139	164	188	212	237	261
179		285	310	334	358	382	406	431	455	479	503
180		527	551	575	*600	624	648	672	696	720	744
181		768	792	816	840	864	888	912	935	959	983
182	26	007	031	055	079	102	126	150	174	198	221
183		245	269	293	316	340	364	387	411	435	458
184		482	505	529	553	576	600	623	647	670	694
185		717	741	764	788	811	834	858	881	905	928
186		951	975	998	*021	*045	*068	*091	*114	*138	*161
187	27	184	207	231	254	277	300	323	346	370	393
188		416	439	462	485	508	531	554	577	600	623
189		646	669	692	715	738	761	784	807	830	853
190		875	898	921	944	967	990	*012	*035	*058	*081
191	28	103	126	149	172	194	217	240	262	285	308
192		330	353	375	398	421	443	466	488	511	533
193		556	578	601	623	646	668	691	713	735	758
194		780	803	825	847	870	892	914	937	959	981
195	29	003	026	048	070	092	115	137	159	181	203
196		226	248	270	292	314	336	358	380	403	425
197		447	469	491	513	535	557	579	601	623	645
198		667	688	710	732	754	776	798	820	842	863
199		885	907	929	951	973	994	*016	*038	*060	*081
200	30	103	125	146	168	190	211	233	255	276	298
201		320	341	363	384	406	428	449	471	492	514
202		535	557	578	600	621	643	664	685	707	728
203		750	771	792	814	835	856	878	899	920	942
204		963	984	*006	*027	*048	*069	*091	*112	*133	*154
205	31	175	197	218	239	260	281	302	323	345	366
206		387	408	429	450	471	492	513	534	555	576
207		597	618	639	660	681	702	723	744	765	785
208		806	827	848	869	890	911	931	952	973	994
209	32	015	035	056	077	098	118	139	160	181	201
210		222	243	263	284	305	325	346	366	387	408
211		428	449	469	490	511	531	552	572	593	613
212		634	654	675	695	715	736	756	777	797	818
213		838	858	879	899	919	940	960	980	*001	*021
214	33	041	062	082	102	122	143	163	183	203	224
215		244	264	284	304	325	345	365	385	405	425
216		445	465	486	506	526	546	566	586	606	626
217		646	666	686	706	726	746	766	786	806	826
218		846	866	885	905	925	945	965	985	*005	*025
219	34	044	064	084	104	124	143	163	183	203	223
220		242	262	282	301	321	341	361	380	400	420
221		439	459	479	498	518	537	557	577	596	616
222		635	655	674	694	713	733	753	772	792	811
223		830	850	869	889	908	928	947	967	986	*005
224	35	025	044	064	083	102	122	141	160	180	199
225		218	238	257	276	295	315	334	353	372	392
226		411	430	449	468	488	507	526	545	564	583
227		603	622	641	660	679	698	717	736	755	774
228		793	813	832	851	870	889	908	927	946	965
229		984	*003	*021	*040	*059	*078	*097	*116	*135	*154
230	36	173	192	211	229	248	267	286	305	324	342
231		361	380	399	418	436	455	474	493	511	530
232		549	568	586	605	624	642	661	680	884	717
233		736	754	773	791	810	829	847	866	884	903
234		922	940	959	977	996	*014	*033	*051	*070	*088
235	37	107	125	144	162	181	199	218	236	254	273
236		291	310	328	346	365	383	401	420	438	457
237		475	493	511	530	548	566	585	603	621	639
238		658	676	694	712	731	749	767	785	803	822
239		840	858	876	894	912	931	949	967	985	*003
240	38	021	039	057	075	093	112	130	148	166	184
No.	L	0	1	2	3	4	5	6	7	8	9

Proportional parts

	25	24	23	22	21	20	19	18
1	2.5	2.4	2.3	2.2	2.1	2.0	1.9	1.8
2	5.0	4.8	4.6	4.4	4.2	4.0	3.8	3.6
3	7.5	7.2	6.9	6.6	6.3	6.0	5.7	5.4
4	10.0	9.6	9.2	8.8	8.4	8.0	7.6	7.2
5	12.5	12.0	11.5	11.0	10.5	10.0	9.5	9.0
6	15.0	14.4	13.8	13.2	12.6	12.0	11.4	10.8
7	17.5	16.8	16.1	15.4	14.7	14.0	13.3	12.6
8	20.0	19.2	18.4	17.6	16.8	16.0	15.2	14.4
9	22.5	21.6	20.7	19.8	18.9	18.0	17.1	16.2

* Indicates change in the first two decimal places.

Table 1-1. Five-place Common Logarithms of Numbers—(Continued)
240–310

No.	L	0	1	2	3	4	5	6	7	8	9
240	38	021	039	057	075	093	112	130	148	166	184
241		202	220	238	256	274	292	310	328	346	364
242		382	359	417	435	453	471	489	507	525	543
243		561	579	596	614	632	650	668	686	703	721
244		739	757	775	792	810	828	846	863	881	899
245		917	934	952	970	987	*005	*023	*041	*058	*076
246	39	094	111	129	146	164	182	199	217	235	252
247		270	287	305	322	340	358	375	393	410	428
248		445	463	480	498	515	533	550	568	585	602
249		620	637	655	672	690	707	724	742	759	777
250	39	794	811	829	846	863	881	898	915	933	950
251		967	985	*002	*019	*037	*054	*071	*088	*106	*123
252	40	140	157	175	192	209	226	243	261	278	295
253		312	329	346	364	381	398	415	432	449	466
254		483	500	518	535	552	569	586	603	620	637
255		654	671	688	705	722	739	756	773	790	807
256		824	841	858	875	892	909	926	943	960	976
257		993	*010	*027	*044	*061	*078	*095	*111	*128	*145
258	41	162	179	196	212	229	246	263	280	296	313
259		330	347	364	380	397	414	430	447	464	481
260		497	514	531	547	564	581	597	614	631	647
261		664	681	697	714	731	747	764	780	797	814
262		830	847	863	880	896	913	929	946	963	979
263		996	*012	*029	*045	*062	*078	*095	*111	*127	*144
264	42	160	177	193	210	226	243	259	275	292	308
265		325	341	357	374	390	406	423	439	456	472
266		488	504	521	537	553	570	586	602	619	635
267		651	667	684	700	716	732	749	765	781	797
268		815	830	846	862	878	894	911	927	943	959
269		975	991	*008	*024	*040	*056	*072	*088	*104	*120
270	43	136	152	169	185	201	217	233	249	265	281
271		297	313	329	345	361	377	393	409	425	441
272		457	473	489	505	521	537	553	569	584	600
273		616	632	648	664	680	696	712	727	743	759
274		775	791	807	823	838	854	870	886	902	917
275	44	933	949	965	981	996	*012	*028	*044	*059	*075
276		091	107	122	138	154	170	185	201	217	232
277		248	264	279	295	311	326	342	358	373	389
278		404	420	436	451	467	483	498	514	529	545
279		560	576	592	607	623	638	654	669	685	700
280		716	731	747	762	778	793	809	824	840	855
281		871	886	902	917	932	948	963	979	994	*010
282	.45	025	040	056	071	086	102	117	133	148	163
283		179	194	209	225	240	255	271	286	301	317
284		332	347	362	378	393	408	423	430	454	469
285		484	500	515	530	545	561	576	591	606	621
286		637	652	667	682	697	712	728	743	758	773
287		788	803	818	834	849	864	879	894	909	924
288		939	954	969	984	*000	*015	*030	*045	*060	*075
289	46	090	105	120	135	150	165	180	195	210	225
290		240	255	270	285	300	315	330	345	359	374
291		389	404	419	434	449	464	479	494	509	523
292		538	553	568	583	598	613	627	642	657	672
293		687	702	716	731	746	761	776	790	805	820
294		835	850	864	879	894	909	923	938	953	967
295		982	997	*012	*026	*041	*056	*070	*085	*100	*115
296	47	129	144	159	173	188	202	217	232	246	261
297		276	290	305	319	334	349	363	378	392	407
298		422	436	451	465	480	494	509	524	538	553
299		567	582	596	611	625	640	654	669	683	698
300	47	712	727	741	756	770	784	799	813	828	842
301		857	871	886	900	914	929	943	958	972	986
302	48	001	015	029	044	058	073	087	101	116	130
303		144	159	173	187	202	216	230	245	259	273
304		287	302	316	330	344	359	373	387	402	416
305		430	444	458	473	487	501	515	530	544	558
306		572	586	601	615	629	643	657	671	686	700
307		714	728	742	756	770	785	799	813	827	841
308		855	869	883	897	911	926	940	954	968	982
309		996	*010	*024	*038	*052	*066	*080	*094	*108	*122
310	49	136	150	164	178	192	206	220	234	248	262
No.	L	0	1	2	3	4	5	6	7	8	9

Proportional parts

	18	17	16	15	14
1	1.8	1.7	1.6	1.5	1.4
2	3.6	3.4	3.2	3.0	2.8
3	5.4	5.1	4.8	4.5	4.2
4	7.2	6.8	6.4	6.0	5.6
5	9.0	8.5	8.0	7.5	7.0
6	10.8	10.2	9.6	9.0	8.4
7	12.6	11.9	11.2	10.5	9.8
8	14.4	13.6	12.8	12.0	11.2
9	16.2	15.3	14.4	13.5	12.6

* Indicates change in the first two decimal places.