Cooling Water Treatment
Principles and Practice

COOLING WATER TREATMENT
Principles and Practice

Colin Frayne

CHEMICAL PUBLISHING CO., INC.
New York, N.Y.

ISBN: 0-8206-0370-8

Printed in the United States of America

ABOUT THE AUTHOR

Colin Frayne, LRIC, MCIWEM, MICorr. (U.K.) is an international water treatment consultant and small business owner. He has more than 30 years of experience in the practice of industrial chemistry and industrial water systems management, and has worked and lectured in over 40 countries. During those years he has also lived on four continents, with his family, while being variously employed in Q.C. and R & D laboratories, in technical sales, sales management, marketing, training, international business development, import/export, and general management. He graduated in analytical chemistry from North London Polytechnic (now the University of North London), in the United Kingdom, and later obtained various business diplomas from colleges in the U.K. and South Africa, including Wits Business School in Johannesburg. Mr. Frayne is British, but has resided in the United States for several years, with his wife and two daughters. In early 1999 he relocated from Georgia to New York City to join the Metro Group, Inc., an environmental services and water treatment company, in a senior executive capacity.

PREFACE

The water treatment market, like most other services markets, is constantly changing. Today's market is more complex, global, and competitive than ever before. However, the vital key to successfully providing efficient cooling water treatment programs today is something it has always been—excellent customer service!

Gone are the days when the very largest industrial organizations had all the necessary in-house skills to take care of their own water treatment programs, while the small companies either did not know or did not care about water treatment and water management. The tremendous changes in all sectors of the water treatment marketplace in recent years, in line with industry globalization and technology changes in other markets, have forced all players to review and modify how we conduct business. In addition, increased sophistication, production demands, and environmental and finanacial pressures in all kinds of heat-transfer processes have demanded that buyers, sellers, and users of water treatment products, services, and management systems keep absolutely up to date.

Today, field-based water treatment services need to provide the customer with an increasing depth and rapidity of authoritative information and support. The service demanded is a high-quality mix of applied chemistry, business management, and hands-on technical skills. In addition, practical advice, fully communicated to the customer, both up and down the line is required.

Providing chemical water treatment programs to end-user customers, irrespective of their industrial, commercial, or institutional origins, has always required a blend of tangible and intangible products and services. The particular recipe tends to change back and forth with time, based on a customer's particular application needs and the relevant financial and marketing pressures. Each program reflects a combination of chemical research and applications development, bank-office and home-office support services, plus technical and marketing skills in the field; it is still some art mixed in with science.

The success of all programs, however, depends on both the *chemistry* employed by the water treatment provider and the *chemistry* that jointly develops between the provider's field personnel and the customers. Staying close to the customer, working out problems together, and drawing on a battery of skills, experiences, and technology weapons to provide cost-effective and satisfying solutions is the only way to retain the customer's business. Computer and other technologies available now will probably never replace the need for hands-on, experienced field service personnel. Therefore, water treatment field people must be effective salespeople, communicators, and marketers as well as expert technicians in water systems management if they and their companies are to succeed.

My fascination with the psychology of selling, the international marketing efforts put into cooling water (cooling water treatment products and services are major profit earners for water treatment companies), the variables that collectively contribute to waterside problems, and the management of field skills and resources in resolving problems for the benefit of the customer were, among others, some of the factors that challenged me to write this book.

Personally, I see little point in regurgitating all the finer technical points regarding cooling water chemistry and management, or even remembering everything. The aim of this book is to encompass more than the pure technical matters involved in cooling water treatment. It has been written to be essentially a practical, technical book, international in nature that contains some theory and much practice. It also confronts and discusses the issues of marketing, and buying and selling of water treatment, an integral part of the daily job, yet avoided in almost all other water treatment books. The book was designed to allow both providers and customers to use it regularly, and hopefully it will find its place on desks or will be carried in the field.

Apart from the basics, this book also includes some aspects of cooling water chemical formulations and programming that hitherto have been taboo for open publication (on the possible grounds that if field engineers or their customers got hold of all this information, the secrets of out industry would be out in the open).

Lesson: Customers buy our products and services because of the benefits they can obtain, not because they particularly want to become active water treatment product manufacturers themselves.

Increased knowledge of the raw material components tends to make for more informed consumers. And besides, this type of information is now becoming more readily available from the specialty, raw materials chemical vendors, who provide much of what is blended into modern water treatment chemical formulations.

There are some excellent marketing books available that focus on practical implementation rather than on theory. (My favorite marketing authors include Al Ries, Jack Trout, and Torn Peters.) There are also many superb technical books on water treatment and possibly thousands of papers on water treatment on individual technical subjects. This technical information tends to supplement the classroom training given to field sales and technical services representatives and has mostly been written by experts within the water treatment companies. These books provide authoritative text without any undue self-promotion and, increasingly, they are appearing on the customers' shelves as well, which is a welcome trend and should be encouraged. (Some well-thumbed examples on my own shelves include the volumes from Nalco Chemical Company; Betz Dearborn, a division of Hercules Inc.; and Drew Industrial, a division of Ashland Chemical Co.). By their very nature, these publications cover a wide range of water treatment and tackle each subject in a general and theoretical way.

There is little available that is specifically written about cooling water treatment. James W. McCoy's book is a notable, if slightly dated, exception. The book by J. N. Tanis contains the most practical hands-on sections I have read in a long time, and the recent *NALCO Guide to Cooling Water Systems Failure Analysis* is excellent. These books are concerned with applied water treatment and are suitable for regular use in the field. But there seems to be a need for more of these practical water treatment handbooks to be written and published, and certainly one or two that deal with the sales and marketing issues!

The starting point for *Cooling Water Treatment Practice: Principles and Practice*, was James W. McCoy, whose first edition of *The Chemical Treatment of Cooling Water* was enthusiastically received by the industrial community when it was published by Chemical Publishing Co. of New York in 1974. Mr. McCoy showed his readers how to use water treatment chemicals beneficially and how to evaluate their effectiveness. He also dispelled much of the misinformation prevalent at that time concerning water treatment technology. In this second edition, published in 1983, McCoy acknowledged having some temerity in writing a practical book that might not satisfy the demands of academics, but wrote that most of us can live with their scorn. It is hoped that in today's world there is more tolerance of nonacademic technical authors. The judge concerning the merits or otherwise of this book should be the operations/maintenance/process/production/ project engineer who has a water system problem and needs to find an answer—quickly, simply, and economically—either directly from these chapters or via a well-read and experienced water treatment field service representative. Therefore, McCoy inspired this book, and consequently I am happy to be working with the same publisher.

My personal interest and involvement in all areas of water treatment, but especially in cooling water management, has taken me all over the world and still continues to do so, providing friends and colleagues, a career, and a source of revenue. It has also given me many frustrations and sleepless nights over the years. I have enjoyed researching and writing this book, although at the beginning I did not realize that writing was such antisocial behavior, requiring me, as it did, to work uninterrupted, isolated from all the other activities taking place in the house, and often working through the night. As a consequence, I must give due recognition to my wife, Carol, for enduring the tortuous time I put her through while writing this book. I also thank Silvia Soto-Galicia and her staff at Chemical Publishing Co. for all the support provided in getting this book published. I now have a new and healthy respect for all the other authors of books and technical information who labored under similar circumstances.

Colin Frayne
Macon, Georgia
1998

CONTENTS

MODERN COOLING WATER TREATMENT PRACTICE

Modern cooling water treatment practice is the planned, actioned, and documented management of cooling systems to produce and maintain operational and economic benefits for the users.

Achievement is by the provision of innovative chemistry, together with other appropriate technologies, and the application of practical expertise in the field, in order to prevent waterside and operational problems from occurring. When problems do arise, detection and identification of the causes, together with suitable remedies that will prevent recurrence, are required.

Good water treatment practice at site should not be the sole prerogative or responsibility of any one person, rather, it requires the active participation, support, and communication of the service company and the owners and users of cooling water systems and other equipment, if success is to be attained and maintained.

INTRODUCTION MARKETING COOLING WATER TREATMENT

Imagine three drums of different "antiscalent" chemical products in a manufacturer's warehouse awaiting delivery to, say, a sugar mill customer. The first drum contains a process additive for addition to the feedwater for an RO plant, the second drum contains a performance chemical for the sugar juice multiple effect evaporators, while the third drum holds a water treatment deposit control agent for cooling system hard water makeup. The labels, brand names, and respective selling prices are all different, yet the applications appear to be similar and the formulations for all three products are almost identical! What is the difference?

The selection of the RO process additive formulation and its rate of application was primarily based on the RO feedwater analysis and type of membrane used, and the product is expected to continuously perform its antiscaling duties with a minimum of supplier monitoring. The performance chemical is slightly different; it was recommended to help solve scaling problems in the evaporation process, to permit longer production runs and higher sugar Brix levels, thereby adding value to the customer's own product. To obtain maximum product performance with this second chemical requires the supplier to advise on monitoring points and periodically review addition rate adjustments.

The third product, however, the water treatment chemical, is merely one component (albeit a very important one) of a comprehensive water treatment program that includes the supply of a variety of on-going customer support and technical services in order that the applications technology provided not only maintains cooling system efficiency but also keeps operating costs within budget and avoids problems from ever-tightening environmental regulations. Thus there are some significant differences in these chemical applications and the customer's technical service support expectations.

Precisely how and why a chemical product is proposed and then used for any particular process application is at least as important as its formulation components. And it has been shown that the degree of technical support services required to ensure maximum performance can vary considerably!

The fact is that all the aforementioned antiscalent applications add value to the customer's operations, but there is a difference between selling chemicals designed perhaps to maintain consistent operating conditions, or to primarily perform basic value-adding tasks, and the marketing of water treatment chemicals as part of a total products and service package, where intangibles such as customer confidence and freedom from worry are an inherent part of the marketing process. And the difference is the requirement for a high degree of on-going customer site technical services.

Water treatment, based on applied chemicals technology, is a service business. The cooling water sector, because of its inherently large number of variables, is especially so. (In certain countries, the service aspect of the water treatment chemicals market has developed so much, due to market demand or regulations, as to be sometimes completely independent of the chemicals element and now overlaps the maintenance services industry.)

Continual change and development take place in the global water management marketplace. The larger, international "service companies" in the water treatment chemicals market also regularly develop and launch a variety of performance chemicals for value-adding processes, gaining financial benefits from technologies perhaps originally developed for water treatment markets (or vice versa) and thus creating the potential for additional sales. Similarly, many major chemical corporations that manufacture specialty products for different markets continually explore opportunities to develop niches within the water treatment chemicals/service industry market sectors.

Additionally, around the world today there is ever-increasing competition in many market sectors as the traditional boundaries between them fade. There are now many privatized potable water supply companies that were once state-owned, moving into the higher margin and nonregulated specialty sectors. There are also major capital equipment sales corporations, providing alternative technologies (such as wastewater treatment, RO, or ion exchange) that, through acquisitions and mergers, are buying into the water treatment chemicals and services markets.

Many regional markets around the world have grown considerably in recent years, although not always in predicted directions or along traditional lines, and this has encouraged water treatment companies of all sizes, and from various home market bases, to develop international departments. This explosive market expansion is most noticeable in high-growth economies such as China, India, ASEAN (Association of South East Asian Nations) Pacific Rim states, and certain Latin American countries, where new customers often seek to conduct business and cement relationships with water treatment companies on their own terms, and in ways not always common to those accustomed to operating solely in the United States or Western Europe.

However, with rapid growth and profit opportunity comes financial risk. This was demonstrated by major financial instability problems with Mexico in the mid-1990s, then a little later in the ASEAN countries, especially Thailand, Indonesia, and the Philippines, and, most recently, South Korea, so it is not all "plain sailing." Several major water treatment companies have experienced a loss of sales and profits in the region that may take several years to overcome. In line with the growth in international markets, the rate of change in our industry continues to gather pace. Water treatment service companies have become even more competitive, quality-oriented, aggressive, and technologically astute, while their customers are more knowledgeable about water treatment practice, are more selective concerning potential suppliers, and seek improved value for their continued support. Consequently, the methods and subtleties by which the individual product ranges and technical service skills are presented to the marketplace demonstrate a significant change from only a few years ago.

Many major water treatment companies are now market sophisticates; they have already become world businesses, operating with global strategies, or are on their way to becoming one, and they are not all to be found in the United States any more! Several multibillion Japanese and European companies, starting from different positions, and with considerable strengths in specialty process chemicals, capital water treatment equipment, or potable and wastewater treatment project engineering, have now grown to be major players in the water treatment chemicals and services market and are influencing the marketplace in yet further diverse ways.

Today it is difficult to determine where many water treatment market sectors begin and end. The market overlaps, the globalization and acquisition strategies of major players, plus the fairly recent phenomenon of alliances between seemingly noncompeting suppliers (seen especially in the United States) have served to further weaken traditional water treatment sector demarcation lines. Now water treatment chemical companies are not manufacturers at all, but are marketers of engineered chemical products and technical support services. They are water systems managers and have a high degree of customer needs awareness, directing their products and services accordingly. These forward-thinking businesses recognize that a strong market focus, staying close to the customer, and a swift response to changes in the market or to aggressive competitive moves is vital for their survival and future prosperity!

What do all the current global market developments, customer/end-user requirements, and strategic responses have to do with modern cooling water treatment practice? The answer to this lies in water treatment companies grasping the opportunities presented for both the growth in chemicals volumes for cooling water (and other areas) and the higher profit margins to be earned by the tailoring of their products' technical services support to meet the more exacting needs of today's customers. To further explain, it is first worth looking at some specific factors: due to the growth, merging and cross-over of traditional market sectors, it is difficult to pronounce with any real certainty on the true size of the world market for specially water treatment chemicals and services. It is probably now worth approximately $7 billion per year, with the United States worth over $3 billion and the Pacific Rim area having grown in excess of $1 billion, with opportunities continually arising. The old adage of "the harder you look, the more you find" is certainly true here!

Sales of traditional water treatment chemicals and services in the United States (the world's largest water treatment market) have slowed to an annual increase of perhaps only 3 percent in recent years, whereas Pacific Rim and Latin America were averaging 16 percent growth per year until 1997. (Incidentally, sales of performance chemicals is another major opportunity, now typically averaging an annual growth of 13 percent in some parts of the world). Thus to grow, or at least to retain market share in terms of dollar margin income, American water treatment companies must conduct business differently than they have done in the past. Also, to take an appropriate share of the rapidly developing markets in international high-growth economies requires new and revitalized ways of working! This in part explains the buildup of alliances and customer partnerships in the United States as a way of resisting customer base erosion, the need to buy market share in the United States, and the very aggressive acquisition strategies we have seen, that are required to gain entry to those growth markets around the world. (We have also seen in recent times that some large water treatment companies have been much more successful than others in their acquisition and assimilation of smaller competitors.)

The principal subsectors of the water treatment chemicals and services market are for incoming water, boiler water, cooling water, and wastewater. Of these various subsectors, cooling water uses the most innovative chemical raw materials, shows the greatest opportunities for volume growth (due in no small part to the new industrial and other infrastructural development in high-growth economies), and enjoys the highest percentage gross margin. It also requires the most proficient and far-reaching technical support services.

Typically in the specialty chemicals market, approximately 55 percent of U.S. buyers choose either quality or price as the single most important factor when selecting a supplier, but about 70 percent of those who change their suppliers do so because they did not like the human side of doing business with the product and service provider! This is a peoples business and to succeed requires more than just good products. So the global marketing of cooling water treatment in new and innovative ways is vital to the future lifeblood of water treatment companies, and the most important component is the people services element! In view of this statement, it becomes easier to see why today so much emphasis is being placed on gaining business by enhancing customer support services. Some of the strategies employed are:

- The recruitment of considerable numbers of new field personnel, both from within and on either a secondment or permanent basis, to the countries with high-growth economies in order to maximize the penetration of those global growth opportunities presented.
- The redeployment of home office support staff to the field in order to provide additional and closer ties with the customer (and to compensate for experienced field staff sent to obtain a share of the newer, high-growth markets).
- The provision of "customer friendly" laptop computers and design/diagnostic/database software to sales staff and other field personnel in order to provide a competitive edge for gaining and retaining business (but perhaps also to reduce the time requirements for training field staff by traditional means).
- The development and intensive marketing of "real time" chemical product tracing systems and computerized analytical record and data interpretation programs, for customers' water systems, in order to provide a further competitive edge.
- The growth of "customer partnerships," "strategic alliances," and "customer account management technologies," which are terms used in the development of closer working arrangements with customers, and designed to protect service companies' customers from competitive pressure.

The global nature of the water treatment industry, the explosive growth, and the competitive interactions make for interesting times. And, although this industry, like almost all other industries, is market-driven (i.e., the end-user customer ultimately calls the tune), there are other influences that play a part. It is therefore worth looking briefly at the increasingly influential role of the giant chemical raw material suppliers, who provide much of the specialty additives used in today's water treatment companies formulations, especially those used in cooling water programs.

With limited exceptions, water treatment service companies are not original chemistry researchers; they are applications experts and use a variety of increasingly novel and sophisticated organic chemical raw materials for incorporation in their formulations. The supply of these materials is mainly via a handful of multibillion dollar sales, chemical companies, who are original researchers. They compete aggressively with each other, striving to produce ever more sophisticated, multifunctional, organic performance chemicals, which are designed to tackle higher and higher levels of stressed cooling water treatment applications. These products are then made available to the service companies, often at increasingly elevated prices, and with strong premiums demanded for innovative, value-adding chemistries. Increasingly, the research and manufacturing companies provide awareness campaigns, promoting the features and benefits of their new polymers direct to the end-user customer, thereby stimulating demand yet further. There is no doubt that these companies have had a strong influence in driving up both the attractiveness and the overall value of the cooling water market sector.

The marketing of cooling water treatment today is a both a customer seduction process and a proclamation of the increased strength, adaptability, and value of modern cooling water programs. However, the permutations of chemical product, people skills, field support services, and flexibility in work practices available from individual water treatment companies around the world, whether large or small, and the ways in which these factors can be combined to provide precise solutions to their customers' application problems, go a long way in determining how that company is differentiated and perceived in the marketplace. The customer's perception of each company, the value of its chemical programs, and its hierarchical position in the marketplace is not necessarily directly related to that company's size or revenues, which makes working in this industry both challenging and rewarding, especially to those in the field, who by their combined technical, selling, and problem-solving skills, and by their closeness to the customer, can most directly influence the differentiation of their company and its fortunes.

Apart from the upheaval in the chemical industry as a whole, where new names, such as Novartis, Clariant, Cognis, Avecia, Rhodia, and many others, continue to appear on a regular basis, there are wholesale changes occurring in the global water utilities and water treatment industry. Mergers and acquisitions are changing the nature and business focus of many of the world's major and minor water treatment players, both the service companies and the specialty chemical producer. Most notable among recent moves are the purchase of both Calgon and Nalco by the French Company Suez Lyonnaise (together for close to $5 billion) and U.S. Filter by Suez Lyonnaise rival Vivendi, for $6.2 billion. Also, the merger of Betz with Dearborn, which was then snapped up by Hercules, the decision of Ciba to get back into water treatment (after selling its service company to Drew and its specialty chemical business to FMC some years ago) by acquiring Allied Colloids, and the very recent sale of the Ciba/FMC water additives business to Great Lakes. There seems no immediate cessation in the current penchant for mergers and acquisitions, as companies struggle for strategic advantage. Whether these moves will ultimately provide benefit to water treatment companies and their customers remains, as yet, an open question.

Given the highly competitive and global nature of industry today, the environmental concerns, and the increasingly short-term nature of financial performance assessments, one of the key areas in which water treatment service companies can work closely with their customers, and can provide them with tangible and valuable benefits, is in the field of cooling water management. The modern, high-performance chemicals now available, the speedy computerized information databases and instrumental diagnostic tools increasingly employed, and the various other support services give the customer an unprecedented opportunity to add value to their operations, and for water treatment service companies to continue to make money.

The marketplace is a war zone and the winners are those vendors and customers who work together, for mutual benefit and profitability. The vendors' most important weapons are good people, innovative chemical products, and, increasingly, the ability to provide customers with "real-time," information technology. Computer programs permit on-site predictive analysis, SPC (statistical process control), access to vendor central information databases, benefit/cost comparisons, and financial scenarios.

Above all else, it is the dedication, the good practical knowledge, the experience, the interpretive, communicative, and selling skills of the truly professional water treatment field operator, that makes the difference between success and failure.

BIBLIOGRAPHY

1. Anderson Chemical Company. *ANCOPACK Cooling System Package*. Cooling Water Control Systems Promotional Literature, USA.
2. Ash, Michael and Irene. *Handbook of Water Treatment Chemicals*, 1st edition. Gower Publishers, UK, 1996.
3. ASS/ANZ HB. *Control of Microbial Growth in Air-Handling and Water Systems of Buildings*. Published jointly by Standards Australia/Standards New Zealand, New Zealand, 1995.
4. ASTM. *D2688-90: Standard Test Methods for Corrosivity of Water in the Absence of Heat Transfer (Weight Loss Methods)*. ASTM, USA, 1990.
5. Baltimore Aircoil Company. *Evaporative Condenser Engineering Manual*. Bulletin E115/1-OB, USA.
6. Bardsley, Judy H.; Ellis, Michael J.; Hann, William M. *New Acrylate Polymers for Water Treatment Programs*. Rohm & Haas Company, USA, March 1990.
7. Betz-Dearborn (formerly Grace Dearborn Water Treatment Services, UK). *System Care: Water System Operating and Record Keeping Manual*. Betz-Dearborn, USA, 1991.
8. BF Goodrich Company. *The Role of Polymers in Water Treatment Applications and Criteria for Comparing Alternatives*. Paper presented at 6th Convention, Association of Water Technologies, Inc., November 1993.
9. Boffardi, Bennett P. *Fundamentals of Cooling Water Treatment*. Calgon Corporation, USA, 1987.
10. Bott, T. R. *A Comparison of Chlorine and Ozone for Cooling Water Treatment*. "Waterline," UK, June 1990.
11. Bridger Scientific Inc. *DATS Fouling Monitor System*. Promotional literature, Bridger Scientific, USA.
12. British Association for Chemical Specialities. *The Control of Legionellae by the Safe and Effective Operation of Cooling Systems—A Code of Practice* (see also *Code of Practice Update*, 1995). British Association for Chemical Specialities, 1989.
13. Brunn, Arthur F. *Treatment Service: What Should You Consider When Engaging a Water Treatment Service Company?* Industrial Water Treatment, USA, March/April 1995.
14. Calgon Corporation. *Calgon Software Demonstration Program*. Internet information. htpp://www.calgon.com, Calgon Corporation, USA.
15. Callow, L.M. *Corrosion Monitoring in Inhibited Water*. The Water Management Society, UK, 1995.

16. Carrier Corporation. *Carrier System Design Manual: Part 5, Water Conditioning*, 4th printing. Carrier Corporation, USA, 1972.
17. Chlorine Chemistry Council. *Key Talking Points for Communications Relating to the EPA Recommendations to Phase Out Chlorine and Chlorinated Compounds.* Chlorine Chemistry Council, USA, February 1994.
18. Conley, Jeffery C.; Puzig, Edward H. *Bromine Chemistry: An Alternative to Dechlorination in Cooling Water and Wastewater Disinfection.* "Waterline," UK (reprinted from the proceedings of the 48th International Water Conference, USA), November 2–4, 1987.
19. Darvill, Mike (Hydrotec, Ltd. UK). *Magnetic Water Treatment.* W &WT Journal, UK, July 1993.
20. Degrémont. *Water Treatment Handbook*, 5th and later editions. John Wiley & Sons, USA.
21. Downward, Brian L.; Failon, Brian K. *A New, All Organic High Performance Corrosion Inhibitor for Industrial Cooling Water Systems.* Albright & Wilson, 1996.
22. Drew Industrial Division. *PULSE Analyzer: Advanced Control Systems.* Promotional literature, USA.
23. Eager Jr., Robert G.; Theis, Alan B.; Turakhia, M. H.; Characklis, W. G. *Gluteraldehyde: Impact on Corrosion Causing Biofilms.* Corrosion, USA, 1986.
24. EHS The Health Department, Victoria, Australia. *Guidelines for the Control of Legionnaires Disease.* EHS The Health Department, Victoria, Australia, 1989.
25. Elliot, Thomas C. *Cooling Towers.* "Power" Special Report, USA, March 1973.
26. Ferguson, Robert J. *Computerized Ion Association Model Profiles Complete Range of Cooling System Parameters.* 52nd Annual Meeting, IWC, USA, October 1991.
27. Ferguson, Robert J.; Freedman, A. J.; Fowler, G.; Kulik, A. J.; Robson, J.; Weintritt, D. J. *The Practical Application of Ion Association Model Saturation Level Indices to Commercial Water Treatment Problem Solving.* American Chemical Society, USA, August 1994.
28. FMC Corporation (UK) Ltd. *Process Additives Division. Products for Industrial Water Treatment.* Various technical/commercial literature, UK, 1983–1995.
29. Frayne, C.; Robinson, J. *ANCO Guidelines for the Operation & Maintenance of Cooling Systems to Minimize the Risk of Legionella.* Anderson Chemical Company, Inc., USA, 1995.
30. Frayne, Colin. *Cooling Water Programming: A Basic Guide.* Internal publication for Houseman Ltd., Windsor, Berkshire, UK, 1980.
31. French Creek Software, Inc. *Water Cycle Series Product Information.* Internet information. htpp://www.frenchcreeksoftware.com, USA.
32. Geesey/Lewandowski/Flemming, Editors. *Biofouling and Biocorrosion in Industrial Water Systems.* Lewis Publishers, USA, 1990.
33. Grab, Lawrence A.; Thels, Alan B. *Comparative Biocidal Efficacy vs. Sulfate Reducing Bacteria.* Presented to NACE Annual Conference and Corrosion Show, Paper 184, Corrosion, USA, 1992.

34. Hann, W. M.; Keller, L. H.; Sanders, T. W.; Weinstein, B. *Towards Field-Friendly Traceable Polymeric Dispersants.* 58th IWC Conference, November 1–5, 1997.
35. Harfst, William F. *Chlorine or Bromine: Which Is Right for Your System?* "Power," USA, September 1993.
36. Harris, Arthur; Yeoman, A. M. *Development of an All Organic Ferrous Metal Corrosion Inhibitor.* UK, March 1986.
37. Harris, Norman C. *Modern Air Conditioning Practice,* 3rd edition, McGraw-Hill, Inc., USA, 1983.
38. Hawthorn, Don. *Scaling by Evaporatively Cooled Recirculating Water.* "Waterline," The Water Management Society, UK, 1995.
39. Health and Safety Executive, British Government. *The Control of Legionellosis, Including Legionnaires Disease* (HS(G)70). Her Majesty's Stationary Office, UK, 1991.
40. Henley, Mike. *Biocontrol: Environmental Rules, Safety Issues Impact Biocide Use.* "Industrial Water Treatment," USA, November/December 1993.
41. Henley, Mike. *Environmental: Future Legislation Appears Likely to Impact Water Treatment Decisions.* "Industrial Water Treatment," USA, November/December 1994.
42. Henley, Mike. *Process Contaminants and their Impact on Biocides.* "Industrial Water Treatment," USA, May/June 1994.
43. Henley, Mike, Editor. *Industrial Water Treatment and Ultrapure Water:* Business News & Profiles Sections, Tall Oaks Publishing, Inc., USA, published periodically.
44. Hensley, John C, Editor. *Cooling Tower Fundamentals,* 2nd edition. The Marley Cooling Tower Company, USA, 1985.
45. Herro, Harvey M.; Port, Robert D. *The NALCO Guide to Cooling Water Systems Failure Analysis,* 1st edition. McGraw-Hill, Inc., USA, 1993.
46. Hollingshad, Charles R.; Peters, William R. *A New Generation of Cooling Water Treatment.* American Power Institute Paper (1984 Annual Meeting, Illinois), USA, April 1984.
47. Houseman Limited. *The Good Water Guide: Chemical Cleaning. Technical and Marketing Notes.* Houseman Limited (Member of Degrémont Group), UK, 1981.
48. Houseman Limited. *Basic Microbiology TM1.* Houseman Limited (Member of Degrémont Group), UK, 1980.
49. IDEX Corporation. *PULSAtrol™ Microprocessor Based Controllers and Monitors Reference Guide.* Promotional literature, Pulsafeeder IDEX Corp., USA.
50. Inversand Company. *Manganese Greensand CR & IR: Technology Notes.* Promotional literature, Inversand Company, USA,
51. Jain, Kiran. *Technical Data on Some Chemicals, HOBr Generation Using Sodium Bromide and Chlorine, Toxicity Assessments, Simazine, Chlorine Dioxide.* Various technical papers, USA, 1993.
52. Johnson, Peter R. *Fundamentals of Fluid Filtration: A Technical Primer.* Tall Oaks Publishing, Inc., USA, 1990.
53. Katzaras, William; Brooks, Richard; Malm, Arthur P. *Cooling Towers: Utility Cools with Municipal Effluent.* "Industrial Water Treatment," USA, March/April 1994.

54. Kelly, Dennis, et al. *Triogen Ozone Cooling Tower Planning Manual.* Barr & Wray Ltd., UK, 1993.
55. Kemmer, Frank N., Editor. *The NALCO Water Handbook*, 2nd edition. McGraw-Hill, Inc., USA, 1988.
56. Kuechler, Thomas C.; Rakestraw, Lawrence F.; Graham, David F.; Matson, Jack V. *Development of Monsanto's Towerbrom® Microbiocide, A New Bromine Microbiocide for Recirculating Water Systems.* American Water Technologies Conference, December 1991.
57. Kurtz, John B.; Bartlett, Christopher; Tillet, Hilary; Newton, Ursula. *Field Trial of Biocides in Control of Legionella Pneumophila in Cooling Water Systems.* "Ecology and Environmental Control," UK, 1983.
58. Laronge, Thomas. *The Waterside: A Return to Tradition.* "Industrial Water Treatment," USA, July/August 1994.
59. Laronge, Thomas. *The Waterside: Beyond Tradition.* "Industrial Water Treatment," USA, November/December 1994.
60. Laronge, Thomas; Freedman, Arthur J. *The Importance of Control in Operating Modern Cooling-Water Systems.* "Industrial Water Treatment," USA, July/August 1995.
61. LXF Incorporated. *Track 2 & Water Treatment Handbook on-Disk.* Internet information. htpp://www.lxf.com, USA.
62. LXF Incorporated. *Track 2 Process Management Software*, USA.
63. Macleod Smith, R. I.; Mager, George. *Cooling Tower and System Design Improvements.* The Water Management Society, UK, 1994.
64. Magnatech Corporation. *Non-Chemical Water Treatment Systems.* Literature from Magnatech Corporation (Superior Manufacturing Division), USA.
65. Masler III, William F.; Amjad, Zahid. *Advances in the Control of Calcium Phosphonate with a Novel Polymeric Inhibitor.* NACE/"Corrosion" Paper No. 11, USA, March 1988.
66. McCoy, James W. *The Chemical Treatment of Cooling Water*, 2nd edition. Chemical Publishing Co., N.Y., USA, 1983.
67. McGrane, William K.; Ditzler, Lee. *Ozone: A Study of the Effects of Biocides on Legionella Pneumophila.* "Industrial Water Treatment," USA, November/December 1995.
68. Metal Samples. *Corrosion Monitoring Products for Industrial Processing and Water Treatment.* Promotional literature, Metal Samples, USA.
69. Nalco Chemical Company. *Azole Fluorescence Study: A Cooling Water Diagnostic Program.* Promotional literature, Nalco Chemical Company, USA.
70. Nalco Chemical Company. *Smart System (Advanced Control Systems).* Promotional literature, Nalco Chemical Company, USA.
71. Nalco Chemical Company. *Trasar® Technology and Services for Cooling Water Treatment: Q & A.* Promotional literature, Nalco Chemical Company, USA.
72. Nipa Laboratories Ltd. *The Problem of Microbial Growth in Water Systems.* Internal Technical Department Report, Nipa Laboratories Ltd., UK.
73. Owens, Dean L. *Practical Principles of Ion Exchange Water Treatment.* Tall Oaks Publishing, Inc., USA, 1985–1995.

74. Paul, David H. *Back to Basics: Understanding a Water Analysis Report.* Parts I & II. "Ultrapure Water," Tall Oaks Publishing, Inc., USA, January/March 1998.
75. Pipe, Sue, General Editor. Various "Waterline" and "Waterscan," The Water Management Society, UK.
76. *Positioning: The Battle for Your Mind,* 1st edition–revised. McGraw-Hill, Inc., USA, 1986.
77. Powell, Sheppard T. *Water Conditioning for Industry,* 1st edition. McGraw-Hill, Inc., USA, 1954.
78. Preston Jarvis. American Industrial Chemical Corporation. *Chelates and Their Uses.* An ENCEE Product Review, USA.
79. Puri, Vijay K. *Pretreatment of Water for Cooling Water and Steam Generating Systems.* Calgon Corporation, USA, 1983.
80. Relenyl, Atilla G. *DTEA 15%, Presentation Notes.* USA, 1997.
81. Ries, Al; Trout, Jack. *Marketing Warfare.* McGraw-Hill, Inc., USA, 1986.
82. Rohm & Haas Company. *Optidose Traceable Polymer System.* Video and launch notes. Rohm & Haas Company, USA, 1998.
83. Rohm & Haas Company. *Engineering Manual for the Amberlite® Ion Exchange Resins.* Rohm & Haas Company, USA.
84. Rohrback Cosasco Systems, Inc. *Corrosion Monitoring Equipment, Systems and Service.* Promotional literature, Rohrback Cosasco Systems, Inc., USA.
85. Salaices, Maria; Waterhouse, Bert; Waddams, A. L.; Kamatari, O. *Chelating Agents: A CEH Product Review Document.* Promotional literature, Preston Jarvis/American Industrial Chemical Corporation, USA.
86. Sandler, David H. *You Can't Teach a Kid to Ride a Bike at a Seminar.* Dutton, USA, 1995.
87. Schultz, R. A. *Microbiocides—A Necessary Supplement to Chlorination.* Presented to National Association of Corrosion Engineers, Houston, Texas, 1980.
88. Schwieger Robert G. *Heat Exchangers.* "Power" Special Report, USA, June 1970.
89. Silbert, Marvin D. *Computers: What Is Your System Doing*? Tall Oaks Publishing, Inc., USA, November/December 1996.
90. Simpson, Greg D.; Kuykendall, Clay, Miller, Jay; Averett, Bill. *The Safe and Effective Use of Chlorine Dioxide.* "Industrial Water Treatment," USA, September/October 1995.
91. Simpson, Greg D.; Laxton, Garry D.; Miller, R. F.; William, R. *A Focus on Chlorine Dioxide for "Stressed" Cooling-Water Systems.* "Industrial Water Treatment," USA, September/October 1994.
92. Skidmore, Teresa. *Tolcide PS Biocides: Technical and Marketing Information.* Albright & Wilson, Water Management Chemicals, UK, 1997.
93. Smith, Craig B.; Owens, Randy. *Microbiological Screen Test Data: A Technical Report on MBT/Thione/Isothiazolinone.* Vinings Industries Inc., USA, 1994.
94. Steelhammer, Joe C.; Watson, Carl F.; Youmans, Richard O. *Trends in Industrial Water Treatment: Methods for Microbiological Control.* "Industrial Water Treatment," USA, July/August 1995.

95. Strauss, Sheldon D., Senior Editor. *Instrumentation Advances Improve Fouling*. Corrosion Monitoring, "Power," USA, 1992.
96. Strauss, Sheldon D.; Puckorius, Paul R. *Cooling-Water Treatment, A Special Report*. "Power," USA, June 1994.
97. Strauss, Sheldon D.; Puckorius, Paul R. *Cooling-Water Treatment, A Special Report Update*. "Power," USA, May 1995.
98. Stuart, Christine M; Eastin, Phillip M. *Chemical Treatment: Alkaline Phosphate—A New Direction for Phosphate Cooling Water Regimens*. As reproduced in "Industrial Water Treatment," Vol. 25, No. 1, January/February 1993.
99. Sullivan, Patrick J. O'Brian, Frank. *Biocontrol: Performance of HPA With Oxidizing Biocides*. As reproduced in "Industrial Water Treatment," Vol. 28, No. 1, January/February 1996.
100. Tanis, J. N. *Procedures of Industrial Water Treatment*, 1st edition. Ltan Inc., USA, 1987.
101. The Purolite Company, *Purolite® Product Data Manual*: The Purolite Company, USA.
102. The Water Management Society (formerly Working Party of the Industrial Water Society). *Cooling Water Treatment: A Code of Practice*. The Water Management Society, UK, 1982.
103. The Water Management Society. *Site Logbook for Water Services*. The Water Management Society, UK, 1990.
104. Thompson, John. *Electronic Water Descaling: The Alternative to Chemicals*? "Waterline," The Water Management Society, UK, Winter 1997.
105. U.S. Filter Corporation. *Permutit® Water and Waste Treatment Data Book*, 18th printing. U.S. Filter Corporation, USA.
106. van Brederode, H.; Bessems, E. *Antimicrobial Fatty Amine Derivatives*. A paper presented in London, June 1992.
107. Various Authors and Editors. *BETZ Handbook of Industrial Water Conditioning*, 8th edition. Betz-Dearborn, USA, 1980.
108. Various Authors and Editors. *Principles of Industrial Water Treatment*, 9th edition. Drew Chemical Corporation, USA, 1987.
109. Willa, James. *Evolution of the Water Cooling Tower*. "CTI Journal," 1992, Vol. 13, No. 1, Cooling Tower Institute, USA.
110. Young, Thomas J. *The Proper Use of Modern Polymer Technology in Cooling Water Programs*. Association of Water Technologies Inc. Paper (3rd convention), USA, December 1990.
111. Zuhl, Robert W.; Amjad, Zahid; Masler III, William F. *A Novel Polymeric Material for Use in Minimizing Calcium Phosphate Fouling in Industrial Cooling Water Systems*. Cooling Tower Institute Paper No. TP87-7, USA, February 1987.
112. Zuñiga, Patricia O.; Miller, Kenneth; Winters, Michael. *A Cooling Water Fouling Monitor* Senses Upsets, Evaluates Changes. Reprinted from "Chemical Processing," April 1990.

INDEX

A

D

E

H

I

M

N

O

P

Q

R

T

X

Y

Z