Chemical Publishing Company
chemical-publishing.com

The following pages contain the table of contents, index and first few sample pages of this title
Click here to purchase this title
or to visit the product page.
Boiler Water Treatment
Principles and Practice

Volume I

Boiler Basics and Steam-Water Chemistry

Colin Frayne
ABOUT THE AUTHOR

This is the second book written by Colin Frayne and complements Cooling Water Treatment: Principles and Practice, which was published in 2000. Mr. Frayne continues to work as an international water treatment consultant and small business owner. In addition, he is employed in a senior executive capacity by the New York City–based, Metro Group, Inc., a water treatment, mechanical, and environmental services organization.

Colin Frayne has more than 30 years of experience in the practice of industrial chemistry and management of industrial and commercial water systems. Also, he has worked and lectured in over 40 countries and lived on four continents with his family, during which time he has managed various water treatment businesses. Mr. Frayne is British-born but holds dual nationality, having resided in the United States for several years with his wife and two daughters.
This is my second book. It follows a similar style and with similar objectives and outlook to Cooling Water Treatment: Principles and Practice, which was published in early 2000. In the preface to that book, I stated that "the vital key to successfully providing water treatment programs today is something it has always been—excellent customer service!" In this particular aspect, some things just do not change, and for the vast majority of industrial, institutional, and commercial boiler plant owners around the world, this message is hopefully welcome. I say this because in order to attain and maintain optimum day-to-day boiler waterside operating conditions, owners and operators will continue to need the very best technical advice and other services possible to manage proactively the water treatment programs they employ.

There are some differences, however, between cooling water customers and boiler water customers in their overall requirements for water treatment program management (in Sandler® Sales Institute sales training "speak," the level of customers' "pain"). And it is these differences that, in part, gave rise to my decision to write this particular book.

It is a certainty (at least in my mind) that there is no cooling system anywhere in the world, from the smallest to the very largest, whose owner or operator cannot benefit from working with an appropriately qualified water treatment service company to some degree or other. The complexities of interrelated waterside problems, the variability of today’s water supplies, and the sheer range of modern chemical treatments (now globally available), equipment options, and application techniques are simply overwhelming. This means that owners and operators of cooling water systems cannot remain conversant with all the causes and effects of waterside problems or keep abreast of marketplace technologies and developments in support services.

However, it is not always the case with certain types of modern boiler plant that the respective owners, operators, and technical committees can significantly benefit from working with a water treatment company.
For example, in some very specialized areas of boiler water treatment (such as nuclear power units and especially utility power generation), there is probably little or nothing of any practical value that service companies can teach the current practitioners.

For a second group, however, comprising the owners and operators of just about every other type of commonly available boiler plant, this is not always the case. The engineers responsible for the great majority of “ordinary” boiler plants found in commercial buildings, hospitals, hotels, and general industry around the world typically do not have the same level of resources as the power generation industry. Consequently, they need to be in a position to reliably obtain specialty waterside treatment programs and technical support services.

It is these differences in in-house boiler plant facility resources and the perceived need to obtain technical support from an external source that led me to consider grouping boiler plant systems in a slightly different way than is typically perceived, which in turn provided a focus for this book. Thus, although commercial, industrial, and utility steam generators can be classified in several different ways (such as by pressure, output, fundamental design type, etc.), their owners and operators can be classified as members of one or other of only two groups.

The first group consists almost exclusively of these large utility organizations that operate electrical power generators and employ high-pressure, fossil fuel or nuclear power fired boiler plant for steam generation. This international power generation group understands their own particular waterside problems very well and the chemicals, mechanisms, and protocols needed for proper control. Their field of water treatment is fairly narrow, but they possess an incredibly deep knowledge of high-pressure boiler waterside technology and consequently need no assistance from me. (Nevertheless, for the sake of completeness, and hopefully for the interest of many operators, some information on higher pressure boiler water treatment practice has been included in this book).

The second group consists of every other type of boiler plant owner or operator. This group includes not only all the engineers operating steam generators in countless small factories, commercial premises, and institutional buildings, but also the various larger process industries and some facilities that may, in fact, generate electricity (albeit at only moderately high pressures) such as the cogeneration/combined cycle plants.

Within this second group, the various types and designs of boiler operated are very broad and the classifications and applications of boiler water treatments are equally wide.
At first glance, and despite there having been little in the way of
ground-breaking advances in treatment chemicals, equipment, or pro-
gram applications for many a year, the fundamentals of the science and
business of boiler water management appear to be, on the whole, still
imperfectly understood by this group.

It also appears that most commonly available technical books and
other sources of literature tend to concentrate on the higher pressure
“glamour” end of the boiler plant range, and there is little that is suffi-
ciently practical or comprehensive concerning the lower pressure mar-
ket. And, of course, it is this lower pressure market (when measured by
physical number) that globally constitutes the vast majority of boilers
and where the user skills and experience in applied water treatment are
most often limited.

In mitigation, a deep knowledge of such a specialist area generally
is not required for most lower pressure boiler owners and operators, as
they need to focus their attention on primary profit-making activities
and other core business competencies.

It is, thus, to the second group that this book on boiler water treat-
ment is primarily addressed. My key objective was to provide the read-
er with useful and practical boiler plant information that will help
improve waterside cleanliness and add value to their facilities’ opera-
tional efficiencies.

Additionally, a personal objective was to provide the information
contained within this book in such a way that it could be used regularly
in the field rather than be relegated to a bookshelf with other works
of occasional reference. As such, although this book is essentially con-
cerned with applied chemistry, I found it necessary to devote several of
the initial chapters to a discussion on some basic but practical engi-
neering aspects. Subjects covered include fluid dynamics, thermody-
namics, the various types and designs of boilers to be found, and the
function of all the critical system auxiliaries and components. The sub-
ject of boiler water chemistry is so inextricably bound up with the
mechanical operation of boiler plants and all their various systems and
subsystems that it is impossible to discuss one topic without the other.

As with my first book, which covered cooling water treatment, this
book also started life after rereading the (still largely relevant) books
written by the late James W. McCoy, who was a supervisor of refinery
services at Standard Oil Company of California. This time my primary
source of inspiration was The Chemical Treatment of Boiler Water,
which was first published by Chemical Publishing Company of New
York in 1981.
In this preface I also wish to highlight the contributions to the subject from some other publications, such as the more modern book *Procedures of Industrial Water Treatment* by J.N. Tanis and the *NALCO Guide to Boiler Water Systems Failure*, as well as the massive, but superb tome, *Steam, Its Generation and Uses* from Babcock & Wilcox, which is now in its 40th edition. These are all excellent works.

Other notaries are the *Consensus on Operating Practices for the Control of Feedwater and Boiler Water Chemistry in Modern Industrial Boilers* (1994 edition), published by the American Society of Mechanical Engineers, and *BS 2486:1997 Recommendations for Treatment of Water for Steam Boilers and Water Heaters* from the British Standards Institution. The 1994 Consensus (with its engineering background) and the 1997 version of BS 2486 (with its strength in operational chemistry) complement each other well. I consider that the tables and propositions contained in these two booklets jointly represent a true standard for boiler water treatment operational control. Consequently, I am pleased to be able to reproduce in this book all the tables from both publications, having received permission from the respective organizations to do so.

An acknowledgment of the more than 160 technical references that supported my efforts is provided in the bibliography at the back of this book.

As before, I give due recognition to my wife, Carol, for her unstinting loyalty and support in this project. Her support was especially important, as during the course of writing this book we relocated from Georgia to New York City and most of the problems associated with moving and then remodeling an old Tudor style house were left to her. During much of this period I was busy working in an office during the day, writing at night, and generally insulated from much of the everyday drama.

I also thank Dr. Bennett P. Boffadi for taking time away from his consulting work to pore through this book and correct my technical mistakes.

Finally, I thank Silvia Soto-Galicia and her staff at Chemical Publishing Co. for their perseverance and confidence in publishing my work for a second time.

Colin Frayne
New York City, 2002
# CONTENTS

Introduction: The Function of Boiler Water Treatment and Its Marketing xvii

1 Steam Generation 1
   1.1 Basics of Steam Generation 4
   1.2 Energy, Work, and Power 10
   1.3 Boiler Plant Efficiency 14

2 Boiler Types and Applications 23
   2.1 Electric Boilers 24
   2.2 Fire Tube (Shell) Boilers 29
   2.3 Water Tube Boilers 39
   2.4 Nuclear Reactor Boilers 61

3 Boiler Plant Subsystems, Appurtenances, and Auxiliaries 67
   3.1 Boiler Plant Subsystems 69
   3.2 Boiler Appurtenances 72
   3.3 Boiler Auxiliaries 82
   3.4 Balance of Plant (BOP) Equipment 112
   3.5 Boiler Plant Operational and Water Treatment Basics 119

4 Waterside and Steamside Problems: The Basics 131
   4.1 Hot Water and Steam System Cycles 132
   4.2 The Scope of BW Treatment and Control of Steam/Waterside Chemistry 134
   4.3 Fundamental Steam–Waterside Problems and Water Treatment Objectives 140
   4.4 Deposition 144
   4.5 Corrosion 149
   4.6 Fouling 153
   4.7 Contamination 154
   4.8 Limiting the Potential for Waterside Problems 156
5 Waterside and Steamside Problems: Hot Water Heating and Low-Pressure Steam Boiler Specifics 173
  5.1 Problems with Heating Coils 175
  5.2 Problems Associated with the Use of Glycols 177
  5.3 Problems of Corrosion in Hot Water and Low-Pressure Steam Heating Systems 178
  5.4 Other Waterside Problems in Hot Water Heating and Low-Pressure Steam Systems 180
  5.5 Waterside Problems in Medium-Temperature Hot Water and High-Temperature Hot Water Systems 185

6 Waterside and Steamside Problems: Pre-Boiler Section Specifics 191
  6.1 Overview of Pre-Boiler Section Waterside Problems 192
  6.2 Feedwater Contamination from Makeup Water 193
  6.3 FW Contamination from Returning Condensate 203
  6.4 Problems Associated with the Final Feedwater Blend 206

7 Waterside and Steamside Problems: Boiler Section Specifics 217
  7.1 Boiler Scaling, Fouling, and Deposition 217
  7.2 Passivation and Common Corrosion Problems 237
  7.3 Stress and High Temperature–Related Corrosion 254
  7.4 Other Forms of Corrosion 262
  7.5 Corrosion in Nuclear Powered Steam Generators 265

8 Waterside and Steamside Problems: Post-Boiler Section Specifics 273
  8.1 Steam Purity and Steam Quality 275
  8.2 Corrosive Gases in Steam and Condensate Systems 284
  8.3 Vaporous Silica and Other Steam Volatiles 293
  8.4 Scale and Corrosion Debris Transport 296
  8.5 Oil and Process Contamination 298

9 Pre-Boiler and Post-Boiler Treatment Processes 303
  9.1 Overview of Common External Treatment Process Technologies 306
  9.2 Basic Pretreatment Processes 307
  9.3 Pre-Boiler Purification Technologies 341
  9.4 Post-Boiler Condensate Conditioning 376
  9.5 Novel Pretreatment Oxygen Removal Technologies 382
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td><strong>Internal Treatment Programs</strong></td>
<td>385</td>
</tr>
<tr>
<td></td>
<td>10.1 Outline of Internal Treatment Control and Programs</td>
<td>386</td>
</tr>
<tr>
<td></td>
<td>10.2 Anodic Inhibitor Chemistries</td>
<td>394</td>
</tr>
<tr>
<td></td>
<td>10.3 Tannin Programs</td>
<td>403</td>
</tr>
<tr>
<td></td>
<td>10.4 Coagulation and Precipitation Program Chemistries</td>
<td>411</td>
</tr>
<tr>
<td></td>
<td>10.5 Chelant Program Chemistries</td>
<td>430</td>
</tr>
<tr>
<td></td>
<td>10.6 All-Polymer/All-Organic Programs</td>
<td>437</td>
</tr>
<tr>
<td></td>
<td>10.7 Chelant-, Phosphate-, or Polymer-Based, Combination Programs</td>
<td>461</td>
</tr>
<tr>
<td></td>
<td>10.8 Coordinated Phosphate and Program Derivations</td>
<td>464</td>
</tr>
<tr>
<td></td>
<td>10.9 All-Volatile Treatment Program Chemistries</td>
<td>474</td>
</tr>
<tr>
<td></td>
<td>10.10 Mixed Treatment and Zero Solids Treatment</td>
<td>476</td>
</tr>
<tr>
<td></td>
<td>10.11 An Outline of Water Treatment for Nuclear Powered Steam Generators</td>
<td>477</td>
</tr>
<tr>
<td>11</td>
<td><strong>Adjuncts and Conjunctional Treatments</strong></td>
<td>479</td>
</tr>
<tr>
<td></td>
<td>11.1 Oxygen Scavenger Chemistries</td>
<td>479</td>
</tr>
<tr>
<td></td>
<td>11.2 Oxygenated Treatment (OT)</td>
<td>506</td>
</tr>
<tr>
<td></td>
<td>11.3 Ammonia and Amine Adjuncts</td>
<td>510</td>
</tr>
<tr>
<td></td>
<td>11.4 Alkalinity Boost Chemistries</td>
<td>545</td>
</tr>
<tr>
<td></td>
<td>11.5 Antifoam and Defoamer Chemisties</td>
<td>548</td>
</tr>
<tr>
<td></td>
<td>11.6 Multiblend Formulations</td>
<td>555</td>
</tr>
<tr>
<td>12</td>
<td><strong>Control of Boiler Water Chemistry</strong></td>
<td>559</td>
</tr>
<tr>
<td></td>
<td>12.1 Water Treatment Recommendation Perspectives</td>
<td>560</td>
</tr>
<tr>
<td></td>
<td>12.2 Tables and Supporting Notes</td>
<td>566</td>
</tr>
<tr>
<td>13</td>
<td><strong>Operational Control of Waterside Surfaces</strong></td>
<td>599</td>
</tr>
<tr>
<td></td>
<td>13.1 Sampling and Testing Steam and Condensate</td>
<td>599</td>
</tr>
<tr>
<td></td>
<td>13.2 Managing Standby and Idle Boilers</td>
<td>606</td>
</tr>
<tr>
<td></td>
<td>13.3 Boiler Inspections</td>
<td>612</td>
</tr>
<tr>
<td></td>
<td>13.4 Boiler Cleaning</td>
<td>623</td>
</tr>
<tr>
<td></td>
<td>13.5 Some Troubleshooting Notes</td>
<td>657</td>
</tr>
<tr>
<td>14</td>
<td><strong>Control of Fireside Conditions and Surfaces</strong></td>
<td>669</td>
</tr>
<tr>
<td></td>
<td>14.1 Basic Fireside Problems</td>
<td>670</td>
</tr>
<tr>
<td></td>
<td>14.2 Fuel Treatments/Additives</td>
<td>678</td>
</tr>
<tr>
<td></td>
<td>14.3 Fuel Treatment Formulations</td>
<td>687</td>
</tr>
<tr>
<td></td>
<td>14.4 Combustion Gas Analysis</td>
<td>689</td>
</tr>
<tr>
<td>Appendix</td>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>------------</td>
<td>----------------</td>
<td>------</td>
</tr>
<tr>
<td>Appendix I</td>
<td>Useful Data</td>
<td>695</td>
</tr>
<tr>
<td>Appendix II</td>
<td>Glossary</td>
<td>711</td>
</tr>
<tr>
<td></td>
<td>Bibliography</td>
<td>763</td>
</tr>
<tr>
<td></td>
<td>Index</td>
<td>II</td>
</tr>
</tbody>
</table>
MODERN BOILER WATER TREATMENT PRACTICE

Modern boiler water treatment practice is the planned, actioned, and documented management of the waterside of boiler plant systems, to include pre-boiler and post-boiler functions. The objective is to produce and maintain operational and economic benefits for the users.

Achievement is by the integrated provision of innovative chemistry with other appropriate technologies and the application of practical expertise in the field, in order to prevent waterside and related plant operational problems from occurring. Where problems do arise, then detection and identification of the causes, together with suitable remedies that will also prevent reoccurrence, 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 boiler systems and other equipment if success is to be attained and maintained.
INTRODUCTION: THE FUNCTION OF BOILER WATER TREATMENT AND ITS MARKETING

Boilers are heat-transfer devices, wherein water, in the form of either liquid water or gaseous steam, is commonly employed as a medium for the transport of heat to some distant point of use. Although other heat-transfer mediums are sometimes utilized, water is particularly suitable because of its relative abundance, low cost, and high heat capacity. It is generally the medium of choice in most boiler applications, whether for domestic, commercial, institutional, or industrial purposes.

However, a boiler can only carry out its primary functions of transferring heat to water and (in steam generators) separating steam under pressure from water most efficiently if the quality of the various types of water used (such as makeup water, feedwater, and boiler water) are effectively and continuously controlled. The difficulty in this quality control process is that water is a “universal solvent,” and as a result, all sources of water contain various natural concentrations of dissolved minerals and gases in addition to suspended solids and biological matter. The relative amounts of each of these impurities tend to vary considerably with geographic location and season. This phenomenon results in countless permutations of water type and quality around the world, each potentially available as a source of makeup supply to boiler plant systems, evaporators, and other forms of water heating and steam generating devices. In many industrial applications, the negative impact of these natural impurities may be further compounded by the presence of small concentrations of process contaminants.

The effect of these various impurities or contaminants is to hinder the heat-transfer and steam generation processes, to adversely affect the
quality and purity of steam, and to act as primary instigators in the corrosive wastage of boiler plant system materials of construction. A wide variety of chemical reactions and physical mechanisms can and will take place, including the deposition of various crystalline and noncrystalline scales on the waterside of heat-transfer surfaces, the formation of sludges, metal corrosion, and carryover of contaminants into the steam.

The function of boiler water treatment, therefore, is to control the waterside chemistry of boiler plant systems within certain agreed and relevant parameters and specifications. As these adverse processes are by no means limited to the boiler itself, in practice, boiler water treatment also includes pre-boiler and post-boiler functions and further requires that all the various types of water utilized are controlled through a comprehensive treatment and proactive management program.

Clearly, the lack of or the use of an inappropriate boiler water treatment program creates significant operational difficulties and impacts the economics of the entire process, from start to finish.

With regard to the marketing of boiler water treatment programs and services, in the preface to this book I suggested that, although boiler plant can be classified in several different ways, there are from my perspective, only two groups of boiler plant owner/operator to be addressed.

1. The first group consists almost exclusively of the large utility organizations that operate electrical power generation facilities.

2. The second group consists of all the other types of boiler facilities and is clearly a very large and extremely diverse group, utilizing boiler plant ranging from very small steam producers to very large ones and including many that also produce some electricity together with process steam.

From a water treatment technical and marketing viewpoint, there is, in fact, a fundamental distinction between these two groups, as discussed below.

**Utility power generation group:** This group of boiler operators typically possess boiler plant installations of complex water-tube configuration, often producing steam in excess of 1,500 to 2,000 psig and increasingly, up to double this pressure. They tolerate only very high-purity makeup (MU) water, use very little chemical treatments, and what they do use is generally of a commodity nature.

Internationally, this group has within its ranks an army of experienced chemists and engineers plus a seemingly almost unlimited source of research and development information. Much of this information is
Introduction: The Function of Boiler Water Treatment

F
tightly held within the international utility power generation community and if available in book or other hard-copy form is generally prohibitively expensive for outsiders to purchase.

The fundamental reason for the commitment of this group to attaining the highest purity of feedwater (FW) and the most exactingly controlled internal boiler waterside conditions is the nature of the primary product made available for sale. This group generates electricity, on which all developed and developing nations critically depend for their economic and social well-being. The production of steam is merely an intermediate, but the quality and quantities of steam produced has a direct bearing on total electricity output, generation efficiency, operational and maintenance costs, and ultimately the price paid by the consumer.

**Heating, process steam, and cogeneration group:** As a contrast to the utility power generation group, operators of all the other types of boiler plant typically have installations producing steam (or hot water) at very much lower pressures. In fact, most facilities operate boilers somewhere within the range of only 5 to 125 psig, although larger process plants and cogenerators may reach pressures of up to 1,500 psig.

Because of the diversity of this group, there is no global standardization with regard to makeup (MU) water, FW quality, or boiler water (BW) chemistry control, irrespective of boiler design, pressure rating, or ultimate steam purpose. True, there are various national standards and boiler manufacturer association recommendations, and while these guides are extremely useful, they seldom universally agree on any given parameter or protocol. In mitigation, they cannot hope to provide answers to the myriad of problems and specific circumstances that develop. Rather, they should be viewed as a starting point for control purposes.

What is clear is that it is seldom that MU water or FW quality (i.e., the lack of contaminants) used by this second group ever reaches the incredible standards demanded and produced by the first group. Indeed, it is not at all uncommon to find lower-pressure boiler installations with MU water and FW both inadequately treated and simply inappropriate to the facilities needs.

Low standards of water treatment and waterside chemistry are generally caused by a combination of bad advice and lack of operator motivation or resources, and provide an initiator for the onset of downstream waterside operational problems. However, despite these apparent water treatment imperfections, most operators somehow still manage to function and produce steam of an acceptable quality and quantity, year after year!
This second group also, in fact, contains many electricity producers, the so-called cogenerators or combined-cycle plant operators. While there is no apparent clear-cut distinction between these facilities and the large utilities, in practice, the cogenerators tend not to operate at such high pressures (although the generation of power economically usually requires at least 650 psig). Also, although the demands for good quality FW treatment and steam purity in this group is high, it tends not to reach such extremes of sophistication as demanded by the utility group.

It can be seen that the first group demands the highest possible quality of steam purity and steam generation operating control and waterside chemistry is “knife-edge” technology. Consequently, from a water treatment products and services marketing viewpoint, this group offers the minimum of opportunities as a potential source of revenue. Even where an opportunity exists, perhaps for the supply of a special polymeric dispersant or an esoteric oxygen scavenger, the service company may often discover that because of the bureaucratic and accreditation systems to be worked through, the gain may not be worth the effort.

Looking further at the second group, although many of the larger, non-utility operators around the world retain a resident water services chemist or trained technician, there is a marked tendency for all owners or operators, whether large or small, to work in conjunction with a water treatment service company. There is also a common purpose to use branded BW treatment chemical products rather than commodities.

Thus, a good source of potential revenue for products and services exists in the multitude of smaller boiler-houses to be found operating around the globe. It is here that practical advice is most often needed concerning the suitability and correct application of chemical treatments, the regular interpretation of analytical results obtained, and the strategies to be employed to maximize efficiency and reduce costs.

Marketing to this second group is typically based on selling some form of services-based annual contract, using the customers boiler plant operating capacity or potential for steam production as a guide for determining base requirements and for pricing purposes.

*Hot water heating and LP steam systems* are relatively easy to treat, given:

- Customer acceptance of the need for treatment (which is not always forthcoming).
- An appropriate water treatment program (which is not always provided, often due to cost issues).
Some customer/vendor cooperation (which, thankfully, is usually the case).

In contrast, the treatment of industrial steam generation plants is usually more difficult. There is a need to conform to a good working standard and to produce quality waterside conditions for a long period of time without serious upsets, as the systems are always very dynamic and operating conditions can continually vary. This is especially the case with those facilities whose manufacturing operations may employ some form of on-off cycle or up-down batching process, rather than a steady-state, continuous production stream.

With the smallest heating boilers or low volume/low pressure steam producers, water treatment service companies tend to promote easy-to-understand programs, typically based on only one or two multiple-component, blended chemical products (multiblends or one-drum treatments), or increasingly, the novel crystalline solid concentrates (solid water treatment). These customers often have only very limited, water-related, in-house technical skills, and multiblend product programs will seem attractive because they are relatively easy to apply. However, the blending process makes it notoriously difficult to control individual component reserves in the boiler and generally adds considerably to the overall program costs.

Thus, programs based on multiblends are relatively expensive to use compared with programs based on the use of separate products that are matched to the potential for particular problems identified in a boiler plant. Nevertheless, they remain commonplace for the smallest boiler houses, but as the organizational size of the customer and its volume of daily steam production increases, so the trend for individual chemical treatments on the site tends to predominate. Often, more sophisticated chemical feed and control arrangements are also employed.

Traditionally, customers employ water treatment service companies simply as external contractors to assist in the maintenance of clean and efficient waterside surfaces in their various heating, steam generating, cooling, and certain industrial process systems. The customers benefit from genuine improvements in operating efficiency, reductions in maintenance time, and replacement component costs. In addition, where industrial processes are involved they often profit from an “added-value,” due to an improved product quality or reduction in manufacturing cost.

In this external contractor role, water treatment companies providing technical application and problem solving services are required to possess some general design component and process operating knowledge
of all the very many different types of industrial water systems to be found. In addition, they must possess specific and relevant water treatment technical knowledge, together with the practical experience of anticipating and solving water-related problems. Thus, the service companies that can best utilize their “storehouses” of knowledge and provide the necessary customer technical support and practical field skills also tend to gain a good reputation. Ultimately, they generate profit from their solid asset-base of people and knowledge.

It is a fact of life that the cost of providing water treatment services increases with the size and complexity of boiler plant. This cost may be recovered with larger boiler plants by the higher volumes of chemical treatments sold, as often the chemical selling prices will include an allowance for all the anticipated (and expensive) technical service time requirements.

For smaller chemical volume consumers, especially those with little in the way of in-house BW treatment technical skills, the overall program costs can be relatively high. This typically is due to the disproportionately high requirement for on-site technical service time (including the travel time to and from a customer’s site) compared to the volumes of chemical treatment sold. Travel and on-site time is expensive. Typically, the cost of labor and technical service is two to three times the cost of the chemical raw materials used to provide treatments.

As a result of the high costs of technical services, most water treatment vendors employ a variety of methods that allows them to charge an economic rate for the programs they sell. They will negotiate a price with the customer based on providing the most suitable balance of on-site service time and chemical/equipment requirements, that anticipates and resolves problems, meets the customers needs, and relieves his or her “pain.”

Traditionally, a common solution to the problem of matching relatively higher levels of technical support with lower chemical volumes for these smaller customers has been via a one- to three-year, fully inclusive product and services contract. Such a contract will specify the frequency of service visits to be made to the customer’s site and the type of work to be carried out. It will also, perhaps, limit the maximum volumes of chemical treatments to be supplied during the contract lifetime, or perhaps designate the amount of chemicals required based on treating a certain annual volume of boiler FW. Contracts may include for the provision of chemical feed and control equipment and for the supply of labor for boiler cleaning, chemical addition, and drum removal services (drumless delivery). Product and services contract prices may some-
times be specified as a cost-per-unit of steam produced (i.e., so many cents per 1,000 lb. of steam) or a cost-per-unit of production.

Under these conditions, the customer will receive a demonstrable benefit and, provided the on-site time and the volume of chemicals shipped are adequately controlled, the Service Company will derive a satisfactory profit.

Nevertheless, and irrespective of the particular mechanisms of payment for program services rendered, profit and a win-win situation will only arise for both parties if the work performed is managed competently and in a spirit of mutual cooperation.

Thus, if a field representative believes that the task is completed when the testing of water samples is performed and a service report is issued, or if the representative’s interpretation of results is poor, problems will undoubtedly develop. Also, if he or she fails to adequately review the “bigger picture” rather than merely individual results, the problems will magnify and the contract will ultimately be lost.

Similarly, if the customer refuses to be involved, at least to some degree, in the ongoing water treatment program or fails to take the advice and undertake necessary actions designed to control the program and the boiler system efficiency, the program will again ultimately fail and the contract will be lost.

Today, the traditional view of boiler water treatment (and water treatment in general) is changing. The marketplace is indicating that water treatment is merely part of a more comprehensive technical support and management services industry for various water, wastewater, and manufacturing process systems. Increasingly, water treatment is widening in scope to support global market demands. It is becoming an outsourcing services business for managing all forms of water, energy, utility, and environmental needs.

Even without the current outsourcing trends, it has always been difficult for service companies to find sufficient numbers of well-trained, experienced, and motivated field representatives. This is because the range of water treatment problems and potential solutions are very wide and the business involves the marketing of many different types of chemicals and equipment, coupled with consulting work and innovative trouble shooting.

In the water treatment industry, the first line of service providers has always been the vendor’s technical sales representatives, who, for the most part, are chemists, engineers, microbiologists, or similarly trained people. The field representatives typically rely on a combination of their primary disciplines and a depth of water treatment problem-solving
experience to overcome technical and operational problems and also add value to their customers operations. But in today’s global economy, the sheer permutation of available niche services, the growing demands for both outsourcing of non-core utility functions, and economic fine-tuning, requires that water treaters now commonly have to additionally act as managers and administrators of their customers entire water system facilities.

Today, water treatment companies sell environmental reassurance and technology-based utility support services, not chemicals or equipment.

Boiler water treatment is now an energy management function. And while the business and practice of this industry may be well over 100 years old, it remains a vitally important function and is a cornerstone of the global industrial services market.
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Å</td>
<td>angstrom unit</td>
</tr>
<tr>
<td>AA/AMPS</td>
<td>acrylic acid/2-acrylamido-2-methyl propane sulfonic acid copolymer</td>
</tr>
<tr>
<td>AA/COPS</td>
<td>acrylic acid/sodium 3-allyloxy-2-hydroxy-propane sulfonate (polymer)</td>
</tr>
<tr>
<td>AA/NI-AS-LS</td>
<td>acrylic acid/nonionic aromatic and linear sulfonate (polymer)</td>
</tr>
<tr>
<td>AA/SA</td>
<td>acrylic acid/sulfonic acid</td>
</tr>
<tr>
<td>AA/SA/NI</td>
<td>acrylic acid/sulfonic acid/nonionic (polymer)</td>
</tr>
<tr>
<td>AA/SA/SSS</td>
<td>acrylic acid/sulfonic acid/sodium styrene sulfonate acrylic acid/sulfonic acid/substituted acrylamide (polymer)</td>
</tr>
<tr>
<td>ABMA</td>
<td>American Boiler Manufacturers Association</td>
</tr>
<tr>
<td>ACH</td>
<td>aluminum chlorhydrate</td>
</tr>
<tr>
<td>AGR</td>
<td>advanced gas-cooled reactor</td>
</tr>
<tr>
<td>AMP</td>
<td>aminotri-(methylene phosphonic acid)</td>
</tr>
<tr>
<td>AMP</td>
<td>2-amino-2-methyl-1-propanol, AKA isobutanolamine</td>
</tr>
<tr>
<td>AO</td>
<td>All-Organic</td>
</tr>
<tr>
<td>AP</td>
<td>5-aminopentanol</td>
</tr>
<tr>
<td>AP/OA</td>
<td>All-Polymer/All-Organic</td>
</tr>
<tr>
<td>ASB</td>
<td>Shell Boiler Makers Association (UK)</td>
</tr>
<tr>
<td>ASME</td>
<td>American Society of Mechanical Engineers</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
</tr>
<tr>
<td>1-AP</td>
<td>1-aminopyrrolidine</td>
</tr>
<tr>
<td>ATMP</td>
<td>aminotri-(methylene phosphonic acid)</td>
</tr>
<tr>
<td>AVAT</td>
<td>All-Volatile alkaline treatment</td>
</tr>
<tr>
<td>AVP</td>
<td>All-Volatile programs</td>
</tr>
</tbody>
</table>
INDEX

Abbott Laboratories, 519
ABMA Commercial BW Requirements, 563–565
Absolute pressure, 7
   in condenser, 118
Acacia tannin, 405
Acetaldehyde, DEHA oxidation product, 495, 496
Acetaldehyde, 501
Acetate, DEHA oxidation product, 496
Accretion, of crystals, 224
Acid addition, for RO pretreatment, 367
Acid blend-fill arrangement, in cleaning processes, 639
Acid breakthrough of ion-exchange plant, 198
Acid cleaning
   procedure for larger industrial WT boilers, 655–656
   procedure for smaller FT boilers, 653–654
   procedure for smaller WT boilers, 654–655
Acid cleaning corrosion, 234
Acid, as corrosion inhibitor, 238
Acid dew point, 684
temperature, 676
Acid leaks, 300
Acid neutralizers, 683–684
Acid phosphates, 420, 466
Acid producers, 396
Acid rain, 43, 675
Acid/sequestrant resin cleaner program, 349
Acid smutting, 684
wet, 678
Acid soak, during cleaning, 625
Acid vapor neutralization, 612
Acidity dissociation constant, 522, 524
Acmite, 228, 412
in scales, 645
Acrylamide, 446
Acrylamide/acrylate copolymers, 317, 445, 455
Acrylamide/amino copolymer, 317
Acrylates, 237
Acrylic acid, 446, 452
   for RO pretreatment, 369
Acrylic acid/2-acrylamido-methylpropane sulfonic acid, 447
Acrylic acid/2-acrylamido-2-methyl propane sulfonic acid, 444
Acrylic acid/non-ionic aromatic and linear sulfonate, 447, 455
Acrylic acid/organic phosphate polymer, 451
Acrylic acid polymers, 316
Acrylic acid/sodium 3-allyloxy-2-hydroxypropene, 607
Acrylic acid/sodium 3-allyloxy-2-hydroxypropene sulfonate, 447
Acrylic acid/sulfonic acid, 447
Acrylic acid/sulfonic acid/sodium styrene sulfonate, 447
Acrylic acid/sulfonic acid/substituted acrylamide, 447
Acrylic acid terpolymers, 447
Acrylic acid/vinyl sulfonate copolymer, 455, 447
Acrylicamide, 446
Acrysol®, 447
Activated alumina, for lay-up programs, 610
Activated carbon
   bituminous coal type, 324
   coconut shell type, 324
   Activated carbon filters, 323–325
   Acumer® 1000-1100, 446
   2000-2100-2400-3100, 447
   4161, 452
   4210, 451
   5000, 448
   Adjunct online cleaning formulations, 627–628
   Adjuncts, 385, 389, 479–558
   Adjuncts and conjunctural treatments, 479–558
   alkalinity boosting chemistries, 545–548
   ammonia and amine adjuncts, 510–545
   antifoam and defoamer chemistries, 548–555
   multiblend formulations, 555–558
   oxygen scavenger chemistries, 479–506
   oxygenated treatment (OT), 506–510
Admiralty brass, protection in cleaning processes, 639
Advanced Separation Technologies, 353
Advantage™, 455
Aeration
for iron oxidation and sulfur gas removal, 308
to remove iron, 309–310
for RO pretreatment, 367
Aeration and oxidation, 306, 309–310
aeration towers, 310
pressure aerators, 309–310
Aeration tower, 214, 309, 310
After-precipitation, 201–203
external treatment carryover and, 201–203
Afttreatment deposition, 176
Agar-agar, historical perspective, 393
Ageflo™, 318
Agglomeration, 313
Air blowing, as passivator, 649
Air cocks, see Boiler vents
Air, composition of, 689–690
Air and flue gas management system, 72, 121
Air heater, 17, 86–87
cleaning flue gas side of, 611
corrosion from sulfuric acid, 682
Air heater tube bundle (WT), 45
Air ingress, prevention of in MPP/HPHW systems, 186
Air in-leakage, 178
Air management system, 72
Air ports, inspection of, 620
Air preheaters, inspection of, 620
Air temperature, efficiency, 17
Air vents, 660
Akzo Nobel Group, 540, 648, 686
Alamo Water Refiners, 340
Alarm, high-low water, 82
ALCO Chemical Company, 455
Aldelyde, in cleaning processes, 646
Aliphatic monoaikyamine, 537
Aliphatic solvents, in fuel additives, 680
Alkali, demand for, 225
Alkali/polymer-based multifunctional formulation, 460–464
Alkaline aluminate and silicate-based boiler compounds, 411–413
Alkaline boil-outs, 651–653, 625
in cleaning processes, 646
Alkaline citrates, in cleaning processes, 642
Alkaline copper removal method, in cleaning processes, 645
Alkaline earth metal salts, deposition by, 220–227
deposition of calcium and magnesium salts, control of, 223–227
Alkaline earth metals, as slag modifier, 682
Alkaline EDTA cleaning program, in cleaning processes, 638
Alkaline gluconate programs, in cleaning processes, 646,651
Alkaline hardness, condensate corrosion induced by high natural, 288
Alkaline phosphate solution, as passivator, 172
Alkaline phosphates, 123, 421
Alkalinity
due to calcium bicarbonate, 314
in higher quality water, 304
in raw water, 304
products for boosting, 548
sudden drop in, 196
Alkalinity, boiler water, 546–547
Alkalinity boost chemistries, 545–548
as adjuncts, 389
calculating alkalinity feed-rate requirements, 547–548
as conjunctional, 479
for lay-up programs, 606
notes on boiler water alkalinity, 546–547
products for boosting alkalinity, 548
Alkalinity builders, 545
in cleaning formulations, 650
Alkalinity content tests, 546
Alkalinity feed-rate requirement (with phosphate), 425
calculating, 547–548
Alkalinizing agent, 588
Alkanolamides, 554
Alkylamines, 526
in cleaning processes, 647
Alkylene polyamides, 553
Alkylene Polyamides, 553
Alkylene Polyamides, 553
All-membrane processes, for removal of chlorides/fluorides, 477
All-organic chemistries, functional attributes, 394, 442
All-organic cooling water programs, 419
All-organic one-drum program formulation, 558
All-organic program control chart, 460
All-organic programs, 388–437–461
designing and operating, 454
feed rates, 458
formulations, 460–461
All-organics, to meet boiler plant operating objectives, 455
All-polymer/all-organic chemistries and products, types of, 226, 394, 437–461, 545
as alternatives to PPN programs, 411
cooling water programs, 419
designing and operating, 454–460
functional attributes of APO/AO chemistries, 442–443
phosphino polycarboxylic acids, 451–454
phosphonates, 448–450
Amine salts, 517
Amine treatment, 103
Amine volatility, DR, 523
Amines, 170
as AVT, 389
cavitation effect, 540
close-packing arrangement, 542
control with AVT programs, 476
feeding and sampling, 534
filmers, 536–545
filtration amine, 536–544
flash point, 533
in fuel additives, 680
functional properties of neutralizing amine, 521–530
health and safety, 531–534
indoor air quality problems, 532
monoalkyl, 540
monomolecular film, 541
neutralization capacity, 521
neutralizer/filmers blend, 517
neutralizer/VOS blend, 517
neutralizing amine summary notes, 534–536
neutralizing blend formulations, 529–530
non-amine-based condensate treatments, 544–545
permissible exposure limits, 532
to prevent carbonic acid corrosion, 511
primary aliphatic amines, 540
producing ammonia in condensate, 381
in steam contacting food, 531–532
in steam humidifiers, 532–533
storage and handling, 531–534
straight-chain, 538
testing with sulfanilamide dye, 543
thermal stability of, 530–531
threshold odor concentration, 532
triple blends, 516
types of neutralizing amines, 517–521
twin-blend neutralizing program, 516
vapor/liquid distribution ratio, 527
vapor pressure, 533
Amino methanamine, 505
2-Amino, 2-methyl, 1-propanol, 518, 520
2-Amino, 3-methyl, 1-propanol, 523
4-Aminobutanol, 504
Aminocarboxylic acids, in cleaning processes, 641
2-Aminoethanol, 520
Aminoguanidines, 505
Aminohydroxybenzene, 500
Aminopolyacrylic acid, 432
1-Aminopyrrolidine (1-AP), 504
1-Aminopyrrolidin-2-yl hydrochloride, 504
Aminothianolamines, 495
Aminotri(methylene phosphonic acid), 432, 449
Ammonia, 102, 103, 152, 498, 510, 518, 521, 526

Amides, 517
Amine acetamides, 541
Amine acetates, 540
Amine acylates, 510–545
Amine basicity, 526
Amine carbonates, 522
Amine corrosion inhibitors, for fuel oils, 686
Amine cycle, 381
Amine feeding and sampling, 534
Amine oxidizes, 517
Amine recycling factor, 523

Polyacrylate backbone, co- and terpolymers, 447–448
polyacrylates and related carboxylates, 445–447
polymaleates, 450–451
program formulations, 460–461
tartrates and lignin-based sludge dispersants, 444–445
types of BW AP/AO chemicals and products, 443–454
All-volatile alkaline treatments, 589
All-volatile treatment, 478
in ammonia anion cycle, 378
FW controls, 475
producing ammonia in condensate, 381
program chemistries, 474–476
programs, 54, 252, 256, 389, 464, 526, 546
Alpha particle, 62
Alpha quartz, 229
Alum, 315
Alum/DADMAC polymers, 318
Alum/EPIDMA polymers, 318
Alum/polymer product, 316
Alum precoat coke filters, 381
Alumina, sintered, 359
Aluminum, 210, 412
Aluminum-brazilite, 210
Aluminum chloride hydrate, 316
Aluminum hydroxide, 314
precoat, 299
Aluminum oxides, 146
Aluminum-sodium silicates, 326
Aluminium sulfate, 314
historical perspective, 390
Alums as clarifying agents, 313
partial dealkalizing properties, 313
Amberpack™ design, of resin bed, 352
American Boiler Manufacturers Association, 560
American Industrial Chemical Corporation, Inc., 445
American Society of Mechanical Engineers, 13, 343, 387, 560
American Society for Testing and Materials, 599
Amides, 517
Amine acetamides, 541
Amine acetates, 540
Amine acylates, 510–545
Amine basicity, 526
Amine carbonates, 522
Amine corrosion inhibitors, for fuel oils, 686
Amine cycle, 381
Amine feeding and sampling, 534
Amine oxidizes, 517
Amine recycling factor, 523

Polymer/all-organic chemistries and products, types of (continued)
Ammonia (continued)
adjunct, 510–545
ammonia/ammonium carryover, 483
in ammonia anion cycle, 378
as AVT, 389
with AVT programs, 475
carbon dioxide and carbonic acid, 514–517
in cleaning processes, 637, 644
in condensate, 381
control in supercritical boilers, 476
in OT programs, 508
in steam and condensate, 492
in steam-condensate systems, 284–285,
291, 292, 293
testing in steam/condensate, 602
Ammonia anion cycle, in condensate polishing, 378
Ammonia break, 381
Ammonia control, as functional area requiring chemicals, 387
Ammonia-copper complex, 285
Ammonia/hydrazine mix, as passivator, 549
Ammonia/hydrazine cycle condensate polishers, 380
Ammonia release, 170, 293
Ammoniated citric acid/air/nitrite, in cleaning processes, 644
Ammoniated citric acid, in cleaning processes, 637, 644
Ammoniated EDTA/hydrazine mix, in cleaning processes, 638
Ammonium bicarbonate/hydrazide/oxygen, in cleaning processes, 644
Ammonium bifluoride, 625
in cleaning processes, 639, 645, 646
Ammonium bromate, in cleaning processes, 643
Ammonium carbamate, 212, 232
Ammonium carbonate, 381, 646
Ammonium chloride in clinker treatments, 683
in fuel additives, 680
Ammonium hydroxide, 493, 518
GRAS listing, 531
in steam-condensate systems, 292
for testing sodium, 603
Ammonium nitrite, in cleaning processes, 643
Ammonium perborate, in cleaning processes, 643
Ammonium persulfate, in cleaning processes, 643
AMO-95®, 518
Amorphous iron oxides, in condensate, 379
Amorphous, scale, 224
AMIP, see 2-Amino-2-methyl-1-propanol
Amphiphilic compounds, 538
Analalite, 145, 229
in boiler deposits, 635
historical perspective, 391
in scales, 645
Analysis of glue gas, 691–692
Angstrom units, 648
Angus Chemical Company, 518
Anhydrite, 145, 234
in boiler deposits, 635
in scales, 645
Anion exchange dealkalization, as purification technology, 343
Anion exchange, to limit silica, 294
Anion permeable membrane, 373
Anion resin cleaning program, 349
Anionic or non-ionic surfactant, in cleaning formulations, 651
Anionic polyelectrolyte sludge conditioner, 316, 406
tannins as, 445
Anions, in ion-exchange, 347
Annular flow, 6
Anode, 149
Anodic and cathodic phosphate inhibitors, 399–400
Anodic half-reactions, 149, 286
Anodic inhibitor chemistries, 394–403
anodic and cathodic phosphate inhibitors, 399–400
anodic inhibitor programs, 402–403
azoles, 400–402
borates, 399
nitrates, 395–397
molybdates, 397–398
silicates, 398–399
Anodic inhibitor programs, 241, 388, 402–403
Anodic inhibitors, 171, 438
Anodic passivating agent, 396
Anodic polarization, 151
by phosphate action, 400
Anticaking agents, for fireside cleanliness, 611
Antifoam and defoamer chemistries, 548–555
as adjuncts, 389, 479
formulations, 554
historical perspective, 393
mechanisms of foaming and its control, 549–551
selection, 551–555
block copolymers, 552
polyethylene glycol derivatives, 552–553
polyamides, 553–554
silicones, 554–555
Antifoulant, function of all-organics, 442, 443
Antifreezes, 402
Antimicrobial 728-8536, as RO membrane cleaner, 371
Antiscalents, 146
function of all-organics, 442
Antisettling dispersant, 672
Appurtenances, see Boiler appurtenances
AQ™ Total, nonchemical technology, 340
Aqua Magnetics®, nonchemical technology, 339
Index

Aquadro™ AR-232 -602 -900, 446
AR-540 -550, 447
Aragonite, 406
in scales, 645
sludge, 224
Argo Scientific, 371
Argon, in air, 689
Armohib 28, 31, 648
Aromatic solvents 110, 150, 686
in fuel additives, 680
Arsenic, 210
Ash content of fuel oils, 683
Ashland Chemical Corporation, 455, 552
ASME, 13
ASME Consensus 1994, 560, 561
Aspergillus niger, 404
Asphaltene, 672, 673
dispersant, 672, 685
Asphalts, 685
Asphalt and waxes, cleaning method, 651
Association of Shell Boilmakers, 560
ASTM D-1066, 278, 599
Atomic absorption spectroscopy, 622
Atomic hydrogen, 256
Atomizing oil burners, 83
Attemperating nozzle, 602
Attemperation water, 90
Attemperator, 71
direct type, 91
heat exchange, 91
spray (WT), 47
spray type, 91
spray water quality, 569
surface, 91
WT, 44
A-type WT boiler design, 50
Austenitic steels, 169
stainless steel, 266
Autoclaves, with amines, 533
Auto-ignition temperature, 681
Automatic analyzer, 257
Automatic nonreturn valves (NRVs), 80
AutoTrol™ controllers, 332
Auxiliaries, 71
boiler, 82
see also Boiler auxiliaries
Auxiliary boiler, see Boiler, auxiliary
Aviation kerosene, infection by Clostridium,
686
Avista, 371
AVT, see All-volatile treatment
Azulene formation, of amines, 511
Azoles, 400–402
Bacharach, Inc., 693
Back-end convection area, 675
Backflow preventer, 660
Backpressure, condenser, 118
Backwash, of ion-exchange resin bed, 329
Bacteria, separation of by membrane technology, 360
Bacterial slimes, cleaning in RO plants, 371
Baffles, 85
inspection of, 620
Bag filters
for condenser conditioning, 376
related technologies and, 325–326
for RO pretreatment, 368
Bag house, 678
Bagasse, 17, 58, 671, 683
as fuel, 51
Baked on sludge, 194, 218, 237, 296, 613
Balance of plant (BOP) equipment, 71, 86,
112–119
condensers, 116–117
electricity generators, 113–115
steam and water problems affecting turbines, 115–116
surface condenser operational problems,
117–119
Balanced draft system, 86
Balanced polymer, as conjunctural, 479
Bar gauge, definition of, 3
Barium, 221
Bark, 683
as fuel, 51
fuel treatment formulation, 687
Barrier films, 397
Base load boilers, 465
Base-exchange softener, 161
Base-exchange softening, following dealkalization process, 162
Base-load stage heater units, lay-up, 609
Basic oxygen furnace boilers, 57
see also Boiler, BOF
Basic pretreatment processes, 307–314
aeration and oxidation, 309–310
pretreatment using natural zeolite, greensand, and synthetic resins, 326–332
clarification, 313–320
pre-boiler filtration, 320–326
precipitation softening, 310–313
Basic sediment and water, 685
Basicity, 521, 523–526
of amines, 511, 523
degree of, 316
Basicity dissociation constant, 522, 524, 535
BASF A.G., 520, 552
Batch regeneration processes, 351
Bauxite, for lay-up programs, 610
Bayer AG, 351, 352, 489
Baylubrite®AM, 449
Bead resin deep-bed polishers, 379–382
Belclene®, 161, 370
161/164, 452
Boiler Water Treatment: Principles and Practice

 Belmont® 161 (continued)
  200, 451
  400, 447
  511/512, 401
 Belos®, 285, 370, 435
 Bel-Track®, 441, 662
 Benzene dicarboxylic polymers, 686
  1,4-Benzenediol, 499–501
 Benzol, 395
 Benzotriazole, 395, 401
  in cleaning processes, 647
 Benzoquinone, 500
  as catalyst, 495
 Benzylic alcohol, 686
 Benzylamine, 518
 Beta particle, 62
 Betz, 497
 Bicarbonates, 221–223
 Bilges, 74
 Binders, lignins as, 445
 Biocides, fuel oil, 686
 BioLabs, 401, 441, 662
 Birn® catalyst, 308, 309
 Black liquor recovery boiler, 57–58, 679; see
  also Boiler, carbon monoxide
 Blast furnace gas, 57
  as fuel, 51
 Blend-fill station, 655
 Blistering
  inspection for, 620
  managing, 625
 Block copolymers, 442, 552
  as antifoams, 551
 Blocked intake screens, in condensers, 117
 Blowdown
  calculation of, 78
  continuous, 74, 76
  continuous conductivity measurement
  controlled, 77
  controlling in LP boilers, 182
  intermittent, 76
  intermittent conductivity measurement
  controlled, 77
  main arrangement, 75
  rapid action intermittent arrangement, 77–78
  regulatory requirement, 75
  skimmer type, see Blowdown surface type
  surface type, 74, 76
  timer controlled intermittent, 76
 Blowdown (blow off) valves, 73–79
  calculating blowdown (BD), 78–79
  main (primary or bottom) BD arrangement,
  75–76
  rapid action intermittent BD arrangement,
  77–78
  surface (skimmer) BD arrangement, 76–77
 Blowdown efficiency, 19–20
 Blowdown and heat recovery system,
  inspection of, 621
 Blowdown valve, see Valve, blowdown
 Blowdown water, 75
 Blowdown water and flash steam and heat
  recovery systems, 94–97
 Blow-out program, 625
  to remove oil, 299
 Blow-outs, 625
  of boilers, 123
  need for, 307
  using phosphate, 419
 BOF boilers, see Basic oxygen furnace boilers
 Boiler
  appurtenances, 3
  auxiliaries, 3, 55
  black liquor recovery, 57
  BOF, 57
  carbon monoxide, 57
  cast iron sectional, 33
  basic pretreatment needs, 307
  cleaning, 623–657
  cleaning LP steam generator, 625
  coil
  basic pretreatment needs, 307
  with external recycle, 593
  with integral recycle, 593
  coil type, see Boiler, water tube, coil type
  combined-cycle type, see Boiler, water
  tube, cogeneration
  compact/special design, water quality
  needs, 342
  contamination at startup, 605
  critical pressure, 42
  cyclone fired, once-through, subcritical
  utility, 625
  direct fired, 23
  dryback, 32
  electric, 23, 24
  electrical resistance, 23, 24–27
  basic pretreatment needs, 307
  electrode, 23, 24, 27–29
  basic pretreatment needs, 307
  sprayed electrode type, 28
  steam for turbines, 605
  submerged electrode, 27
  variable water level type, 28
  water-jet type, 28
  energy and power units, 11
  enhanced oil recovery, 58
  field-erected, 9
  fire tube, 2, 23, 29–39
  Cornish, 31
  economic, 30
  externally fired, 30
  firebox, 30, 33
  HRT, 30
  inspection of, 615–618
  internally fired, 30
  Lancashire, 31
  locomotive, 30
Index

**Boiler (continued)**
- vertical type, 30
- Scotch marine, 30, 32–33
  - basic pretreatment needs, 307
- firebox, see Boiler, fire tube, firebox
- firetube plant steam system cycle, 134
- fluidized bed combustion, 58
- fossil-fueled, 679
- higher-pressure units, water quality needs, 341
- highly rated, water quality needs, 342
- horizontal return tubular, see Boiler, fire tube, HRT
- HPHW, 1, 36
  - summary of problems, 187
- hydronic heating, 32
- indirect, 56
- industrial types, see Boiler, water tube, industrial
- jet steam, steam for turbines, 605
- larger and more complex plant, water quality needs, 342
- LP energy losses due to deposition, 666
- LP steam, basic pretreatment needs, 307
- LP steam systems, 175, 178–188
- LPHW, 1, 36, 175, 178–188
  - summary of problems, 187
- marine type, see Boiler, water tube, marine
  - medium-temperature hot water, see boiler, MPHW
- MPHW, 1, 36
  - summary of problems, 187
- MPHW/HPHW, waterside problems, 185–189
- nameplate, 11
- nuclear, 42
- nuclear reactor, 23, 61–66
- packaged, 42
  - horizontal, 34, 35–37
  - vertical, 34, 38–39
- peak-load, 625
- plant, water treatment basics, 119–129
- problems with poor LP system design, 184
- Scotch type, see Boiler, fire tube, Scotch
  - marine
  - shell, see Fire tube
  - single phase, 53
  - steam, managing, 606–612
  - start-up hold times, 504
- steam generation system, 71
- steam–water circulation system, 45
- sugar refinery, 58
- supercritical, 23
- two-phase, 54
- utility, see Boiler, water tube, utility power
- vertical basic pretreatment needs, 307
- vertical type, see Boiler, fire tube, vertical
  - waste heat, 55
  - steelworks, 57

**Boiler (continued)**
- waste heat type, see Boiler, water tube, waste-heat
- waste-to-energy, 59
- water tube, 2, 23, 39–60
  - bent tube design, 41
  - cogeneration, 41, 52–53, 59
  - coil type, 40, 49
  - heat recovery, 53
  - industrial, 40, 49–52
  - inspection, 618–621
  - marine, 41, 55–56
  - radiant, 42, 53–54
  - special purpose designs, 41, 56–61
  - Stirling®, 41
  - utility power, 41, 53–55
  - waste-heat, 41, 56–61
  - watertube cogeneration plant steam system cycle, 134
  - wetback, 32

**Boiler appurtenances, 71, 72–82**
- blowdown (blow off) valves, 73–79
- boiler safety and stop valves, 79–80
- boiler vents, 80
- feedwater regulators, 80–81
- pressure gauges, 81
- steam blowers, 81–82
- water columns, 82

**Boiler auxiliaries, 71, 72, 82–112**
- baffles, 85
- blowdown water and flash steam and heat recovery systems, 94–97
- burners, 82–84
- condensate pumps and tanks, 98
- dampers, 85
- economizers and air heaters, 86–87
- fans, 85–86
- feedwater heaters and deaerators, 98–108
- feedwater pumps, 88
- feedwater tanks for fire tube boilers, 108–112
- sampling coils, 93–94
- spray attenuator, 91
- steam traps, 91–92
- stokers, 84
- superheaters and reheaters, 90–91

**Boiler-bank tube bundle (WT), 46**

**Boiler-bottom sludge, 296**

**Boiler cleaning, 623–657**
- acid cleaning procedure for smaller FT boilers, 653–654
- acid cleaning procedure for smaller WT boilers, 654–655
- boiler scales and deposits, 632–635
- chemical cleaning basics, 625–630
- cleaning solutions and inhibitors, 635–651
- determining necessity for, 631–632
- determining when a boiler needs cleaning, 631–632
Boiler cleaning (continued)
supplementary cleaning notes, 651–657
acid cleaning larger industrial WR
boilers, 655–656
fireside cleaning of small FT boilers,
656–657
precommission cleaning and alkaline
boil-outs, 651–653
Boiler compounds, 389
Boiler cycling, 21, 115
Boiler draft pressure, 86
Boiler energy and power units, 11–13
Boiler heat transfer surface cleanliness, 456
Boiler indirect fired, 23
Boiler inspections, 124, 612–623
inspecting boiler pretreatment plant, 615
inspecting FT boilers, 615–618
inspecting WT boilers, 618–621
preparation for, 613–614
scope of inspection work, 614–615
supplementary inspection notes, 621–623
deposit analysis, 622
nondestructive testing, 622–623
Boiler Lizard™, for lay-up programs, 610
Boiler loading efficiency, 10, 19
Boiler plant
appurtenances, 67–129
auxiliaries, 67–129
operational basics, 119–129
operational management processes, 120
sub-systems, 67–129
Boiler plant efficiency, 14–22
blowdown efficiency, 19–20
boiler loading efficiency, 19
combustion efficiency, 15–17
feedwater and air temperature efficiency,
17–19
steam pressure efficiency, 17
steam trap efficiency, 19
turbine and condenser operation efficiency,
20–22
Boiler plant mechanical operational functions,
120–124
air and flue gas management system
checks, 121
boiler inspection work, 124
condensate return system checks, 121
feedwater supply system checks, 121
fuel management system checks, 121
instrument and control systems checks,
121–122
interlock systems function checks, 121
new boiler work, 123
off-line, safety, and other appurtenance
valve checks, 124
periodic chemical cleaning, 122–123
water-steam appurtenance checks, 120
Boiler plant operational and water treatment
basics, 119–129
Boiler plant operational and water treatment
basics (continued)
boiler plant mechanical operational
functions, 120–124
water treatment program management,
125–129
Boiler plant sections, 43
convection pass section, 43, 44–45
exit gas section, 43, 45
furnace section, 43–44
Boiler plant subsystems, 69–72
air and flue gas management system, 72
balance of plant equipment systems, 71
boiler steam generation system, 71
condensate return system, 72
feedwater supply system, 70–71
fuel management system, 72
steam delivery system, 71
wastewater treatment system, 72
water pretreatment plant system, 69–70
Boiler plant subsystems, appurtenances, and
auxiliaries, 67–129
boiler auxiliaries, 82–112
boiler appurtenances, 72–82
boiler plant systems, 69–72
Boiler safety and stop valves, 79–80
automatic nonreturn valves, 80
safety valves, 79
stop valves, 79
Boiler scales and deposits, 632–635
carbonates, 633
copper salts, 633
iron oxides, 633–634
magnesium, 634
nickel, 634
organics, 634–635
phosphates, 635
silicates, 635
sulfates, 635
Boiler scaling, fouling, and deposition,
217–237
deposition by alkaline earth metals salts,
220–227
deposition by silicates and other common
minerals, 227–237
Boiler section oxygen corrosion, 243–245
Boiler section oxygen removal, 480
Boiler section problems, 217–271
boiler scaling, fouling, and deposition,
217–237
nuclear powered steam generators,
corrosion in, 265–267
other forms of corrosion, 262–265
passivation and common corrosion
problems, 237–254
stress and high temperature–related
corrosion, 254–262
Boiler shell, inspection, 617
Boiler shutdown procedures, 124
Boiler steam generation system, 71
Boiler steam-water circulation system,
45–46
Boiler surfaces deposits, 468
Boiler surfaces passivation, 241–242
Boiler surfaces (WT), 44, 53, 71, 86, 144
Boiler tube failure, understanding the cause
and effect of, 157
Boiler tube, iron oxide deposits, 633
Boiler types and applications, 23–66
  electric boilers, 24–29
  fire tube (shell) boilers, 29–39
  nuclear reactor boilers, 61–66
  water tube boilers, 39–61
Boiler vents, 73, 80
Boiler wash-down, 122
Boiler water alkalinity, 546–547
Boiler water, carryover, 21
Boiler water chemistry
  control of, 559–598
  water treatment recommendation
  perspectives, 560–566
  tables and supporting notes, 566–598
  corrosion caused by unbalanced, 244
Boiler water, operational stability pH for
metals, 524
Boiler water solids, transport of, 203
Boiler water treatment programs, 385–478,
479–558
  meaning of, 139
  minimum requirements, 134
  practical objectives, 142
  servicing functions of, 137
Boilers
  as accumulators, 32
  backup, 607
  blowdown of, 74
  cast iron sectional, 183
  clean-steam type, 323
  coil, steam for turbines, 605
  electrode, water condition guidelines, 564
  highly rated, 13, 230
  HW heating, basic pretreatment needs, 307
  idle, oxygen corrosion in, 243
  idle, waterside protection for longer-term,
  608–611
  idle, waterside protection for short-term,
  606–608
  integral furnace, 42
  low-load, oxygen corrosion in, 243
  low-temperature hot water, see Boiler,
  LPHW
  natural circulation, 655
  nuclear powered steam generators, 474
  once-through, 474
  steam sampling during commissioning,
  605
  resistance, water condition guidelines,
  563–564
Boilers (continued)
  shell, recommended water characteristics,
  564–565
  standby, waterside protection for longer-
  term, 608–611
  supercritical, 474
  watertube, contamination of condensate,
  605
  subcritical, 23
Boiling
  convective, 5, 6
  nucleate, 5
  surge, 7
  two-phase, nucleate, 7
Boiling point, incipient, 6
Boiling point of water, 4
Borates, 399
Borax, 395, 399
Boric acid, 65, 477
Boron, rejection rate with RO, 361
Boroscope™, 124, 619
Bottom ash, 682
Bottom drum, see Mud drum
Bourdon tube, 81
Boyles Law of Gases, 690
BP Chemicals PLC, 520
Brackish water, as source for RO, 365
Breakout of tubes, inspection for, 620
Brine regenerant, inadequate, 197
Brine reject, 363
Briqueta® 301 -50A, 449
Briqueta® ADPA 60A, 449
British Standards Institute, 13, 343, 387, 404,
560, 599
British Thermal Unit, 11
Brittle fracturing, 258
Bromate, in cleaning processes, 644
Bronze, protection in cleaning processes, 639
Brown coal, fuel treatment formulation, 687
Brucite, 224, 423
  in boiler deposits, 634
  in scales, 645
BS 24861978, Treatment of Water for Land
Boilers, 404, 560
BS 24861997, Treatment of Water for Steam
Boilers, 343, 404, 562–563
BS 6098 Section 6, 7, 1994, 600
B-scan ultrasonic testing, 622
BSI, 13
BSI® 89, 446
BS&W, see Basic sediment and water
Bu heat content, of fuels, 670
Bubble rupture mechanisms, 550
Bubble thinning mechanisms, 550
Bubbling fluidized bed, see Fluidized bed,
  bubbling
Bubbly flow, 6
Buffering, using phosphate, 419
Build, own, operate, maintain program, 128
Boiler Water Treatment: Principles and Practice

Bulges, 259
Bulging, inspection for, 620
Bunsenite, 233
Burner cleaning, 649
Burner registers, 85
Burners, 82–84
atomizing oil burners, 83
gas burners, 84
inspection of, 620
pulverized fuel coal burners, 83
vaporizing oil burners, 83
Butyroaldehyde, 501
BW maximum concentration
recommendations for steam boilers, 563
BW treatment and control of steam/waterside chemistry, 134–140
BWT—Europe, 340
Calcite, 144, 631
in boiler deposits, 633
Calcite control, with nonchemical technology, 340
Calcite sludge, 224
Calcium, 221
as slag modifier, 682
Calcium aluminum silicate, historical perspective, 391
Calcium-aluminum silicate zeolite, 411
Calcium bicarbonate, 144, 310
alkalinity, 223, 514
removal, by degassing, 354
Calcium carbonate, 144, 194, 221–222
in scales, 645, 646
limit in RO systems, 369
Calcium carbonate crystal, nucleation of, 228
Calcium carbonate scaling, from hardness breakthrough, 660–661
Calcium chloride, noncarbonate hardness, 312
Calcium fluoride, production during cleaning, 639
Calcium fluoride, in reactor water, 382
Calcium hydroxide
as a softening agent, 311
in scales, 646
Calcium-magnesium-aluminum silicate, 411
Calcium and magnesium salts, control over deposition of, 224–227
Calcium orthophosphate scale, 235
Calcium phosphate, 145, 212, 221–222
deposits, 234
in scales, 645, 646
solubility constant, 422
Calcium salt, in boiler deposits, 633
Calcium salt crystal structures producing calcite, 406
Calcium salts, deposition by, 223–224
Calcium sulfate, 221–222
anhydrous, 145
deposits, 234
in scales, 645, 646
limit in RO systems, 369
noncarbonate hardness, 312
solubility, 234
Calgon®, 422, 497
historical perspective, 392
Calgon® RB-304, 494
Calloway™, 318
Calorific value
low in fuels, 683
of fuels, 670
Camellia sinensis, 408
Candle filters, for condensate conditioning, 376
Captive alkalinity program, 464, 469–470
Carbamates, in fuels, 671
Carbamide, 684
Carbazide, 502
Carbonyldrazide (CHZ), 500, 502–504, 510
with AVT programs, 474
as passivator, 649
Carbon
as combustion, 691
reaction producing carbon dioxide, 691
reaction producing carbon monoxide, 691
Carbon content, of fuels, 670
Carbon dioxide, 102, 152, 217–221, 227, 498, 514–517
in air, 689
in condensate, 381
as corrosion inhibitor, 238
as a dissolving agent for limestone, 311
removal by RO, 360
removal of in water, 312
in steam-condensate systems, 284–285, 510
testing in steam/condensate, 602
Carbon catalyst technologies, 305
Carbon dioxide absorption value, of amines, 521
Carbon dioxide, 514–517
carryover, 288–291
control, as functional area requiring chemicals, 387
removal, by ion-exchange, 349
Carbon filter, 200
Carbon monoxide, 693
as fuel, 51
reaction producing carbon dioxide, 691
Carbon monoxide boilers, 57
Carbon zeolites, historical perspective, 391
Carbonate conditioning, 584, 657
relationship to form mobile precipitants, 580
Carbonate control programs, 164
Carbonate-cycle boiler programs, 413–419
Index

Carbonate cycle program, 227
Carbonate hardness, 311
Carbonate/nitrile mix, as passivator, 649
Carbonate and phosphate control levels, 580
Carbonate-polymer programs, 413
Carbonate removal, using hot-time precipitation softening, 309
Carbonate scale, 226
Carbonate scaling, 238
Carbonate treatment, 413
Carbonates, 211–223, 219, 438, 633
  in boiler deposits, 633
  cleaning in RO plants, 371
  as a precipitant, 388
Carbonic acid, 152, 204, 514–517
  formation in condensate, 289
  penetration rates in steam/condensate lines, 514
Carbonic acid control, as functional area requiring chemicals, 387
Carbonic acid dihydrate, 502
Carbonized or coke deposits, cleaning method, 651
Carbonized organic components, 237
Carborundum, in fuel additives, 680
Carboxy-methylcellulose, 438
Carboxylate, as combustion catalyst, 681
Carboxylate groups, 442
Carboxylic acids
  contaminants in steam-condensate systems, 291
  from tannins, 406
Carboxymethylcellulose, 283
Carvoyer, 33, 115, 154, 155, 183, 194, 200, 202, 276, 282, 283, 290, 300
  boiler sludging and, 194
  cleaning need, 631
  control, as functional area requiring chemicals, 387
degree of, 604
  from excess softener chlorides, 661
  from external treatment, 201–203
  of external treatment, 229
  sampling for, 602–604
  steam–water interface physicochemical factors and, 282–284
Carvoyer of external treatment into feedwater, 201–202
Carvoyer measurement, 602
Carvoyer of water droplets, 8
Carvynder of steam, 8
Cartridge filters, for condensate conditioning, 376
Cartridge filtration, for RO pretreatment, 368
Cast iron
  gray, 211, 402
  nodular, 211
Cast iron sectional boilers, 33–34
Castor oil
  as adjunct, 389
  historical perspective, 393
Catalyst, adventitious, 485
Catalytic devices, 333–341
  with nonchemical technology, 334
Catalytic reduction processes, 684
Catalyzed carbon bed technology, for oxygen removal, 382–383
Catalyzed hydrazine, 494, 510
Catalyzed scavengers, 168
Catalyzed sodium sulfite, 485
  use of in MPH/WHPH systems, 186
Catechol, 506
  from tannins, 406
Cathodic action, of polymer, 448
Cathode, 149
Cathodic depolarizing agent, 250
Cathodic half reactions, 149, 286
Cathodic inhibitors, 647
Cathodic polarization, 150
Cathodic protection, corrosion control through, 167–168
Cation/anion condensate polisher, 380
Cation exchange dealkalization, as purification technology, 342
Cation exchange of hardness, via multifunctional water conditioner, 332
Cation ion-exchange for hardness removal, 309
Cation permeable membrane, 373
Cation resin, cleaning, 349
Cationic polyelectrolytes, 316
Cationic polymer coagulants, 313
Catonic resins, 685
Catrons, in ion-exchange, 347
Cause and effect problems, 136, 174, 238 understanding, 157, 173
Caustic, 123
  in cleaning formulations, 649, 651
  in cleaning processes, 637, 646
  as corrosion initiator, 238
  to provide FW alkalinity, 511
  requirement with phosphate, 423
Caustic addition, in dealkalization process, 161
Caustic alkalinity, 546
Caustic attack, 249–250
Caustic-based corrosion problems, 464
Caustic control, as functional area requiring chemicals, 387
Caustic cracking, 255–256
Caustic deposits, 227, 232
Caustic embrittlement, 255–256
  historical perspective, 393
Caustic free programs, 54
Caustic gouging, 249–250
Caustic precoat coke filters, 381
Caustic resin cleaning program, 349
Caustic soda, 30, 411
Boiler Water Treatment: Principles and Practice

Caustic stress corrosion cracking, 255–256
Cavitation erosion, 89
CDX™ system, 375
Celgard, 383
Cell-pair, in ED technology, 374
Cementite, 261
Cerospheres, 673
Centrifugal pumps, 88–89
Ceramic membranes, 359
Cerium
  in fuel additives, 680
  as slag modifier, 682
Cerium octoate, in fuel additives, 680
Cerium salts, as fuel additives, 675
Cerium sulfonate, in fuel additives, 680
CFR 21 §173.310 (boiler water additives), 60, 444, 452, 460, 484, 489, 553
CFR 21 §182.304, 497
CFR 21 §184.1139, 531
Chain reaction, 61
Charge neutralization, 313
Check valves
  fouling, 201
  sticking, caused by metal transport, 297
Checks
  air and flue-gas management system, 121
  condensate return system, 121
  feedwater supply system, 121
  fuel management system, 121
  instruments and control system, 121
  interlock systems function, 121
  off-line, 124
  valve, 124
  water-steam appurtenances, 120
Chelant attack, 262–265
Chelant-based combination programs, 460–464
Chelant-based multifunctional programs, 388
Chelant corrosion, 262–265, 436
Chelant demand, 435
Chelant overlay programs, 458
Chelant-, phosphate-, or polymer-based combination programs, 461–463
Chelant/polymer formulation, 460–464
Chelant program chemistries, 430–437
  chelant basics, 431–433
  practical application of chelants, 433–437
Chelant programs, 226, 388
  as alternatives to PPN programs, 411
  for wet lay-up, 609
Chelant residual, 435
Chelants, 87, 262, 438
  as continuous support to existing program, 430
  as corrosion inhibitor in cause and effect problems, 238
  function of all-organics, 442
  in low-hardness FW, 430
Chelants (continued)
  need for oxygen control, 436
  used under variable FW conditions, 430
  with phosphate precipitation programs, 430
  as solubilizing programs, 430
  Chelating agents, 431
  Chelation stability constants, 433
  Chelating function, of ligands, 445
  Chelation, in cleaning processes, 637
  Chelonate, 438
Chemical cleaning, 625–630
  of hot water and LP steam heating boilers, 122
  of industrial boilers, 122
  offline cleaning basics, 629–630
  online cleaning basics, 626–627
  online cleaning formulations, 627–629
  of utility boilers, 122
Chemical dosing, for RO pretreatment, 368
Chemical incompatibility, 300
Chemical polishers, 305
Chemical Publishing Company, 560
Chemical treatment
  additions, 125, 126
  hampered, caused by oily surfaces, 299
  testing and interpretation, 125–126
Chemicals, for internal treatment, 385–478
Chemisorption, of azoles, 400
Chemisorption bonds, formation of by inhibitors, 647
Chemisorption process, 151
Chemitreat PTE (Singapore), 375
Chemtall, Inc., 318
Chesnut tannin, 405, 484
Historical perspective, 392
Chile niter, historical perspective, 393
Chipping hammers, 631
Chloride attack, 588
Chloride control, as functional area requiring chemicals, 387
Chloride ions, 169
Chloride leakage, 197–198
  into feedwater, 197–198
  from polishers, 382
Chloride salinity, control over, 169
Chlorides, 217
  as cathodic depolarizing agents, 151
  effect on nitrite feed rate, 396
  penetrating deposits, 144
  in water supplies, 234
Chlorinated hydrocarbons, in cleaning formulations, 650
Chlorine addition, for RO pretreatment, 367
Chlorine, chemisorption by GAC, 323
Chlorine removal, 323
Chloroform extraction, 543
Chlorophenols, 404
Chordal thermocouple, measurement, 623
Chromate, 397
  inhibitors, 580
Index

Chromatic acid
  in cleaning formulations, 651
  in cleaning processes, 646
Chromium, 268
  in higher quality water, 305
Chromium oxides,
  in corrosion debris, 296
  transport of, 232
Chromium transport, 212
Churn flow, 6
Ciba Chemical Specialties, 318
CIP, see Clean-in-place
Circulating fluidized bed, see Fluidized bed, circulating
Circulation rates
  of boiler water, 14
  of two-phase mixtures, 14
Cis-butenedioic anhydride, 443
Citrate/iron/nitrite mix, as passivator, 649
Citrato acid, 432
  in cleaning processes, 637, 638
  as erythorbate stabilizer, 498
  in RO cleaners, 372
Citrosolve process, 644, 649
Clarification, 306, 313–320
  in anthracite filters, 309
  definition, 314
  inorganic coagulants, 314–316
  organic polymeric coagulants and flocculants, 316–320
  by sedimentation, 308
Clarification processes, 313–320
ClariFlo, 318
Clarity, of treated water, 320
Clean-In-Place, for RO, 366
Clean-steam generators, 60
Cleanup rate, during online cleaning, 626
Cleaner formulations, 650
Cleaning
  supplementary notes, 651–656
  using phosphate, 419
Cleaning methods, 623
Cleaning notes, supplementary, 651–657
Cleaning program, multiple step approach, 655
Cleaning solutions and inhibitors, 635–656
  inhibitors for cleaning solvents, 647–648
  passivators for cleaning solvents, 648–649
  removal of copper/copper oxides, 641–643
  solvents for removing copper and copper oxides, 643–645
  solvents for removing iron oxides, 637–641
  solvents for removing organics, 649–651
  solvents for removing scales, 645–647
Clinker eutectic point, 683
Clinker treatments, 683
Closed and dry lay-up programs, 610
Closed feedwater heaters, 99–100, 305
Closed loop heating system, 133
Clostridium, 686
Coagulants, 305
  coagulant aids, 320
  organic polymeric types, 316–320
Coagulation, definition of, 313
Coagulation and precipitation program
  chemistries, 388, 411–430, 440
  alkaline aluminate and silicates-based boiler compounds, 411–413
  carbonate-cycle boiler programs, 413–418
  phosphate-cycle boiler programs, 419–430
Coal, 670
  anthracite, 16
  bituminous, 17
  subbituminous, 17
Coalescence mechanisms, 550
Coalescing filters, 381
Coating filters, 381
Coating, temporary, for lay-up programs, 612
Cobalt, as catalyst, 505
Cobalt corrosion products, 267
Cobalt hydroxide, 289
Cobalt-induced, outer-core radiation field, 266
Cobalt oxide, corrosion products in NP primary circuits, 477
Cobalt salt, 268
cobalt, 268
Cobalt, 267, 477
Cobalt, 267
Cobalt, 267
Cobalt sulfite, 485
Cobaltous hydroxide, 485
Cobaltous nitrate, 484
Cobaltous sulfate, 484
Coco-alkylamine acetate, 540
Coconut monoethanolamide, 554
Co-current resin regeneration, 351
Code of Federal Regulations 21, 444, 448, see also CFR
Codex, 551, 449
  8503, 449
Coefficients of thermal expansion, metals, and deposits, 148
Coke densifiers, oil-in-water, 545
Cogeneration, 15, 51
Cogeneration boilers, 52–53
Coil boilers, 49, see also Boiler, water tube, coil type
Coke, 670
Coke deposition, caused by oily surfaces, 298
Coke media, 310
Coke over gas, 57
  as fuel, 51
Coke, petroleum, 16
Coking, of oil constituents in heater, 685
Cold degreasers, 649
Cold-end acid attack, of economizers, 87
Cold-end acid corrosion/fouling, 680
Cold-end sulfuric acid attack, inspection for, 621
Cold-end zone, fireside, 669
Cold-end zone problems, 675–677
Cold-flow improver, 685
Cold lime process, to limit silica, 294
Cold plant startup, 120
Cold precipitator, 678
Colloidal amorphous silica, 227
Colloidal clays, 283
Colloidal material, 306
in raw water, 304
Colloidal metals, function of all-organicins, 443
Colloidal pectins, as process contaminants, 283
Colloidal starches, historical perspective, 393
Colloids, 205
Color problems, due to tannin, 409
Combination heating and power services, 51
Combined combustion improver, sludge dispersant, and fuel stabilizer, 688–689
Combined cycle, see Cogeneration
Combined cycle boiler, see Boiler, cogeneration
Combined cycle boiler systems, 59
Combined cycle systems, 43
Combined phosphate/carbonate-cycle programs, 418
Combining ratio, of oxygen scavengers, 482
Combustion additives, for fireside cleanliness, 611
Combustion area, inspection of, 620
Combustion catalysts, 681–682
oil-soluble formulation, 687
Combustion catalysts and improvers, 681–682
Combustion efficiency, 15–17
Combustion and environmental analyzer, 693
Combustion gas analysis, 689–693
analysis of flue gas, 691–692
combustion of fuels, 690–691
composition of air, 689–690
gas measuring equipment, 693
Combustion improver/stabilizer, formulation, 688
Combustion improvers, in fuel additives, 680, 681
Combustion problems, of fuel oils, 672
Combustion quality characteristics, of solid fuels, 670
Combustion system (Wt), 43
Combustion temperature, of fuels, 673
Combustion zone, fireside, 669
Combustion zone problems, 673–674
Comet tails, 264, 436
Compact bed, design of resin bed, 353
Competing anion effect, 433
Complex condensed polyphosphates, 420
Complex silicate scales, 412
Complexing agent, in cleaning processes, 637
Composition of air, 689–690
Compound™ design, of resin bed, 352
Concentrate recycle RO plants, 366
Concentrate/reject stream compartment, in ED technology, 374
Concentrate water, 363
Concentrated cell corrosion, 246–248
crevice corrosion, 247–248
pitting corrosion, 248
tuberculation, 246–247
under-deposit corrosion, 248
Concentrating effects on corrosion, 468
Concentrating mechanism, need for in caustic gouging, 249
Concentration cell corrosion, additional forms of, 248–250
Condensate, 70, 98
low-grade, 282
pure, 603
sampling temperature, 600
variable pH of, 282
Condensate conditioning, 376–382
Condensate contamination of feedwater, 202–205
Condensate line corrosion control, as functional area requiring chemicals, 387
Condensate line corrosion inhibitors, as adjuncts, 479
Condensate line, inspection of, 621
Condensate polisher, 138, 298, 378
Condensate polishing, 307, 376, 377–382
bead resin deep-bed polishers, 379–382
to control condensate quality, 591
by ion-exchange, 346
powdered-resin pretreatment filters, 379
as purification technology, 343
Condensate polishing capacity, effect due to amine loading, 511
Condensate pumps and tanks, 98
Condensate receivers, 109
inspection of, 621
vented, 536
Condensate receiving tank, 72
Condensate return tank, 109
mechanical system, 72, 98, 121
vacuum system, 98
Condensate return pump, inspection of, 621
Condensate return purification, 307
Condensate sampling in higher-pressure boilers, 600–601
in lower-pressure boilers, 602
Condensate sampling/testing, 599–605
Condensate strainer-filter units, 376
for condensate conditioning, 376
Condensate system, iron oxide deposits, 633
Condensate treatments non-amine-based, 544–545
as primary support chemical, 389
as program primary support chemicals, 385
Index

Condensation of steam, partial, 604
Condensed phosphates, 419, 420
Condensed tannins, 406, 445
Condenser in-leakage, 382
Condenser leaks, 299
Condensers, 116–117
air-cooled steam, 117
in boiler deposits, 634
chloride in-leakage, 476
direct contact, 117
main, 56
operating efficiency, 20
operational problems, 117–119
surface, 21, 116
Conductivity
of steam/condensate, 344
testing in steam/condensate, 602
of treated water, 198
Conductivity control, with AVT programs, 475
Confined space entry permits, 599, 614
Congruent control, 389
Congruent phosphate program, 464, 470–472, 474, 478, 546
Conjugate acid, of amine, 524
Conjunctural treatments, 385, 387, 479–558
Consensus on Operating Practices for Control of FW and BW, 343
Constant boiling mixtures in deaerators, of amines, 511
Contaminant binding, caused by oily surfaces, 298
Contaminant mass balance summaries, 456
Contaminants
as contributors to boiler scales and deposits, 234
in feedwater, 219
Contaminants control, as functional area requiring chemicals, 387
Contamination, 140, 154–156
as a result of corrosion, 153
carryover, 155
of condensate, 299
foaming, 154
from industrial processes, 299–300
from oils, fats, and greases, 298–299
surching (priming), 155
Continuous analyzer, 600
Continuous BD line, sampling from, 605
Continuous deionization, 372
Continuous regeneration processes, 351
Control of boiler water chemistry, 559–598
Control limits
AVT, section 10.9, 475
boiler salines, notes to McCoy table, 598
carbonate cycle BW, table 10.3, 417
carbonate cycle reserves, table 10.2, 415
chelant/all-organic, table 10.7, 459
coil boilers, notes to BS 24861997 table, 593–594
Control limits (continued)
coordinated/congruent phosphate, figure 10.5, 471
electrode boilers, notes to BS 24861997 table, 594–595
electrode, jet type boilers, notes to ASME table, 576–578
fired WT boilers, notes to BS 24861997 table, 586–589
FW quality guidelines, notes to McCoy table, 597
HW systems, notes to BS 24861997 table, 580–582
industrial FT boilers, notes to ASME table, 571–573
marine propulsion, WT boilers, notes to ASME table, 575–576
non-fired WT boilers, notes to BS 24861997 table, 589–591
once-through boilers, notes to BS 24861997 table, 592
phosphate cycle FT boiler, table 10.4, 428
phosphate cycle WT boiler, table 10.5, 429
PWR primary coolant, section, 10.11.1, 477
tannin residuals, table 10.1, 408
very-HP/supercritical boilers, notes to McCoy table, 595–596
water for higher pressure boilers, table 9.3, 341
Control of oxygen, 168–169
Control parameters, optimizing in HP industrial boilers, 661–662
Control of water chemistry, 559–598
Controlled-pH phosphate programs, 464, 467, 469–474
congruent phosphate program, 470–472
coordinated phosphate program (captive alkalinity program), 469–470
equilibrium phosphate program, 472–473
formulations, 473–474
non-acid phosphate programs, 473
precision control phosphate program, 472
Convection, 47
Convection area slugging, 674
Convecrive boiling mechanisms, 465
Converters, for LPHW/LP steam, 185
Coodinated/congruent phosphate, 531
Coordinated phosphate, 427, 546
Coordinated phosphate and program deviations, 464–474
captive alkalinity program, 469–470
HP boiler waterside problems and controlled-pH program considerations, 465–469
types of controlled-pH phosphate programs, 469–473
Coordinated phosphate programs, 389, 469–470
flaws, 467
see also Phosphate programs, coordinate
Cooling coils, 600
Copolymers, 442
historical perspective, 393
Copper, 214, 233
as adventitious catalyst, 485
as catalyst, 495
as combustion catalyst, 681
as erythorbate catalyst, 497
in fuel additives, 679
in higher quality water, 305
plating out in the boiler, 141
stains of elemental, 232
testing in steam/condensate, 602
vaporous, 295
Copper alloy passive films, 406, 445
Copper-ammonium ion, 293
Copper carbonate, hydrated, 176
Copper cathode, with nonchemical technology, 334
Copper chloride, in clinker treatments, 683
Copper-complexing agent, 625
Copper contamination removal, in condensate, 377
Copper control, as functional area requiring chemicals, 387
Copper/copper oxides, removal of in cleaning processes, 641
Copper corrosion, 265
due to phosphonate, 448
Copper cracking, risk during cleaning, 645
Copper/iron pickup, 162
Copper and nickel control, with AVT programs, 475
Copper oxide passivation film, 489
Copper oxides, 146
in boiler deposits, 633
in corrosion debris, 296
removal, 625
steam-distillation, 116
steam distilling, 295
Copper phosphate, trihydrate, 176
Copper pickup, with hydrazine, 492
Copper release, 293
Copper salts, 633
in boiler deposits, 633
Copper in steam, control in super-critical boilers, 476
Copper-steel couples, 402
Copper sulfate
in boiler deposits, 633
as DEHA buffer, 499
Copper-thiourea monochloride, in cleaning processes, 643
Copper transport, 212
Copperas, 315
historical perspective, 390–391
Core reactivity controlling agent, 477
Cornish boiler, see Boiler fire tube, Cornish
Cornstarch, historical perspective, 393
Corrosion, 136, 140, 144, 149–153
acid, 176, 177, 183, 300, 647
due to acid breakthrough, 198
acid attack example, 253–254
acid cleaning, 254
acid phosphate attack, 469
acid phosphate corrosion, 468
acid pitting, 235
acid regenerative infiltration, 252
acidic cold-end, inspection for, 620
ammonical, 265, 285, 293
amphoteric, 282
anodic area pitting, 265
anodic, of economizers, 87
anodic half reaction, 286
biocorrosion, in condensers, 117
boiler section, as functional area requiring chemicals, 387
brass, 246, 293
carbonic acid, 289–290, 483
carbonic acid pitting rates in steam/condensate lines, 514
cathodic half reaction, 286
cauetic cracking, 198
risk of, 649
cauetic embrittlement, 240, 466, 468
cauetic gouging, 152, 157, 196, 227, 232, 236, 239, 249, 257, 465, 468, 469
under deposits, 233
cauetic-induced, 169
cauetic-induced, stress corrosion cracking, 227, 236, 466
cavitiation, 211
chelant, 262–265
oxygen induced, 207
chloride involvement in, 248, 250
circumferential fatigue cracking, of condenser tubes, 382
cleaning need, 631
course magnetite, 242–243
cold-end, 675
cold-end acid, 680
concentration cell, 170, 244, 246–250, 466
condensate line, 178, 288
control of, 167–172
copper, 265
in condensers, 117
of economizers, 87
copper oxide, 285
copper-induced, 231
creviced, 170, 247–248, 476
in condensers, 117
cupronickel, 246
deeerator, 207
Index

Corrosion (continued)
deleoying, oxygen induced, 210
decarburization, 257
deknickelification, 210
destannification, 210
development of fouling, 181
dezincification, 210
differential aeration, 178
differential-aeration cell, 247
ductile gouging, 231, 236, 249
during dry layup, 248
economizer, 87, 207
embrittlement, 236, 254–256, 387
enhanced condensate line, 204, 285, 290, 512
erosion, 176, 204, 211, 300, 308
caused by metal transport, 297
in condensers, 117
erosion-corrosion, 520
exfoliation, 210
in PW heaters, 609
fatigue, 91, 248, 255, 256, 258, 473
condenser, 118
feed-line, 207
feed tank, 207
galvanic, 150, 176, 180, 209
galvanic conditions, 152
general etch, 153, 245–246, 266
glycol derived, 177
gouging, of economizers, 87
graphitic, 89, 210, 262
high temperature, 257–260, 261, 466
high-temperature waterside, 174
hot-end acid, 680
in HW systems, 178–180
hydrogen embrittlement and hydrogen
damage, 255, 256–258, 261, 265
impingement, caused by metal transport, 297
in LP steam heating systems, 178–180
in nuclear powered steam generators,
265–267
in pre-boiler section, 207–211
in turbine low-pressure stage, 116
inhibitor, amine-based, 178
initiator, 246
inspection of general waterside damage,
616
inspection of under-deposit, 616
intercrystalline, 254
intergranular attack, 254, 266
intergranular creep cracking, 259
intergranular oxidation, 261
layer dezincification, 210
liquid metal embrittlement, 265
localized, 245, 246
localized conditions, 152
longitudinal gouging/grooving, 249
Corrosion (continued)
low pH, 250, 251–254, 256
low pH localized, 466
metal fatigue, 254
nickel, 285, 293
nodule, 247
oxygen, 178, 181, 206, 285–287
in boiler section, 243–245
persistently high temperature, 261
pinhole, 176
pitting, 110, 153, 169, 170, 181, 195, 206,
246, 248, 480
in condensers, 117
under deposits, 233
plug dezincification, 210
pre-boiler, as functional area requiring
chemicals, 387
rate-determining steps, 150
risks to condensate, 194
saline, 250, 465
salinity involvement, 248, 250
salt contamination, 252
SCC of nickel alloys by lead, in NP
secondary circuits, 478
SCC of SS by chlorides, in NP secondary
circuits, 478
seawater contamination, 252
selective leaching, 210
self-limiting effect of magnetite, 512
shell boiler, 207
sodium hydroxide involvement in, 248
spheroidization, 261
stainless steel, 246
stress, 245
stress and high temperature related,
254–262
stress corrosion cracking, 169, 232, 236,
240, 247, 255–254
stress cracking, 476
stress rupture, 260
sulfate involvement in, 246, 248
sulfur, in fuel systems, 673
thermal effect, 254
thermal fatigue cracking, 255, 258
thermal oxidation, 261
ternally induced, 254
top drum, 207
transcrystalline, 254
transgranular, 254
tube pitting, 207
tube/tube sheet crevice, in NP secondary
circuits, 478
tuberculation, 110, 153, 170, 178, 180,
246–247
of economizers, 87
tuberculation deposits, 232, 247
under-deposit, 180, 244, 246
under-deposit prevention, 652
zinc, 285, 293
Corrosion caustive agents, sulfates as, 170
Corrosion control, as functional area requiring
chemicals, 386
Corrosion, control of, 167–172
  cathodic protection, 167–168
  control of oxygen, 168–169
  control over salinity and adverse chemical
  reactions, 169–170
  passivation, 170–172
Corrosion debris, 218
  controlling in MWH/HWH systems, 187
  deposition, 231–237
  pickup, transport, and redeposition, 204
  transport problems, with CHZ, 503
Corrosion-enhancement problems, from
  oxygen in-leakage, 503
Corrosion fatigue, 169, 258
Corrosion in hot water and low-pressure
  steam heating systems, problems of,
  178–180
  galvanic, acid, and under-deposit corrosion,
  180
  oxygen corrosion, 178–180
Corrosion inhibition
  function of all-organics, 443
  by phosphate action, 400
Corrosion inhibitor treatments, basic internal
  types, 307
Corrosion inhibitors
  for cleaning solvents, 647–648
  for fuels, 686
  for fuels, 683–684
  loss of in LP boilers, 183
  multi-metal, 178
Corrosion, intergranular, 466
Corrosion, localized, 245–246
Corrosion mechanisms, 149–153
  influence of dissolved gases, 151–152
  influence of fouling, 152–153
Corrosion in nuclear powered steam
  generators, 265–267
Corrosion problems
  affecting pre-boiler section equipment,
  209–211
  oxygen-influenced, 242–248
Corrosion processes, 141
Corrosion product, 218
Corrosion tuberculation, 245
Corrosive attack, critical areas due to erosion-
  corrosion, 508
Corrosive gases and related impurities,
  291–293
  in steam-condensate systems, 284–293
Corrugation of flues, 32
Cortec Corporation, for lay-up programs, 610
Costs of amines, 511
Coupling agents, 454, 686
CPS, Inc., 318
Cracking, 259, 260
  inspection for, 619
Creep, 259
Creep rupture, 260
Creep temperature, managing, 625
Crevice corrosion, 247–248
Crimp™, 545
Crijet™, 545
Critical heat flux, 15, 37
Critical mass, 65
Critical miscelle concentration, 647
Critical pressure, 7
CrodA PLC, 545
Cross-contamination, 299
Cruel, 503
levels, 508
in NP primary circuits, 478
Crude oil heater, refinery, 679
Cryojet™, 624
Crystal distortion
  using phosphate, 419
  of polymers, 413
Crystal growth retardation, function of all-
  organics, 443
Crystal modification, function of all-organics,
  443
Crystal modifiers, 166
Crystalline iron oxides, in condensate, 379
Crystalline scale, 136, 201, 224
Cupric ammonium complex ion, 265, 293
Cupric copper, as catalyst, 489
Cupric ion, production during cleaning, 642
Cupric oxide, 493, 494
  in boiler deposits, 633
  cleaning process of, 637
  deposit on turbine blades, 295
  production during cleaning, 642
Cuprite, 233
Cupro-nickels, 210
  protection in cleaning processes, 639
Cuprous chloride, in gas analysis, 693
Cuprous ion, production during cleaning, 642
Cuprous oxide, 176, 494
  in boiler deposits, 633
  cleaning process of, 637
  deposit on turbine blades, 295
  oxidation with air in-leakage, 496
Cuprous oxide film, need for passive, 241
Current density of corrosion process, 151
Cutch, historical perspective, 392
Cyaniem™, 318
Cyclic diketones, from tannins, 406
Cyclohexylamine, 498, 518, 521
  with AVT programs, 475
  level in steam contacting food, 531
  neutralization reactions, 515
Cyclohexylamine carbonate, 523
Cyclone furnace, 82
Cyclone scrubber, 675
Index

Cyclone separator, 678
Cyclone tube, cleaning, 625
Cyclones, 325
for condensate conditioning, 376
Cyclonic flame, 39
Cytec Industries, 318

Dampers, 85
Dead plant startup, 120
Deaerating feedwater heater, 17, 207
Deaerator pegging, 504
Deaerator performance calculation, 107
Deaerator purge gas, 102
Deaerator spray heads and trays, inspection of, 615
Deaerator steam demand, estimation of, 666–667
Deaerator troubleshooting, 104–108
Deaerator vent condenser, 103
Deaerators, 98–108, 161–162, 305
acid attack, 299
atomizing type, 104
chemical, 102
exchange packing type, 103
see also Heater, feedwater deaerating
lay-up of idle, 611
performance calculation, 107
pressure, 100
reduced venting, caused by metal transport, 297
spray type, 103
steam demand estimation, 666
tray (baffle) type, 103
vacuum, 100, 108
Deaerators and other equipment, need for, 161

Dealkalization
by ion-exchange, 346
lack of capability in feedwater, 193–196
to reduce amine consumption, 532
as source of feedwater contamination, 198
Dealkalization processes, 353–357
Dealkalizer
chloride anion exchange, 195
split stream strong acid cation, 195, 198
strong acid cation, 195, 198
weak acid cation, 195, 198
Deaerating, 210
Deaeration
efficiency, 104
problems caused by lack of, 206–209
Dearborn Chemical Company, 550
Dearborn Neuton®  53, 494
Decarbonization, 354
Decarburization, 262, 466
Decolorization, 324
Deconcentration of BW, 74
Deep-bed sand filtration, 308
Deflocculants, using phosphate, 419
Deflocculants, 440
function of all-organics, 443
Defoamer chemistries, 548–558
Defoamer selection, 551
Defoamers, as adjuncts, 389
Degussers, to reduce amine consumption, 533
Degassing
in dealkalization process, 161
of carbon dioxide, 354
Degree of agglomeration, of fuels, 670
De prermon/Suez-Lyonnaise, 455
DEHA, see Diethylhydroxylamine
Dihydrorascorbic acid, 498
Deionization
deep-bed, 345
for MPHw/HPHW systems, 186
packed-bed, 345
as purification technology, 342
Demineralization
by ion-exchange, 346
as purification technology, 342
to reduce amine consumption, 532
as source of feedwater contamination, 198
Demineralization processes, 358–359
Demulsifier, for fuel oils, 671
Demulsification effect, of antifoams, 550
Demulsification, of fuel oils, 671
Denting, 476
in NP secondary circuits, 478
Deodorants, for fuels, 671
De-oiling of new boilers, 123
DEOXb process, 383
Department of Transportation, 484
Departure from nucleate boiling, 144, 157,
220, 250, 465
Deposistivating agents, 250
due to chloride leakage, 197
sulfates as, 169
Depassivation, 169
Deposition of metal surfaces, 206
Depolarization, due to chloride leakage, 197
Deposit, 140
Deposit analysis, 622
Deposit binding, 206
Deposit control agents, 61, 146, 166, 226, 442
as adjuncts, 386
Deposit formation, signs of, 631
Deposit modifiers, 682–683
as fuel additives, 675
Deposit morphology, 147
Deposit problems, in steam turbines, 116
Deposit thickness, tolerance for, 164, 631
Deposits on LP boiler tube, 182
Deposition, 140, 144–148, 201, 218
by alkaline earth metal salts, 218–221
avoidance of waterside, 164
of calcium salts, 223–224
cause and effect in higher pressure boilers, 236
Deposition (continued)
caused by scaling and corrosion in lower pressure boilers, 236
of economizers, 87
eggshell thickness standard, 164
of iron oxide and other corrosion debris, 231–237
limiting, 163–167
of magnesium salts, 224
mechanisms of, 146–148
in pre-boiler section, 211–215
by silicates, 227–231
Deposition by alkaline earth metal salts, 220–227
Deposition control, as functional area
requiring chemicals, 387
Deposition, limiting, 163–167
Deposition of calcium salts, 223–224
Deposition of magnesium salts, 224
Deposition of scale and corrosion debris in pre-boiler sections, 211–215
Depositions, 136
analysis of, 632–635
originating from inorganic salts and organics, 233–237
in steam systems, 282
in superheaters, 90
Deprotonation step, of oxygen scavenger, 482
Dequest® 2000/2006, 449
2010/2016, 449
2054, 450
2066, 450
Derusting of new boilers, 123
Desalination by RO, 360
Desiccants, 610
Desilication processes, 357–358
Desilicization, as purification technology, 343
Desuperheater, see Attemperator (WT)
Desuperheaters, 91
Desuperheating water, 586, 589
Desuperheating, water quality limits, 591
Detergent cleaners, in cleaning processes, 637
Determining when a boiler needs cleaning, 631–632
Dew point, 18, 611
Dew point condensation, 54
De-watering agent, 685
De-wetting functionality, of amines, 539
D-gluconic acid, sodium salt, 432
D-glucosamine, from tannins, 405
Diamine corrosion inhibitors, for fuel oils, 686
Diamine salts, in fuel additives, 680
Diamines, 489–494, 537, 540, 542, 686 as biocides for fuel oils, 686
in cleaning processes, 647
1,2-Diaminoethane, 521
Diatomaceous earth filters, 381
2,2-Dibrom-3-nitropropionamide, 371
Dichlorophen, 404
Dicyclohexylamine, 519
Dicyclohexylammonium nitrate, 607
Diesel tanks, infection by Clostridium, 686
Diethanolamine, 498, 519
Diethanolglycine, 432
Diethylamine, DEHA oxidation product, 496
Diethylamineethane, level in steam contacting
food, 531
Diethylamineethanol, 500, 519
with AVT programs, 475
Diethyldihydro, 1, 2, 4, 5-tetrazine, 505
Diethylendiamine, 520
Diethyleneoximide, 520
Diethylendiamine (methylene phosphonic acid), 450
Diethylendiamineacetic acid, 432
in cleaning processes, 637
Diethylethanolamine, 519
Diethylhydroxyamine (DEHA), 305, 394,
395, 410, 494–497, 500, 510, 512, 519
as AVT, 389
with AVT programs, 474
use of in MPH/WHPH systems, 186
as passivator, 649
Diffuse layer thickness, reduction of, 513
Diffusion barrier, 647
Dihydro-tetrazine, 505
Dihydroxyacetone (DHA), 505
Dihydroxy flavonoids, 406
Dihydroxyacetone, 505
1,3-Dihydroxyacetone, 505
2,3-Diketo-1-gluconic acid, 498
Disobutylammonium sulfate, 607
3,6-Dimethyl, 1,2-dihydro, 1, 2, 4,
5-tetrazine, 505
Dimethylamine, for testing sodium, 603
Dimethylamino-2-propanol, 519
2-Dimethylaminoethanol, 519
Dimethylaminoethoxypropanol, 520
Dimethylisopropanolamine, 519
Dimethylpolyisoxolanes, 554
Diminished phosphate salt solubility, 471
Diocylsulfosuccinate, in cleaning
formulations, 651
Diphenylamine, in cleaning processes, 647
Diphenylidinehydro, 1, 2, 4, 5-tetrazine, 505
Dipotassium phosphate, 402
Direct fired steam generator, see Boiler, waste
heat
Dirt Loading, 631–632
conditions for lack of tolerance, 473
levels, 456
standards and example, 632
Dirt pockets, 176
Disc steam traps, 92
Disodium hydrogen phosphate, 421
in cleaning solutions, 652
Index

Disodium phosphate, historical perspective, 392
Dispersants, 166, 283, 305
Flocculating effect of, 219
function of all-organics, 442, 443
lignins as, 445
silica specific, 294
use of in MPH/HPH systems, 187
water-in-oil type, 684
Dispersion effect, 424
Dissociation constants
amine basicity, 525
for amines, 524
for water, 525
Dissociation reaction
for primary amine, 524
of amines, 527
Dissolution of organics, in cleaning processes, 637
Dissolved/entrained hydrogen in FW and steam as indicator of corrosion rates, 663–665
Dissolved gases, influence of in corrosion mechanisms, 151–152
Dissolved oxygen, 151
reduction needs in FW, 578
Dissolved oxygen removal, high demand for, 285
Dissolved oxygen testing
Chemet® ampoules, 105
Rhodazine D method, 105
Winkler method, 105
Distearoylethyleneamide, 554
Distribution pipeline, 71
Distribution Ratio, 521
of amines, 511, 526–530
Disulfides, in scales, 646
Ditetracarboxyamido-EDTA, in cleaning processes, 638
Divinylbenzene, 347
DMA-2-P0-77, 519
Dodecylamine, 540
Domestic heating coil
internal corrosion, 176
internal deposition of, 176
Double pass RO plants, 366
Dow Chemical Co., 352, 361, 371, 432
Downcorner tubes (WT), 45
Downcorners, inspection of, 619
Downflow precipitation softening, 311
Draft, 85
Draft gauge, 693
Drain pan, 660
Draw-and-fill cooling, 607
Drawing compounds, cleaning, 651
Drew Industrial Division, 455, 501, 552
Drop runoff rate, 536
Droplet flow, 6
Dropwise condensation process, 536
Drum plates, inspection of, 620
Drumless delivery, 132
Drumless delivery service, 127
Dry ice blasting, 624
Dry lay-up
corrosion problems, 248
programs, 606, 610
protection of waterside by, 610–611
Dry powder polyelectrolytes, 316
Dryback boiler, see Boiler, dryback
Dryout, 14, 55, 229
D-type WT boiler design, 50
Dual-amine technology program, 537
Dual-chelant programs, 460
Dual-temperature systems, 133, 394
inhibitor requirements, 396
Ductile fracture, 258
Ductile gaging and caustic attach, 249–250
Dulco Power Company (Charlotte NC), 489
Durance OL., 686
DuPont Company, 361
Dust binder, for solid fuels, 671
Dust collector (WT), 45
Dust content, of solid fuels, 671
Dutch oven furnace, 59
DVCG Guidelines, 340
Dyes, causing discoloration of condensate, 206
Effluent cooling, 53
E-cell®, 375
Ecochem, Inc., 305, 383
Economic boiler, 30, see also Boiler, fire tube, economic
Economizer problems, 87
Economizers, 14, 44, 17, 71, 86–87, 98, 153, 305
and air heaters, 86–87
cleaning flue gas side of, 611
inspection of, 618, 620
iron oxide deposits, 633
non-steaming, 86
outlet header (WT), 45
oxygen scavenger feed point note, 583
steaming, 86
EDI stack, in ED technology, 374
EDTA (neutralized tetrasodium)
in cleaning processes, 646
as erythorbate stabilizer, 498
see also Ethylenediaminetetraacetic acid
in RO cleaners, 372
EDTA/organic acid mix, in cleaning processes, 638, 646
Effective water treatment practice, 156–158
control of water chemistry, 157–158
training and experience, 156
understanding cause and effect, 157
Egg-shell scale, inspection of, 616
Eggshell thickness of scale, historical perspective, 392
Elagiantins, 405
Electric boilers, 24–29
- electrical resistance boilers, 25–27
electrode boilers, 27
Electric heaters, 305
Electric Power Research Institute, 464
Electric powered steam generators, to reduce
amine exposure, 533
Electrical generators, 20, 113
Electrical resistance boilers, 25–27
Electrical resistivity of steam/condensate, 344
Electricity generators, 113–115
- impulse stage turbines, 114
- large steam turbine generators, 113–114
- reaction stage turbines, 114
- smaller steam turbine generators, 114–115
Electrochemical corrosion process, 149, 647
Electrochemical series, 150
Electrode boilers, 27–29
- sprayed electrode boilers (water-jet
electrode boilers), 28–29
- submerged electrode boilers, 27–28
Electrodeization, 374–376
Electrodeionization, 372–376
- purification by, 372–376
Electrodialysis, 307, 366, 372, 373
- as purification technology, 342
Electrodialysis reversal, 372, 373–374
- to limit silica, 294
Electroionization, to limit silica, 294
Electrolyte, 149
Electrolytic devices, 334
Electromagnetic filtration (EMF) and
- electromagnetic separation (EMS), 377
Electromagnetic radiation particles, 62
Electromagnetic separators, 298
- for condensate conditioning, 376
Electromotive force, 167
Electronic nonchemical devices, 334
Electropure, 375
Electrostatic devices, 333–341
Electrostatic nonchemical devices, 334
Electrostatic precipitators, 45, 54, 675, 678
ElectroStatic Technologies, nonchemical
technology, 339
Electrostatic units, in nonchemical
technology, 337
Elf Atochem, 489, 494, 519
Elimin-Ox®, 502
Ellagic acid, 408, 505
-sodium salts, 405
Ellagotannin, 406
Emergency standby, 607
Emission control systems (WT), 43, 45
Emission levels, of nitrogen oxides, 16
Emissions zone, tireside, 669
Emissions zone problems, 677–678
Emulsification, 550
- by non-ionic detergents, 637
Emulsified fatty acid soap, in fuel additives, 680
Emulsifiers
- in cleaning formulations, 650
- in lignins as, 445
- water-in-oil type, 545, 671
Emulsifying degreasers, 649
Emulsion additives, 684
Emulsion breaker, 685
Emulsion for fuel oils, 671
Emulsion polymers, 316
Energy balance summaries, 456
Energy loss estimation, in scaled LP boilers, 666
Energy losses in low-pressure boilers caused
by deposition, 666
Energy, work, and power, 10–14
- boiler energy and power units, 11–13
- heat release coefficients, 13–14
Ener-tec®, nonchemical technology, 339
Enhanced oil recovery boilers, 38, see also
Boiler, enhanced oil recovery
Enriched fuels, 63
Entrained boiler water, in steam, 604
Entrainment, 155, 281
Enthalpy, of evaporation, 4
Enthalpy loss, 16
Entropy, 431
Environmental issues of amines, 511
Environmental Protection Agency, 484
Environmental protection programs, 43
Enzyme-based reodorants, 671
Eosin, 543
Epichlorohydrin-dimethylamine polymers,
517
Epitaxial nucleation, with nonchemical
technology, 340
Equilibrium phosphate concentration theory,
472
Equilibrium phosphate program, 389, 464,
472–473
Equipment failure, 136
Equivalent square feet of steam radiation
surface, 12
Erosion
- critical areas due to erosion-corrosion, 508
- of economizers, 87
- gas-side dust erosion, 87
- of preboiler system, 201
- solid particle, 116
- at steam-water interface, 282
Erosive microjets, 211
Erythorbate, as passivator, 208, 649
Erythorbic acid and sodium erythorbate, 394,
497–499
Etch oxygen corrosion, 245
Ethanediolic acid, in cleaning processes, 638
Ethanol, 2-(diethylamino), 519
Ethanolamine, 500, 520
Index

Ethanoldiglycine, 432
Ethoxylated alkylphenol alkyleneoxide polymer, 555
Ethoxylated diamines, 540
Ethoxylated soya amine, 537
Ethoxolation of amines, 538
Ethylene bistirenoic acid, 554
Ethylene bistearamide, 554
Ethylene glycol, 402
Ethylene carbonate, 446
Ethyleneediaminetetraacetic acid, 262, 431, 448
in cleaning processes, 637
Ethoxylation of (3)-N-tallow-1, 3-diaminepropane, 540
Eutectic temperature, 681
Eutectics of metal oxides, 675
Evaporation, application to reduce TDS, 162
Evaporator, 61
see also Seawater evaporator
thermo-compression, 61
vapor compression, 61
Excess air
problems caused by inadequate, 673
problems caused by too much, 673
Excess air requirements, 691
Exchange of ionizable materials, in condensate, 378
Exfoliation of high temperature oxide scales,
115, 259
Exit gas, as combustant, 691
Exit-gas volume, 677
Expansion joint cracking, inspection for, 621
Expansion tank, 660
External conditioning, need for, 158
External conditioning processes, as compliment to chemicals, 385
External and internal treatments, historical
perspective of, 389–393
External treatment carryover and after-
precipitation, 201–203
External treatment equipment, 305
External treatment process technologies, 306–307
External treatments, 304, 389–394
historical perspective, 389–394
meaning of, 139
External water treatment processes, development of, 3
Fabric filters, 54
Fan coil units, 132, 660
Fans, 85–86
forced draft fans, 85
induced draft fans, 85–86
inspection of, 620
Fast rinse, of ion-exchange resin bed, 329
Fatigue cracking of turbine blade, 116
Fatigue failure, 144
Fats
contamination from, 298–299
separation of by membrane technology, 360
Fatty amines, 517, 540
FBC boilers, see Fluidized bed combustion boilers
Feeding hydrazine, 491–492
Feeding sodium sulfite, 487
Feedline blockages, 204
Feedwater and air temperature efficiency,
17–19
Feedwater contamination from makeup water,
193–203
acid breakthrough of ion-exchange plant,
198
chloride leakage, 197–198
external treatment carryover and after-
precipitation, 201–203
hardness breakthrough, 196–197
lack of softening or dealkalization
capability, 193–196
organic fouling, 200
sodium and silica leakage, 198–199
Feedwater control levels for solids, alkalinity,
silica, 578
Feedwater contamination from makeup water,
193–202
Feedwater delivery, 88
Feedwater heaters, 71, 98–108
closed, 71, 99–100
closed high pressure, 86
closed low pressure, 86
deeatering type, 20, 71
direct type, 71
efficiency, 17
electrical resistance type, 71
high pressure, 100
indirect type, 71
lay-off of idle, 641
low pressure, 71, 100
open deeatering, 86
open type, 71, 100
regenerative, 98
steam sparge pipe type, 71
supply system, 45
volume demands, 219
Feedwater heaters and deaerators, 98–108
closed feedwater heaters, 99–100
high-pressure FW heaters, 100
low-pressure FW heaters, 100
open feedwater heaters, 100–108
Feedwater problems in final blend, 205–213
Feedwater pumps, 88–89
centrifugal pumps, 88–89
reciprocating FW pumps, 89
steam turbine-driven FW pumps, 89
turbine pumps, 89
Feedwater regulators 73, 80–81
Boiler Water Treatment: Principles and Practice

Feedwater regulators (continued)
  float FW regulator, 81
  thermo-expansion FW regulator, 80
  thermohydraulic FW regulator, 80–81
Feedwater supply system, 70–71
checks, 121
Feedwater tanks for fire tube boilers, 108–112
Ferric ammonium carbonate, hydrated basic, 212, 232
Ferric carbide, 262
Ferric chelolate, production during cleaning, 645
  Ferric chloride, 314
  Ferric hydroxide, 309, 315, 433
    in boiler deposits, 634
    corrosion in steam/condensate lines, 513
    formation in corrosion reaction, 286
  Ferric hydroxide precoat, 299
  Ferric ion chelation, 433
  Ferric ions, production during cleaning, 640
  Ferric iron, 497, 663
  Ferric oxide, 145, 243, 493
  as slag component, 682
  black corrosion in steam/condensate lines, 514
    in boiler deposits, 634
    corrosion in steam/condensate lines, 513
    production during cleaning, 640
    red corrosion in steam/condensate lines, 514
  Ferric phosphate, 235
  Ferric sulfate, 315
  Ferrite, 261
  Ferrite ions, 465
  Ferromagnetic iron oxide, separation, 377
  Ferrous-ferric oxide, 243
    corrosion products in NP primary circuits, 477
  Ferrous bicarbonate, 180, 181, 214, 512
    resulting from condensate corrosion, 289
  Ferrous carbonate, 512
  Ferrous chelolate, production during cleaning, 645
  Ferrous hydroxide, 433
    corrosion in steam/condensate lines, 513
    formation in corrosion cell, 286
    presence in strong alkaline conditions, 265
    in secondary galvanic corrosion process, 293
  Ferrous ions, production during cleaning, 640
  Ferrous metasilicate, 181, 212, 230
  Ferrous oxide, in boiler deposits, 634
  Ferrous sulfate, 315
    historical perspective, 390
  Ferrous sulfide, contaminant in steam-
    condensate systems, 291
  Ferrous transition process, 397
  Ferrous-ferric oxide, in boiler deposits, 634
  Ferrous-ferrite, 243
  Ferrous/ferric/Mo oxides complex, 397
  Fiberscope, 623, 631
  use in inspections, 619
  Film boiling, caused by oily surfaces, 298
  Film formers, for lay-up programs, 612
  Film forming corrosion inhibitors, for fuel
    oils, 686
  Film-forming emulsifiers, 545
  Filtration, application of, 540–543
  Filming amine and filming-neutralizing amine
    blend formulations, 543–544
  Filming amines, 510, 536–544
    application of filters, 540–543
    in cleaning processes, 647
    functional properties and mode of action
      of, 537–539
      mode of action, 537–539
      as primary support chemical, 389
      to reduce amine consumption, 533
      tendency to strip iron oxide deposits, 543
      types of, 539–540
  Filmwise condensation process, 536
  Filter media, 321, 322
  Filters
    activated carbon, 323–325
    air scouring, 323
    anthracite, 320
    backwashing using air scour, 321
    bag, 325–326
    bed depth, 321
    candle, 325
    cartridge, 325
    ceramic membrane, 325
    dual media, 322
    effective grain size, 321
    gravity, 320
    greensand, sizing and operation,
      327–328
    horizontal tank type, 321
    roughing, 322, 342
    triple media, 322
    inspection of, 615
    multimedia, 322–323
    naked, 325
    precoat, 325
    pressure media bed, 320
    sand, 320, 321–322
    vertical tank type, 321
  Filter-aids, 305, 325
    for cartridge filters, for condensate
      conditioning, 376
Filtration
  deoq-bed sand, 308
  historical perspective, 390
  of suspended solids, in condensate, 378
  Fin-tube convectors, 132
  Final feedwater blend, problems associated
    with, 206–215
Final feedwater blend, problems associated with (continued)
corrosion problems affecting pre-boiler section equipment, 209–211
deposition of scale and corrosion debris in pre-boiler sections, 211–215
inadequate feedwater deaeration, 206–209
Fines, of polymers, 320
Fire tube (shell) boilers, 29–39
development of PT boiler designs, 30–34
modern, packaged horizontal and vertical boilers, 34–39
Firebox boilers, 33, see also Boiler, firetube, firebox
basic pretreatment needs, 307
Fireside, basic problems, 670–678
Fireside cleaning, 649
of small FT boilers, 656–657
Fireside cold lay-up, 612
Fireside conditions and surfaces, control of, 669–693
basic fireside problems, 670–678
combustion gas analysis, 689–693
fuel treatment formulations, 687–689
fuel treatments/additives, 678–686
Fireside control, 669–693
Fireside hot lay-up, 611
Fireside problems, 670–678
cold-end zone problems, 675–677
combustion zone problems, 673–674
emission zone problems, 677–678
high-temperature zone problems, 674–675
preflame zone problems, 670–673
Fireside protection of idle boilers, 611–612
Firing rates, effect on turbines, 115
Fish mouth rupture, 260
Fissures, 259
Fixed water level, submerged electrode boilers, 28
Flaking, in FW heaters, 609
Flame impingement, cause and effect problem, 174
Flame misalignment, 617
Flame photometer, 9
for testing sodium, 603
Flameout, 81
Flash steam and heat recovery systems, 18, 20, 71, 94–97
Flash rusting, 649
Flashpoint of amines, 511
Flavon-3,4-diols, from condensed tannins, 406
Flavonoids, 406
Flaxseed oil, historical perspective, 393
Floc™ controllers, 332
Float FW regulator, 81
Float thermostatic steam traps, 92
Floc, 314
Floc size, of treated water, 320
Flocculants, 305
organic polymeric types, 316–320
Flocculation, 313
in boilers, 237
processes, 313–320
Flocculation improvers, 440
Flocon®, 100, 370
260, 371
Floergar, 318
Flow improvers, for fuels, 671
Flue gas damper (WT), 45
Flue gas exit stack, inspection for, 621
Flue gas management system, 72
Flue gases
analysis, 691–692
as combustant, 691
high dust-burden, 675
Fluid Systems, Inc., 361
Fluidized bed combustion boilers, 58, see also Boiler, fluidized bed combustion
Fluidized bed reactor, 679
Fluidite™ design, of resin bed, 352
Fluidtron Electronic fluid treatment systems, 339
Fluorescent tracer dye, 660
Fluorescent tracing systems, online, 662
Fluorometers, 662
Flushing stage, during cleaning, 625
Flux rate, of hollow fiber RO modules, 363
Fly ash, 85, 682
sulfated, 673
Foam breakers, 549
Foam control, as functional area requiring chemicals, 387
Foam stabilizers, 549
Foams, stable, 205, 300
Foaming, 115, 154, 155, 183, 200, 283–284, 548
mechanisms of control, 549–551
Fogging, 280, 284
Food Chemical Codex, 497
Food and Drug Administration, 484
Food, as process contaminants, 283
Force, 10
Forced draft fans, 85
Forced ouages, 612
Formaldehyde, 371
as RO membrane cleaner, 371
Formates, 498
Formic acid, in cleaning processes, 637, 638
Formulations, on-line cleaning, 627–629
Foulants, 140
cleaning in RO plants, 371
control, as functional area requiring chemicals, 387
controlling in MPH/W/HPW systems, 187
Fouling, 137, 140, 153–154, 203, 218
due to boiler sludging, 194
of conductivity electrodes, caused by oily surfaces, 299
Fouling and deposition, influence of in corrosion mechanisms, 152–153
Fouling inspection for, 621
Four pipe heating, system, 133
Fractures, 259
Fre-flo™ Water System, 340
Free-aromatic, 527
Free carbon dioxide, 102
Free caustic, 464
need for in caustic gaging, 249
presence of in corrosion processes, 468
Free caustic alkalinity, 226, 546
Free caustic programs, 389
Free-caustic regimen, 239
Free convection, 6
Free hydroxyl alkalinity, 464
Free potassium hydroxide alkalinity, 568
Free sodium hydroxide alkalinity, 568
Freeboard, of ion-exchange resin bed, 329
Freeze-point depressants, for fuels, 671
Freeze protection, 177
Frequency modulation devices, in nonchemical technology, 334
Frothing, 548
FSQLR, see Flash steam and heat recovery systems
FT boiler designs, development of, 30–34
cast iron sectional boilers, 33–34
firebox boilers, 33
horizontal return tubular boilers, 30
internally fired FT boilers, 30–32
Scotch marine boilers, 32–33
FT boilers, inspection of, 615–618
tube inspections, 617–618
waterside inspections, 615–617
Fuel-to-air ratio, 15
Fuel corrosion inhibitors, 683–684
Fuel filter plugging, 672
Fuel line plugging, 672
Fuel management system, 72
Fuel management system checks, 121
Fuel oil conditioners, 685–686
formation, 688
Fuel oil storage additives, 685
Fuel oils, 17
problems with, 671–673
Fuel preparation equipment, 72
Fuel treatment for lower grade solid fuels, 687
Fuel treatment formulations, 687–689
combined combustion improver, sludge dispersant, and fuel stabilizer, 688–689
fuel oil emulsion breaker, 689
fuel treatment for lower grade solid fuels, 687
liquid fuel oil conditioner/stabilizer, 688
liquid, oil-soluble combustion catalyst and slag modifier, 687–688
Fuel treatment programs, 669
Fuel treatments/additives, 678–686
acid neutralizers (fuel corrosion inhibitors), 683–684
clinker treatments, 683
combustion catalysts and improvers, 681–682
emulsion additives, 684
fuel oil conditioners and storage additives, 685–686
NOx emission control additives, 684–685
slag modifiers and deposit modifiers, 682–683
Fuels, combustion of, 690–691
Fugitive dust, in solid fuels, 671
Full-flow condensate polishing program, 476
Full-service and outsourcing programs, 127–129
Fulvic acids, 319, 568
contaminant in steam-condensate systems, 291
Functional attributes of all-polymer/all-organic chemistries, 442–443
Functional neutralizing amines, 521
Furfuraldehyde, in cleaning processes, 647
Furnace area catalyst, 681
Furnace heat flux, measurement, 623
Furnace heat release coefficients, 13
Furnace heat release rates, 12
Furnace, membrane (WT), 46
Furnace puff, 81
Furnace structural system (WT), 43
Furnace-wall generating tubes, inspection of, 619
Fusible plugs, 73
Fusion point, of slag, 682
FW contamination from returning condensate, 203–206
corrosion debris pickup, transport, and redeposition, 204
oil and process contamination, 204–206
oxygen loading, 203–204
transport of boiler water solids, 203
FW deaeration, 306
to reduce amine consumption, 533
FW pump turbines, 89
Gallic acid, 506
from tannins, 405
sodium salts, 405
Gallotannin, 208, 405
Galvanic, acid, and under-deposit corrosion, 180
Galvanic series, 150
Gamlen®, 679
Gamma-ferric oxide, 406
Gamma-hydrated ferric oxide, 648
Gamma iron oxide, 407
Gamma iron oxide/tannin complex, 406
Gamma rays, 62
Index

Gas burner combustion tester, 695
Gas burners, 84
Gas governor, 84
Gas measuring equipment, 693
Gas oil, 685
Gas scrubbers, 45, 54
Gas transfer membrane technology, for oxygen removal, 383
Gas turbines, 53, 679
Gas velocity, high, 617
Gaseous fuels, 673
Gases, influence of in corrosion mechanisms, 151
Gasification, 83
Gauge cocks, 73, 82
Gauge glass blowdown lines, 82
Gauge glasses
blowdown of, 75
flat, 230
see also Water column gauge glass
Gauge pressure, definition of, 2
G.E. Betz, 350, 371
General waterside corrosion, avoidance via coordinated phosphate, 464
Generally Recognized As Safe, 484
Generating tube bank, inspection of, 620
Generating tubes
inspection of, 619
see also Membrane wall tubes
Giant silica, 228
Glassy polysilicates, 398
Glassy scales, 228
Glaucite greensands, 326
Global warming, 43
Gluconate-ferrie ion complex, in cleaning processes, 640
Gluculates, 123, 444
as iron chelants, 406
as passivator, 649
Gluconic acid, 432
Glucose, 544
Glucose derivatives, historical perspective, 393
Glycerol, in RO cleaners, 372
Glycol, ethylene, 177
Glycol inhibitors, 402
Glycolic acid/formic acid mix, in cleaning processes, 640
Glycols
problems with use of, 177
propylene, 177
winterization with, 177
Goetheite, 233
Good-Rite®, K-752, 370, 446
K732, 446
K781, K797, K798, 447
Goofer balls, 537, 541
Granular activated carbon, 324
Graphite, 65
Graphite moderated fuels, 63
Graslikization, 259, 262
GRAS, see Generally Recognized As Safe
Grease, 381
in boiler deposits, 634
cleaning, 651
contamination from, 298–299
removers, 649
Great Lakes Chemical Corp., 370, 401, 441, 662
Green liquor, 58
Green vitriol, historical perspective, 390
Greenhouse gases, emissions of, 676
Greensands, 326
Grooving of horizontal tubes, condensate corrosion producing, 289
Gross heating values of fuels, 16
Ground fault arcing, 577
Guaniidine, nonvolatile derivatives, 505
Gulping, 281, 284
Gunk balls, 537, 541
caused by oily surfaces, 298
Gunking, 426
Gunnmetal, 210
Hagan® phosphate, historical perspective, 392
Hampene®, 150, 432
Hampshire Chemical, 432
Hard water, definition of, 217
Hardness, in raw water, 304
Hardness breakthrough, 196–197, 328
breakthrough into feedwater, 196–197
in lower pressure boilers, 660–661
Hardness conditioning, 306
Hardness destabilization, 398
Hardness precipitation and deposit control, 400
Hardness removal, by nonchemical treatments, 306
Hardness roughing treatment, 161
Hardness salt sources, 220–223
Hardness salts, 160
Hardness stabilization by phosphate action, 400
function of all-organics, 443
using phosphate, 419
Header
connecting (WT), 45
inspection of, 619
Header bottom, inspection of, 620
Headers (WT), 43
Health issues, of amines, 511
Hearth furnace, 324
Heat of dilution, in cleaning processes, 641
Heat energy, 1, 20
Heat exchangers, for LPHW/LP steam, 185
Heat flux, 6, 69, 665
Heat flux density, 219
Heat recovery boiler, see Boiler, water tube, heat recovery
Heat recovery calculation, 96–97
Heat release coefficients, 13–14
Heat-recovery boiler, see Boiler, waste heat
Heat recovery system, 75
Heat saturation temperature, 4
Heat sink, 4
Heat transfer coefficients, 13, 218
Heat transfer rate, per unit area, 6
Heaters, feedwater deaerating, 98–108
Heating coils
  flanged copper, 175
  problems with, 175–177
Heavy aromatic naphtha, for fuel oils, 686
Heavy-duty industrial cleaners, 649
Heavy fuel oils, 673
Heavy water, 65
HEDTA/citric mix, in cleaning processes, 638
Helium, in air, 689
Helmholtz double layer, 394
Hematec, 145, 146, 154, 168, 170, 233, 296, 663
  in boiler deposits, 633, 634
  hydrated passive film, 241
  as particulate oxide, 232
transport, 297
Henry’s Law, 102
Heterogeneous reactions, of hydrazine, 492
Hexadecylamine, 540
Hexafluorouracil ion, production during cleaning, 639
Hexahydric alcohol, 544
Hexamethylenediaminetetra (methylene phosphonic acid), 449
Hexasil, 422
Hexylamine, 518
Hideout, 235, 473, 588, 589
High-alkali fluid feeders, effect on amine feed, 521
High alumina porcelain insulators, 576
High ash fuels, 673
High concentrations of caustic/saltines, effect of, 468
High-firing cycle operations, 230
High iron levels, significance of in chelant program, 658–659
High-opacity stack gases, 677
High oxygen residuals, corrosion caused by, 243
High-pressure FW heaters, 100
High-pressure industrial boilers, treatment programs and control in, 661–665
  monitoring dissolved or entrained hydrogen in FW and steam as indicator of corrosion rates, 663–665
  monitoring iron oxide transport, 662–663
  monitoring via tracer and tagged polymer systems, 662
High-pressure steam systems, 37
High purity/quality FW process configurations, 343
High-purity steam generation, 60–61
  clean-steam generators, 60–61
  kitchen steam generators, 60
High quality/purity steam applications, water quality needs, 342
High silica levels in raw water makeup, 658
High sludge problems in lower pressure boilers, 657–658
High temperature corrosion, 259–262, 681
High-temperature zone, fireside, 669
High-temperature zone problems, 674–675
High water losses in HW heating and other closed-loop systems, 658–660
Higher pressure boiler waterside programs and controlled-pH program considerations, 465–469
Higher quality condensate, 304
Higher quality makeup water, 304
Higher quality, pre-boiler water treatment, definition, 147
HLB value
  in cleaning formulations, 651
  see also Hydrophilic-lipophilic balance of water-in-oil dispersants, 684
Hoechst Celanese, 383
Hold-down design, of resin beds, 351
Hollow fiber permeator, 363
Hollow fiber RO modules, 363
Homogeneous oxygen scavenging reaction, of hydrazine, 492
Homopolymeric carboxylates, 446
Homopolymers, 442
Horizontal return tubular boilers, 30
Hot alkaline wash, 625
Hot and cold lime-soda processes, 311
Hot-end acid corrosion/fouling, 680
Hot lime process, to limit silica, 294
Hot-time/softening processes, 327
Hot precipitator, 678
Hot-spot scaling, 141
Hot standby, of LP boilers, 607
Hot water generators, 49–50, 67
Hot water and steam system cycles, 132–134
Hot water heating and low-pressure steam boiler specifics, 173–189
  problems of corrosion in hot water and low-pressure steam heating systems, 178–180
  problems associated with use of glycols, 177
  other waterside problems, 180–185
  problems with heating coils, 175–177
  waterside problems in medium-temperature hot water and high-temperature hot water systems, 185–189
Hot water heating system cycle, 132–133
Hot water return tank, 109
HTHW/HPHW systems, 395
Humic acids, 319, 568
Humidifiers, with amines, 533
Hydraulants, Inc., 361
Hydrazine, 123, 168, 170, 305, 382, 395, 489–494, 521, 578
with AVT programs, 474
breakdown in steam-condensate systems, in cleaning processes, 638
control with AVT programs, 476
feed points, 491
feeding hydrazine, 491–492
HQ as catalyst for, 500
hydrazine reactions, 492–494
level in steam contacting food, 531
non-volatile derivatives, 505
in OT programs, 508
as oxygen scavengers, 483
as primary support chemical, 389
producing ammonia in condensate, 381
in steam-condensate systems, 292
using with condensate pre-coat filters, 379
Hydrazine hydrate, 489
Hydrazine replacements, 168
Hydrazine reactions, 492–494
Hydrazine sulfate, 489
Hydrocarbon contaminants, 237
Hydrocarbon removal, using multifunctional water conditioners, 332
Hydrocarbons, cleaning method, 651
Hydrochloric acid, 625
in cleaning processes, 638, 646
forming under pits, 250
Hydrochloric acid/bifluoride mix, in cleaning processes, 639
Hydrochloric acid regenerant, 349
Hydrochloric acid/stannous chloride, 640
Hydrochloric acid/thiourea mix, in cleaning processes, 643
Hydrofluoric acid, in cleaning processes, 639, 646
Hydroquinone, 499–501
Hydrogen, as combustant, 691
reaction producing water, 691
in steam-condensate systems, 291
testing in steam/condensate, 602
Hydrogen analyzers, 663
Hydrogen blanket, 152
Hydrogen bonding, 445
in water, 2
Hydrogen carryover, limit in steam, 291
Hydrogen cation exchange softening, with ED, 374
Hydrogen damage, 256–258, 466, 665
Hydrogen embrittlement, 256–258, 466, 588
Hydrogen in FW and steam, as indicator of corrosion, 663
Hydrogen in steam, limits, 665
Hydrogen peroxide, as RO membrane cleaner, 371
Hydrogen phosphate ion, 466
Hydrogen production
with boiler loading, 665
with general corrosion, 665
with localized corrosion, 665
Hydrogen sulfide
contaminant in steam-condensate systems, 291
control via multifunctional water conditioner, 332
evolution during cleaning, 646
removal, by zeolites, 327
in steam-condensate systems, 284–285
from sulfite, 486
Hydrogen/hydroxide cycle condensate polishers, 380
Hydrogenated tall oil/alkylamine acetate, 540
Hydrolysis, of phosphates, 400
Hydrolyzable tannins, 405, 444, 505
hydrolysis products off, 408
Hydrolyzed polyacrylamide polymers, 317
Hydrotrope
hydrolysis products off, 408
Hydroxylated alcohols, 477
Hydroxide alkalinity, 546
requirements with phosphate, 420
Hydroxide ion, presence in corrosion cell, 286
Hydroxyacetic acid, in cleaning processes, 640
Hydroxyacetic acid/formic acid mixture, 625
Hydroxyapatite, 145, 224, 235, 422, 423
in boiler deposits, 635
historical perspective, 392
in scales, 645
Hydroxyacetoxylic acids, 432
2-Hydroxyethylamine, 520
Hydroxyethylidiaminetriacetic acid, in cleaning processes, 637
1-Hydroxyethylidene-1,1-diphosphonic acid, 432, 449
in cleaning processes, 640
Hydroxyethyliminodiacetic acid, 434
Hydroxyl ions
- from free caustic program, 241
- localized over-concentration, 144
Hydroxyamine, 495
Hydroxyamine sulfate, 495
Hydroxylation, of fuels, 673
Hydroxymethyl benzene, 686
2-Hydroxytetraethylamine, 519
Hyfor Process, in cleaning processes, 640
Hygroscopic nature of dry polymer, 319
Hyperfiltration, 360
Hypoferite ions, 465
ICI PLC, 545, 552
ID fans, cleaning flue gas side of, 611
Ideal gas, 690
Ideal gas law, 7, 677
Idle boilers, fireside protection of, 611–612
Idle boilers (longer-term offline), protection of, 608–612
Ignition temperature, of fuels, 673
Ignitor, 82
Imidazole carboxylate, 686
Imidazole surfactant, in cleaning processes, 647
Imidodiacetic acid, 434
Inpulpment, 264, 300
Inpulpment problems, fireside, 617
Impulse stage turbines, 114
Impulse steam traps, 92
Inpurity concentration in reactor water, maximum, 382
Inadequate feedwater deaeration, 206–209
Inconel alloys, 266
800, 266, 477
Incongruent phosphate, effects on corrosion, 468
Indian mangrove, historical perspective, 392
Indirect steam generator, see Boiler, indirect
Induced draft fans, 85–86
Industrial processes, contamination from, 299–300
Industrial WT boilers, 49–52
hot water generators, 49–50
water tube steam generators, 50–52
Infrared thermometry, 623
Inhibitor levels, maintaining in LP boilers, 182
Inhibitors
- acid cleaning, 254, 647
  Ammonia® types, 648
  general adsorption types, 647
  nitrogen types, 647
  Rodine® types, 648
  sulfur types, 647
  anodic types, 647
  for cleaning solvents, 647–648
  for HF/mineral acid mixes, 648
Inhibitors (continued)
  for hydrochloric acid, 648
  for organic or powdered acids, 648
  for SCC, 256
Initial-fill dose of chemical inhibitor, 123
Inorganic coagulants, 314–316
historical perspective, 390
Inorganic oxidizing cleaners, 643
in cleaning processes, 642
Inorganic process contaminants, 283
Inorganic salts and organics, deposits from,
  233–237
Inspecting boiler pretreatment plants, 615
Inspecting steam and condensate equipment, 621
Inspection
  additional notes, 621
  of boilers, 612–623
  FT boiler fireside, 617–618
  FT boiler waterside, 615–617
  pretreatment equipment, 615
  scope of work, 614–615
  WT boiler waterside, 618–621
  WT fireside, 620–621
Inspection attendant, 614
Inspection process, informal, 613
Inspection notes, 621–623
Inspection safety, 614
Inspection work, scope of, 614–615
Instruments and control systems checks,
  121–122
Inspector
  authorized or regulatory, 612
  informal, 612
  plant, 612
Interfacial tension, 539
Intergranular creep cracking, 260
Interlock systems function checks, 121
Intermediate flow, 6
Internal energy, 2
Internal softening, 657
Internal softening reaction, 289
Internal treatment chemicals, as polishers, 385
Internal treatment control and programs, outline of, 386–393
historical perspective of external and internal treatments, 389–393
types of internal treatment program, 387–389
Internal treatment programs, 305, 385–478
all-polymer/all-organic programs, 437–461
all-volatile treatment program chemistries, 474–476
anodic inhibitor chemistries, 394–403
chelant-, phosphate-, or polymer-based
combination programs, 461–463
chelant program chemistries, 430–437
coupling and precipitation program chemistries, 411–430
Index

Internal treatment programs (continued)
coordinated phosphate and program
derivations, 464–474
development of, 3
mixed treatment and zero solids treatment,
476
nuclear powered steam generators, water
treatment for, 477–478
outline of internal treatment control and
programs, 386–393
tannin programs, 403–410
types of, 387–389
Internal treatments
caucho, 31
historical perspective, 389–394
lignin, 31
meaning of, 139
phosphate, 31
soda ash, 31
starch, 31
wattle tannin, 31
Internally fired FT boilers, 30–32
Interplast S.A., 679
Inverse-temperature solubility, 145
problems, 234
Inverted-bucket steam traps, 92
lodine number, 324
mixed bed demineralization, 51
twin bed demineralization, 51
Ion-exchange basics, 347–351
Ion-exchange, demineralization, continuously
regenerating type, 353
Ion exchange plant, inspection of, 615
Ion-exchange resin bead polymer
composition, 347
Ion-exchange resin bead structures, 347
Ion-exchange resin bead
anion, 347
cation, 347
double compartment design, 352
layered design, 352
mixed design, 352
multiple bed design, 352
sandwich design, 352
single compartment design, 352
stratified, 331
stratified design, 352
Ion-exchange resin cleaning, 349
Ion-exchange resins, 326–331
absorption, 330
crystalline, 347
anion, 347
anion ion-exchange, 327
bed expansion, 329
carboxylic acid, 327
cation, 327, 347
cross-linking, 327, 347
Ion-exchange resins (continued)
exhaustion of, 328
freeboard, 351
gel type, 327, 347
generic categories, 347
hydrogen form, 327
inert, 353
inspection for cracked and broken beads,
615
iron fouling, 615
iron fouling problems, 328
isoporous, 330
loss of capacity, 615
macroporous, 327, 330
macroporous type, 347
macrotire, 327, 330
quaternary ammonium, 327
sodium form, 327
strong acid cation, 327, 347, 348
strong base anion, 330, 347, 349
strong/weak acid, 327
strong/weak base, 327
sulfonated polystyrene, 327
type 1, 349
type 2, 349
weak acid cation, 347, 348
weak base anion, 331, 347, 349
special grades, 344
Ion-exchange softeners, for MPH/HPHW
systems, 186
Ion-exchange softening, 308
for RO pretreatment, 367
Ion-exchange, softening by, 328–330
Ion-exchange system design bases, 351–359
Ion-exchange systems, practical functions,
353–359
Ion-selective electrodes for sodium analysis,
198
IOnics, 375
Iron, 221, 306, 412
as adventitious catalyst, 485
carryover, 276
as combustion catalyst, 681
contaminant in steam purity, 603
corrosion via multifunctional water
conditioner, 332
as erythorbate catalyst, 497
in fuel additives, 679
in higher quality water, 305
in raw water, 304
soluble, 212
testing in steam/condensate, 602
understanding significance with chelant
program, 658–659
Iron and manganese removal using
greensands, 327–328
Iron and silica transport polymers, 468
Iron carbide, 257, 262
Iron chelants, 406, 445
Iron contamination removal, in condensate, 377
Iron control terpolymer, for RO pretreatment, 371
Iron control
  as functional area requiring chemicals, 387
  with AVT programs, 475
Iron deposits, feeding, 213
Iron dispersants, use of in MPHW/HPHW systems, 187
Iron dispersion, as adjuvant requirement, 389
Iron fouling of softener, 197
Iron metaphosphate, 400
Iron oxide and other corrosion debris deposition, 231–233
Iron oxide transport, monitoring of, 662–663
Iron oxides, 633–634
  black, 287
  in boiler deposits, 634
  in condensate, 231, 232
  corrosion debris, 297
  in corrosion debris, 296
  corrosion products in NP primary circuits, 477
  gamma, 172
  hydrated passive film, 241
  magnetic, passive film, 241
  particulate, 171
  transport, 297
  removal with cleaning solution, 625
Iron particulates, contamination in WT boilers, 605
Iron pick up, with hydrazine, 492
Iron removal
  by zeolites, 327–328
  via aeration, 309
  via polymer-assisted flocculation, 308
Iron salts, in water supplies, 231
Iron silicate scales, 230
Iron silicates, 298
Iron in steam boilers, recommendations for maximum total, 563
Iron tallate, in fuel additives, 680
Iron tannate complex, 445
Iron tannate film, 407
Iron tannate-magnete film, 208
Iron tannates, 171, 406
Iron transport, 168, 212, 388, 440
  as adjuvants requirement, 389
Iron$$^{39}$$, 268
Isep$$^{	ext{®}}$$, resin bed design, 353
L-ascorbic acid, 394, 497–499
  thermal decomposition limits, 591
Isobutanolamine, 518, 523
Isobutanolamine carbonate, 523
Isobutylenes, 446
Isokinetic multipor nozzle, 601
Isopropyl alcohol, 686
Isothiazolinones, 404
  as biocides for fuel oils, 686
  as RO membrane cleaner, 372
IX resins, basics of, 347–351
IX system designs, basics of, 351–353
IX systems, practical functions of, 353–359
demineralization processes, 353–357
desilication processes, 357–358
Jar testing, 319
Jet-type electrode boilers, 546
Jetting boilers, 624
Johnson March Systems, Inc., 661
Kathon$$^{	ext{®}}$$, 404
Kelip$$^{	ext{®}}$$ 100, 445
Kerosine, in cleaning processes, 637
Ketones, 500
Kinetic energy, 10
King Lee, 371
Kitchen steam generators, 60
Kraft lignins, 445
Kraft pulping process, 57, 445
Krypton, in air, 689
Kurita Water Industries Ltd., 504
Lack of softening or dealkalization capability, 193–196
Lancashire boiler, see Boiler, fire tube, Lancashire
Lancashire boiler compound, 393
Large steam turbine generators, 113–114
Larson–Laine steam analyzers, 278, 603
L-ascorbic acid, 497–499
Latent heat, 97
Latent heat of vaporization, 4, 7
Law, Henry’s, 515
Lay-up
  boiler, 120
  of boilers, 606
    dry, 91, 246
    fireside, 611
    using phosphate, 419
Lead and lag boiler operation, 184–185
Lewis base, 524
Ligand, 431
Light water, 283, 551
Lignin sulfonates, 433
Lignin/tannic acid polymer test, 409
Lignins, 30, 403, 438, 443, 445
  as adjuvants, 386
  as decharacterizer, 485
  historical perspective, 392
Lignites, 17, 670
  fuel treatment formulation, 687
Lignosulfonates, 237, 283, 404, 433, 438
Lime, as a softening agent, 311
Magnesium (continued)
   as a softening agent, 312
   as slag modifier, 682
   Magnesium aluminate, 411
      historical perspective, 391
   Magnesium anodes, 167
   Magnesium-based additives
      as slag modifier, 682
      as fuel additives, 675
   Magnesium-based treatments, to neutralize
      acid vapor, 612
   Magnesium and calcium salts, control over
      deposition of, 224–227
   Magnesium carbonate, in scales, 646
   Magnesium chloride, in boiler water, 234
   Magnesium fluoride, production during
      cleaning, 639
   Magnesium hydroxide, 145, 224, 228, 423,
      472, 658
      in fuel additives, 680
      in scales, 645, 646
   Magnesium hydroxyphosphate, in boiler
      deposits, 634
   Magnesium orthodisilicate, 224
      hydrated, 214
   Magnesium oxide, in fuel additives, 680
   Magnesium phosphate, 154, 212, 423, 472
      basic, 235
   Magnesium silicate, 214, 224, 228
      in scales, 646
      sludge, 412
   Magnesium sulfate, in fuel additives, 680
   Magnetic devices, 167, 333–341
   Magnetic particle separators, 138
   Magnesite, 146, 153, 170, 227, 233, 406, 407,
      631, 663
      blisters, 259
      in boiler deposits, 633, 634
      coarse, 243, 257
      coarse black, 91
      crystalline, 298
      formation in corrosion reaction, 286
      needles, 251
      as particulate oxide, 232
      removal during cleaning, 640
   Magnesite film, need for passive, 241
   Magnesite-passivation effect, of sulfite, 486
   Main (primary or bottom) blowdown
      arrangement, 75–76
   Main blowdown valve, see Valve, blowdown
   Main condenser, see Condenser, main
   Maintaining inhibitor levels and controlling
      blowdown and surging, 162–184
   Makeup water, 70
      pretreatment system, 45
   Malachite, 212, 232
   Maleates, 438, 442, 443, 450
   Maleic anhydride, 443, 450
   Malodors, in fuels, 671

Macroporous resins, in bead resin deep-bed
polishers, 380
Magnafloc™, 318
Magnesium, 221, 634
   in boiler deposits, 634
   in fuel additives, 679

Lime/cement kiln, 679
Lime-soda softening process, 161, 311
Limestone, dissolution of, 310
Limiting deposition, 456
Linear kinetic cell, nonchemical technology, 339
Linear polyols, 552
Linseed oil, as adjunct, 389
Liqui-Cel®, 383
Liquid face velocity rates, in organic traps, 324
Liquid fuel oil conditioner/stabilizer, 688
Liquid, oil-soluble combustion catalyst and
   slag modifier, 687–688
Lithium hydroxide, 65
Live plant startup, 120
Localized acidic concentration
   DNB effect, 253
   process contaminant effect, 253
   shielding deposits effect, 253
   waterline evaporation effect, 253
   localized corrosion, 245–246
      historical perspective, 393
   Lockout/tagout procedures, 614, 657
   Long-chain cationic surfactants, filmers as, 536
   Long-term overheating, 157, 259–260, 466
   Lonza S.A., 540
   Loss on ignition, in boiler deposits, 635
   Low-alloy steel boiler tubes, corrosion of, 141
   Low ash fuels, 673
   Low heat-transfer rates, 147
   Low-to-high fire rates, 16
   Low-level alarm point, sampling from, 605
   Low-load conditions, 21
   Low NOx burners, 684
   Low pH corrosion, 251–254
      acid cleaning corrosion, 254
      general corrosion, 251–252
      localized corrosion, 252–254
   Low-pressure FW heaters, 100
   Low-pressure steam systems, 36
   Low-temperature corrosion, 681
   Lower water-wall headers, 74
   LP steam systems, 394
   LPHW heating systems, inhibitor
      requirements, 396
   /Threonic acid, 498
   LTHW/LPHW systems, 394
   Lumenside, of membrane contactors, 383
   Lysing, of water molecules, in ED technology, 374

Index
Boiler Water Treatment: Principles and Practice

Managing standby and idle boilers, 606–612
fire-side protection of idle boilers, 611–612
protection of standby boilers (long-term off-line), 608–612
protection of standby boilers (short-term off-line), 606–608
Manganese, 54, 214, 221, 268, 306
as combustion catalyst, 681
control via multifunctional water conditioner, 332
in fuel additives, 679, 680
Manganese chloride, in clinker treatments, 683
Manganese fouling of softener, 197
Manganese greensand, 526
Manganese removal, via aeration, 309
Manganese salts, in water supplies, 231
Manganese oxide, in fuel additives, 680
Mannich polymers, 317
Manoxol OT, 543
Marcel® XE, 445
Maraxperse®, 445
Marite, 469
Marine boilers, 55–56
Mass balance profiles, for amines, 535
Mass burning fuel, 59
Materials balance, assessment, 181
Maximum allowable working pressure, 191
Maximum continuous rating, 12, 95, 165
Maximum permissible temperature of tube alloys, measurement, 623
Mayonnaise emulsions, as process contaminants, 283
Mayoquest® (120-1500-2100, 449
-1635-1860, 450
-3000, 451
McCoy Chemical Treatment of Boiler Water 1984, 560
Mcdermott-Canning, Inc., 679
MCR, 12
Mechanical cleaning, 623
Mechanical deaeration, 98
Mechanical work, 20
Media filtration, 306, 307
Medium hardness water, definition, 217
Mekor®, 501
Membrane capacity rating, 365
Membrane contactors, 383
Membrane distillation, 360
Membrane purification technologies, 305, 307, 359–376
Membrane softeners, 360
Membrane wall tubes (WT), 42, 43, 45, 46
Metal acrylate deposition, 446
Metal aluminates, spinels as, 642
Metal burning, 261
Metal damage, of pre-boiler system, 203
Metal failure, thermally induced, 254
Metal ferrates, spinels as, 642
Metal oxide powder, in fuel additives, 680
Metal passivation benefit of tannins, 404, 408
Metal scaling, 261
Metal-scan techniques, 622
Metal surface cleaner, function of all-organics, 443
Metal surface cleaning, by phosphate action, 400
Metal transport polymers, 485
Metal wastage, 55, 136, 140
Metals in FW, weighted mean content limits, 586, 592
Metasilicates, 398
Methacrylamide, 446
Methacrylic acid, 446
Methane, reaction producing carbon dioxide and water, 691
Methanoic acid, in cleaning processes, 638
3-Methoxy, N-propylamine, 520
3-Methoxypropylamine, 521
Methoxypropylamine, 500
Methyl orange alkalinity, 546
Methylthylketoxime (MEKO), 501–502
with AVT programs, 475
2-Methylpropenoic acid, 446
Microanodes, 149
Microbiocide, for fuel oils, 671
Microbiological biofilms, in fuel oils, 672
Microbiologically induced corrosion, in fuel systems, 686
Microcathodes, 149
Microdroplets of boiler water, 284
Microfiltration, 359
Microorganisms, in fuels, 671
Microporous polypropylene hollow fiber gas transfer membranes, 383
Mill scale
in boiler deposits, 634
removal, from boiler, 625
transport, 605
Milliequivalents per liter, 347
Millipore membrane filter, 663
Mineral acidity, removal, 356
Minimal reserve alkalinity, 472
Mist flow, 6
Misting, 155, 280, 284
Misting control, as functional area requiring chemicals, 387
Mixed bed, design of resin bed, 353
Mixed treatment and zero solids treatment, 476, 478
Mixing, of dry polymer, 320
Moderator, 477
water as, 62
Modulation mechanisms, for FW supply, 280
Modulation, of output, 35
Moisture absorbents, 610
Molecular hydrogen, 257
Molecular orientation, of amines, 538
Molecular sieves, 326
Molybdate/nitrite formulation, 403
programs, 398
Molybdate/silicate programs, 398
Molybdates, 183, 394, 397–398
as anodic inhibitors, 388
Monel 400, 266
protection in cleaning processes, 639
Monitoring via tracer and tagged polymer systems, 662
Monoaliphatic tertiary amines, 540
Monoamines, 537, 542
Monoammonium amides, 505
Monoammonium citrate, in cleaning processes, 637, 644
Monoatomic adsorbed hydrogen, 150
Monobed design, of resin bed, 352
Monoethanolamine, 500, 520
Monomers, 440
Monosodium phosphate, historical perspective, 392
Monsanto Chemical Company, 519
Morlex® DEEA, 519
Morpholine, 381, 498, 518, 520, 521
in ammonia anion cycle, 378
with AVT programs, 475
level in steam contacting food, 531
neutralization reactions, 515
as primary support chemical, 389
MTHW/MPHW systems, 395
MU water pretreatment, 306
Mud drum, 41
inspection of, 619
Mudcoves, 124
Multiblend formulations, 555–558
Multifunctional water conditioners, 331–332
Multimedia filters, 322–323
for RO pretreatment, 368
Multisport valve, 601
Municipal solid waste, as fuel, 51
Municipal waste incinerator, 679
Muratic acid, 629
in cleaning processes, 638
Myrobalan tannins, 405
Naked MB condensate polishers, 380
Nanocrystal formation, with nonchemical technology, 334, 340
Nanofiltration, 360
Naphtha in cleaning formulations, 651
in cleaning processes, 637, 649
Naphthenic-based fuels, 672
National Sanitary Foundation, see NSF International
National Starch, 455
Natriolite, 229
Natural circulation, 6
Natural tannins, 388
Natural uranium fuels, 63
Natural zeolite treatments, 306
historical perspective, 390
Navy boiler compound, 395
Necking down of vertical tubes, condensate corrosion producing, 289
Negative ion exchange, 326
Negative ions, 347
Neon, in air, 689
Nepheline, 229
Nephelometric turbidity units, 322
Net positive suction head, 88
Net thermal efficiency, 54
Neutral phosphates, 421
Neutralization capacity, 521–523, 535
of amines, 511
Neutralization pH, of amines, 522
Neutralization/passivation, during cleaning, 625
Neutralizer/finisher amine blend formulations, 543–544
Neutralizing acid washes, 653
Neutralizing amine summary notes, 534–536
Neutralizing amines, functional properties of, 521–539
basicity, 523–526
neutralization capacity, 521–523
types of, 517–521
volatility, relative volatility, and distribution ratio or partition coefficient, 526–530
Neutralizing capacity, 521
Neutron particle bombardment, 61
New boiler work, 123
NexGuard®, 662
N-hydroxyethylaminetriacetic acid, 432
Nickel, 210, 634
in fuels, 673
in higher quality water, 305
Nickel compounds in fuel, 674
Nickel oxides, 146
in boiler deposits, 634
in corrosion debris, 296
corrosion products in NP primary circuits, 477
transport of in condensate, 231, 232
Nickel sequioxide, in boiler deposits, 634
Nickel transport, 212
Nickelcide oxide, in boiler deposits, 634
Nickelous oxide, in boiler deposits, 634
NIPA Laboratories, 404
Nipacide®, 404
Nitrate, 217
in steam-condensate systems, 292
Nitric acid, 171
in cleaning processes, 641
Nitric acid regenerant, 349
Nitritotriacetic acid, 262, 432, 448
Nitrite-based inhibitors, 151
to stifle anodic reaction, 241
Nitritoborate/TTA formulation, 396
Nitrite chemistries, as anodic inhibitors, 388
Nitrite/molybdate programs, 396
Nitritesilicate formulation, 403
Nitrites, 209, 394, 395–397
as anodic inhibitor, 395
as passivator, 395
in steam-condensate systems, 292
*Nitrobrocher agilis*, 395
Nitrogen
in air, 689
in steam-condensate systems, 284
Nitrogen blanket, for out-of-service deaerator, 107
Nitrogen blanketing, 608
Nitrogen dioxide, evolution of, 641
Nitrogen oxides, 16
Nitrogen pressurization, 608
*N,N*-diaminomaleic, 502
*N,N*-diethyllethanamine, 519
*N,N*-diethylhydroxylamine, 494–497, 519
*N,N*-dimethylethanolamine, 519
Non-acid phosphate programs, 473, 464, 473
Non-amine-based condensate treatments, 544–545
Noncarbonate hardness, 311
Noncatalytic reduction processes, 684
Nonchemical treatments (magnetic, electrostatic, and similar devices), 333–341
examples of nonchemical technologies for scale and hardness control, 338–341
review of nonchemical treatment technology, 334–338
Noncombustible deposits, in furnaces, 683
Noncombustible residuals, of fuels, 670
Noncondensable gases, 92, 151
in higher quality water, 304
Nondestructive testing (NDT), 622–623
Non-fired steam generator, see Boiler, indirect
Nonfoaming surfactants, 123
Nonhydrolyzable tannin polymer functional groups, 407
Nonhydrolyzable tannins, 406, 445
Nonionic block copolymers, 552
Nonionic functional groups, of all-organics, 442
Nonionic polyelectrolytes, 316
Nonionic surfactants, 545
Nonvolatile alkalis, 589
Nonwettable boiler surfaces, 206
Normal operating water level, 80
Noselite, 229
Novel pretreatment oxygen removal technologies, 382–383

**Novel pretreatment oxygen removal technologies (continued)**

- oxygen removal using catalyzed carbon bed technology, 382–383
- oxygen removal using gas transfer membrane (GTM) technology, 383

Noveon, Inc., 370
NO, emission control additives, 684–685
NO, gases, emissions of, 676
NSF International, 60, 318, 484
NTA, see Nitritotriacetic acid
*N*-tallow-1,3-diaminopropane, 540
Nuclear fission process, 61
Nuclear fuel control rod system, 65
Nuclear grade anion exchange, 477
Nuclear plant, materials selection, 266
Nuclear plant steam generator materials selection, 266
Nuclear power reactors, 62–63
containment system, 65
coolant primary circulation system, 62, 63, 65
heat-sink, 65
integrated control system, 65
pressurizer, 65
primary-coolant pumps, 66
steam generator, 65, 66
vertical recirculating, inverted U-tube, 66
vessel, 63
Nuclear powered steam generators
corrosion in, 265–267
water treatment for, 477–478
treatment of primary circuit coolant water, 477–478
treatment of secondary circuit working fluid, 478
Nuclear reactor boilers, 61–66
see also Boiler, nuclear reactor
nuclear steam supply system, 63–65
principles of nuclear reactor boiler plant operation, 65–66
straight tube NO steam generator, 66
vertical recirculating inverted U-tube NP steam generator, 66

Nucleate boiling region, 6
Nucleation of microcrystals, 224

Nuclides
artificial, 62
naturally occurring, 62

*o*-Diaminohydroxybenzene, 500
O-type WT boiler design, 50
Oak tannin, 405
Occupational Safety and Health Administration, 484
Octadecylamine, 536, 537, 540
as primary support chemical, 389
for wet lay-up, 609
level in steam contacting food, 531
Index

Octadecylamine acetate, 540
Octadecylamine carbonate, 540
ODA, 540, see also Octadecylamine
Odor removal, using multifunctional water conditioners, 332
Odorless kerosene, in cleaning processes, 649
Odors, objectionable, 300
Off-line cleaning basics, 629–630
Off-line, safety, and other appurtenance valve checks, 124
Oil balls, caused by oily surfaces, 298
Oil/hydrocarbon contamination, 204
Oil preheaters, inspection of, 620
Oil and process contamination, 204–206, 298–301
from industrial processes, 299–300
from oils, fats, and greases, 298–299
Oil removers, 649
Oil-soluble emulsifier, PEG as, 553
Oil-soluble surfactant, in cleaning formulations, 651
Oils, 237, 381
in boiler deposits, 634
as contaminant, 154
cleaning, 651
contamination in WT boilers, 605
contamination from, 298–299
as deposit binder, 154
separation of by membrane technology, 360
Oily/rusty surfaces, cleaning method, 651
Oily sludges, 672
Oily surfaces, 298
cleaning method, 651
Oleophilic resins, 381
Olin Mathieson Corporation, 489
On-line cleaning, 625
basics of, 626–627
need for, 617
On-line cleaning formulations, 627–629
Once-through boiler, 53
ONDIEC Degréumont, 352
ONDIEC Nalco, 455, 497, 502, 544, 662
One-drum product programs, 555
One-stop shop services, 128
Opacity, 681
of stack gases, 677
Open and dry lay-up programs, 610
Open feedwater heaters, 100–108
atomizing deaerators, 104
exchange packing deaerators, 103
pressure deaerator troubleshooting, 104–108
spray deaerators, 103
tray (haffle) deaerators, 103
vacuum deaerators, 108
Open FW heaters, 100
Operational control of waterside surfaces, 599–667
boiler cleaning, 623–657
boiler inspections, 612–623
managing standby and idle boilers, 606–612
sampling and testing steam and condensate, 599–605
troubleshooting notes, 657–667
Optical fiber camera, 623
Optidose, 441, 662
Order of chelation, 433
Organic acids, in cleaning processes, 637
Organic chemical treatment, overdosing, 219
Organic flocculants, historical perspective, 390
Organic fouling of feedwater, 200–201
Organic matter, 200
Organic phosphates, 448
Organic polymeric coagulants and flocculants, 316–320
Organic process contaminants, 283
Organic scavengers, 330–331
Organic soils, causing foaming, 549
Organic-solute process contaminants, 550
Organic surfactants, in cleaning formulations, 649
Organic traps, 200, 324, 330–331
by ion-exchange, 346
Organics, 306, 634–635
in boiler deposits, 634
cleaning process, 637
cleaning in RO plants, 371
in raw water, 304
Organopolysiloxane, 552
Orifice plate, inspection of, 621
Oxidation apparatus, 691
Oxidant gas analysis, 406
Orthophosphates, 400, 419, 420, 424, 466
Orthophosphoric acid, 420
Orthosilicates, 398
Osmonics, Inc., 361, 375
Osmotic pressure, 363
Osmotic shock, to ion-exchange resin, 327
OT, see Oxygenated treatment
Outages, planned for cleaning, 625
Outer-core radiation field, 267
Outsourced water services, 305
Outsourcing
labor, 128
makeup water, 70
programs, 127–129
services, 115, 132
utilities, 128
Overfeed stokers, 84
Overheating effects and high-temperature corrosion, 240, 259–262
decarburization, 262
graphitization, 262
high-temperature corrosion, 261
long-term, 238, 258, 259–260
managing, 625
metal burning and metal scaling, 261
Overheating effects and high temperature corrosion (continued)
short-term, 238, 259, 260–261
signs of, 618
spheroidization, 261–262
thermal oxidation, 261
Overlay product, chelants as, 434
Overlays, polymers as, 454
OWGW Guidelines, 340
Oxalates, 498
Oxalic acid, 498
in cleaning processes, 638
Oxidation, 149
to remove iron, 309–310
Oxidation potential, 149
Oxides
as combustion catalyst, 681
as slag modifier, 682
Oximes, 501
Oxyanion, 495
Oxygen, 102
in air, 689
as a cathodic depolarizer, 152
in condensate with hydrazine, 492
control of, 168–169
as corrosion inhibitor, 238
from makeup water, 178
as a pre-boiler corrodant, 151
in steam-condensate systems, 284, 285–297
Oxygen control, 586, 590
as functional area requiring chemicals, 387
Oxygen corrosion, 178–180
cause and effect problem, 174
of economizers, 87
Oxygen damage, inspection of, 616
Oxygen infiltration, 285–288
from operating practices, 287
Oxygen-influenced boiler corrosion problems, 242–248
boiler section oxygen corrosion, 243–245
coarse magnetite corrosion, 242–243
concentrated cell corrosion, 246–248
general etch oxygen corrosion, 245
general wastage corrosion, 245
localized corrosion, 245–246
uniform rate corrosion, 245
Oxygen in-leakage, 178, 503
Oxygen loading, 203–204
Oxygen pitting corrosion, in fuel systems, 686
Oxygen removal
using catalyzed carbon bed technology, 382–383
using gas transfer membrane (GTM) technology, 383
Oxygen removal, DA claims and performance, 481
Oxygen removal technologies, novel types, 382–383
Oxygen scavenger chemistries, 479–506
aminoguanidines, 505
L-aminopyrimidines, 504
carboxyhydratide, 502–504
diethyldihydroxyamine, 494–497
dihydroxyacetone, 505
ezthoracic acid and sodium erythorbate, 497–499
hydroquinone, 499–501
hydrdazine, 489–494
methylhydroxyketoamine, 501–502
sodium bisulfite, 487–488
sodium metabisulfite, 488–489
sodium sulfite, 483–487
tannins, 505–506
tetrazines, 505
Oxygen scavengers, 102, 178
as adjuncts, 479
for lay-up programs, 607
as primary support chemical, 389
as program primary support chemicals, 385
as reducing agents and passivates, 482
tannin as, 404
from tannins, 406
use of novel chemistry organics, 168
Oxygen scavenging
as functional area requiring chemicals, 387
via tannins, 388
Oxygen scavenging capability, 179
Oxygen solubility, 481
Oxynated treatment (OT), 168, 480, 506–510, 586, 590
Oyster shell, as fuel additive, 678
PAC/DADMAC polymers, 318
PAC/EPIDMA polymers, 318
Packaged, horizontal FT boilers, 35–37
Packaged vertical boilers, 38–39
Packed-bed design, of resin bed, 352
Paraffin crystal modifier, 685
Paraffin crystalline waxes, 672
Paraffin waxes, in fuel oils, 672
Paraffinic-based fuels, 672
Parke Amchem/Henkel Group, 648
Partial pressure of atmospheric gases, 102
Partial pressure, of carbon dioxide in steam, 515
Particle fluidization, 424
Particle size, of solid fuels, 670
Particulate adsorption, function of all-organics, 442
Particulate sludge dispersants, for fuel oils, 686
Partition coefficient, of amines, 511, 526–530
Passivated film, thickness of, 648
Passivated layer, corrosion problems when imperfect, 244
Passivated surface, inability to form, 240
Passivating control, via tannins, 388
Index

Passivation, 169, 170–172
  of boiler surfaces, 241–242
    function of all-organics, 443
      with hydrazine, 493
        by phosphate action, 400
          using phosphate, 419
    Passivation enhancement process, of HQ, 500
  Passivation and common corrosion problems, 237–254
    boiler surface passivation, 241–242
      low pH corrosion, 251–254
        other forms of concentration cell corrosion, 248–250
          oxygen-influenced boiler corrosion problems, 242–248
  Passivation of new boilers, 123
  Passivators for cleaning solvents, 648–649
  Passive film, of iron oxide, 227
  Passive oxide film, 170
  Passivity, 241
  p-Benzquinone, 499
  PCA16, 452
  p-Dihydroxy benzene, 499–501
  Peaking steam generators, 465
  Pearl River Products, 318
  Pearlite, 261
  Peat, 17
  Peat moss, fuel treatment formulation, 687
  PEG-6 diesterate, 454
  PEG-8 oleate, 454
  Penicillium glaucum, 404
  Penetrants, in cleaning formulations, 650
  Pennad, 150®, 519
  Penastop®, 494
  Penastop® 85%, 519
  Peracetic acid, as RO membrane cleaner, 371
  Perborate, in cleaning processes, 644
  PercolTM, 318
  Periodic chemical cleaning, 122–123
  Permanent hardness, 223, 311
  Permanent noncarbonate hardness, 312
  Permanganate reduction test, 409
  Permeable membrane, in electrodialysis, 373
  Permeators, 363
  Permutit, 353
  Pesticides, removal by carbon filters, 323
  Petroleum coke, 237
    as fuel, 51
  Petroleum products, removal by carbon filters, 323
  Petroleum spirit, in cleaning processes, 637, 649
  PF, 42
  Pfeiz, sodium erythorbate FCC, 497
  pH
    fluctuating, 300
    testing in steam-condensate, 602
  pH alkaliinity control, as functional area requiring chemicals, 387
  pH buffering-type programs, 464
  pH control, with AVT programs, 475
  pH of feedwater, out of balance, 203
  pH of treated water, 198
  Phenolic formaldehyde demulsifiers, 381
  Phenolic molecules, as tannins, 404
  Phenol intimization, in cleaning processes, 647
  Phenylethylene, 443
  Phosphate anodic/cathodic inhibitors, 399–400
  Phosphate-based combination programs, 460–464
  Phosphate-based multifunctional programs, 388
  Phosphate-chelant program, 419, 424
  Phosphate conditioning, 384
  Phosphate-cycle, 413
  Phosphate-cycle benefits and formulations, 427–430
  Phosphate-cycle boiler programs, 419–430
    phosphate-cycle benefits and formulations, 427–430
    phosphate-cycle reactions, 422–425
    phosphate-cycle requirement calculations, 425–427
    phosphate product selection, 419–422
  Phosphate deposits, 202
    cleaning in RO plants, 371
  Phosphate ester bond, 448
  Phosphate feed point, 424
  Phosphate feed-rate requirement, 426
  Phosphate feedline deposits, 212
  Phosphate hideout, 468, 471
  Phosphate hideout point, 427
  Phosphate/nitrile mix, as passivator, 649
  Phosphate overlay programs, 458
  Phosphate/polymer-based multifunctional formulation, 460–464
  Phosphate-polymer programs, 419, 430
  Phosphate precipitant, requirement to remove calcium, 412
  Phosphate precipitation programs, 154, 400
  Phosphate product selection, 419–422
  Phosphate programs
    congruent, to prevent free hydroxyl ion, 240
    coordinated, 250, 256
      to prevent free hydroxyl ion, 240
      equilibrium to prevent free hydroxyl ion, 240
      simple, 430
    for wet lay-up, 609
  Phosphate reversion, 400
  Phosphate scaling, 238
  Phosphate sludge, 226
  Phosphate-sludge conditioner, 424
  Phosphate treatment programs, 54
  Phosphate wastage, 468
  Phosphates, 30, 123, 217, 219, 395, 411, 438, 635
Phosphates (continued)
in boiler deposits, 635
in cleaning formulations, 649
corrosion parameters, 420
corrosion inhibitor, 183, 419
demand for, 225
loss of reserve, 196
as a precipitant, 388
properties and uses, 419–422
threshold and crystal distortion effects, 424
in water supplies, 235
Phosphates as precipitation agents, 419
Phosphino/acrylonitrile acid, 407
Phosphino polycarboxylic acids, 451–454
Phosphinoacrylic acid dispersant, 226, 283
Phosphinoacrylic acids, 407, 413, 444, 607
as adjuncts, 386
Phosphonate, use of to control iron fouling, 197
Phosphonate/citric resin cleaner, 349
Phosphonates, 388, 432, 438, 444, 448–450
in cleaning processes, 640
Phosphono/phosphino polycarboxylates, 444
2-Phosphonobutane-1,2,4-tricarboxylic acid, 449
Phosphonomonocarboxylic acids, 451
Phosphoric acid, 420, 421
in cleaning processes, 641
in RO cleaners, 372
Phosphoric/citric/sodium gluconate resin cleaner, 349
Phos® 2–6, 9, 449
Physiochemical operating conditions, 143
Pickup of scale and corrosion debris, 296–298
Pipe-threading compounds, cleaning, 651
Pit tube, inspection of, 621
Pitting
of economizers, 87
indications of active corrosion in steam/condensate lines, 514
indications of inactive corrosion in steam/condensate lines, 514
Pitting corrosion, 248
Planning, to avoid water-side problems, 173
Plastic deformation, 256
Plated copper metal, cleaning process, 637
Plated metallic copper, removal by cleaning, 645
Plenum unit, 50
Pluronic® L61, L62D, L62LF and L101, 552
PMA, see Polymaleic acid
PMC Specialties, 461
POE 4 sorbitan monolaurate, 544
POE-PPO ether, 686
Polar character, of organic contaminant, 331
Polycryl® A30–43 - A40–43 - A50–43 - P70–40S, 446
Polarization, 150
Polyaloid™, 124
Polisher effluent quality, minimum, 382
Polishers, three-bed, 345
Polishing chemical treatments, 125
Polishing process, 305
Polyacrylamide polymers, 318, 438, 445, 446
Polyacrylamides, 438, 445, 446
Polyacrylate backbone, co- and terpolymers, 447–448
Polyacrylates, 438, 442, 443, 444, 455–457
for RO pretreatment, 369
Polyacrylic hydrazide, 502
Polyacrylic sulfonate, 662
Polyalkylene glycol (PAG) derivatives, 552–553
as antifoams, 551
Polyalkylene glycol monobutylether, 553
Polyalkylene polyamines, 284, 550
Polyaluminum chloride, 315
Polyamide RO membranes, 360
Polyamides, 550, 553–554
as antifoams, 551
Polyamide/DADMAC polymers, 317
Polyamine/EPIDMA polymers, 317
Polyamines, 316
Polycarboxylic component, of polymers, 454
Polycol® 100, 451
43, 447
Polydiallyl-dimethylammonium chloride polymers, 317
Polyelectrolytes, 316–320
Polyether glycols, 552
Polyethersulfone RO membranes, 360
Polyetheroxylates, as adjuncts, 389
Polyethylene glycol, 444, 454, 553
Polyethylene glycol 600 monolaurate, in cleaning formulations, 651
Polyethylene glycol 8 dioëne, 553
Polyfunctional amines, 535
Polyhydroxy aldehydes/ketones, 405
Polylactic acid, 405
Polymaleic acid, 445, 450–451
Polyolefinic acid, 56, 444, 450, 455
for RO pretreatment, 370
Polymer-based combination programs, 460–464
Polymer-based multifunctional programs, 388
Polymer/phosphate/chelant formulation, 460–464
Polymer tagging, 441
Polymeric coagulant/floculant blends, 318
Polymeric dispersants, in fuel additives, 680
Polymeric sludges and tars, cleaning method, 651
Polymerization, of oil constituents in heater, 685
Polymerized silica, separation of by membrane technology, 360
Index

Polymers
- for coagulation/flocculation, 316–320
demand for, 225
dry types, 319
Polyacrylates, 438, 444
Polyacrylic acids, 445
Polymethyleneimine, in cleaning processes, 647
Polyoxyalkylene glycols, 551, 552
Polyoxyethylene sorbitan fatty acid esters, 544
Polyoxyethylene-polyoxypropylene ether, 686
Polyoxypropylene/polyoxyethylene condensates, 552
Polyphos®, 422
Polyphosphate bond, 448
Polyphosphates, 398, 433
- as anodic inhibitors, 400
- as cathodic polarizers, 400
- for RO pretreatment, 369
- thermal degradation, 424
Polyphosphinicarboxylic acid, 370
Polypropylene glycol-polyethylene glycol ether, 686
Polypropylene, Inc., 318
Polyquats, as biocides for fuel oils, 686
Polysaccharides, 405
Polysaccharoses, 405
Polyisocyanates, 398
- as a precipitant, 388
Polyisocyanates, as adjuts, 389
Polyisoprene®, 452
Polysulfone RO membranes, 360
Polysulfone support layer, 363
Polyvinyl alcohol, 610
Polyvinylidene fluoride RO membranes, 360
Poor air removal, in condensers, 117
Porcelain insulators, M Alk. limits with, 594
Porous waterside deposits, 464
Positive ion exchange, 326
Positive ions, 347
Post-boiler conditioning, 138
Post-boiler condensate conditioning, 376–382
- condensate strainer-filter units, 376
- electromagnetic filtration and
  electromagnetic separation, 377
Post-boiler external treatment, 307
Post-boiler section, 71
- corrosion summary, 512–514
- oxygen removal, 480
Post-boiler section problems, 273–301
- carryover, 550
- corrosive gases in steam and condensate systems, 284–293
- oil and process contamination, 298–300
- scale and corrosion debris transport, 296–298
- steam purity and steam quality, 275–284
- vapor silica and other steam volatiles, 293–295
- post-boiler water subsystems, 45
- post-combustion additive, 675
- potassium hydroxide, 545
  - as adjuct, 389
  - in gas analysis, 693
- potassium mercaptobenzothiazole, 401
- potassium permanganate, 327
  - in cleaning formulations, 651
- potassium polysilicates, 398, 412
- potato peelings, historical perspective, 393
- potential energy, 10
- pour-point depressants, 672, 685
- pour-points, paraffinic waxes, 672
- powdered resin filtration, 379
- powdered-resin precoat filters, 379
- Power, 11
- Praestol®, 318
- Pre-boiler and post-boiler treatment, 303–383
  - basic pretreatment processes, 307–341
  - common external treatment process technologies, 306–307
  - novel pretreatment oxygen removal technologies, 382–383
  - post-boiler condensate conditioning, 376–382
  - pre-boiler purification technologies, 341–376
- Pre-boiler conditioning, 138, 304
- Pre-boiler filtration, 320–326
  - activated carbon filters, 323–325
  - bag filters and related technologies, 325–326
  - multimedia filters, 322–323
  - sand filters, 321–322
- Pre-boiler purification by ion-exchange, 345–359
  - basics of IX resins, 347–351
  - basics of IX system designs, 351–353
  - practical functions of IX systems, 353–359
- Pre-boiler purification technologies, 341–376
  - ion-exchange, 345–359
- pre-boiler section, 70
  - oxygen removal, 480
  - water/seawater problems, 191–213
- pre-boiler section equipment, corrosion
  problems affecting, 209–211
- Pre-boiler section waterside problems, 191–215
  - feedwater contamination from makeup water, 193–203
  - feedwater contamination from returning condensate, 203–206
  - overview of pre-boiler section waterside problems, 192
  - problems associated with final feedwater blend, 205–215
Pre-boiler water subsystems, 45
Precipitation softening (PS), 310–313
Precipitation phosphate program, 472
Precommission cleaning, 625, 651–653
and alkaline boil-outs, 651–653
Precipitants, 166
Precipitated iron binder, 214
Precipitating phosphate programs, 224, 425, 545
Precipitation program chemistries, 411, 440
Precipitation softening, 306, 310–313
Precision control phosphate programs, 464, 472
Precipitator filter, 299
Preflame zone, fireside, 669
Preflame zone problems, 670–673
problems with fuel oils, 671–673
problems with solid fuels, 670–671
Preheater tubes, in boiler deposits, 634
Preheaters, feedwater, 20
Pre-operational cleaning of new boilers, 50, 123, 625
Pressure absolute, 81
atmospheric, 81
head, 88
hydrostatic, 81
maximum allowable working, 79
static, 85
Pressure aerators, 309
Pressure-equalizing line, 73
Pressure gauges, 73, 81
Pressure leaf filters, for condensate conditioning, 376
Pressure reducing stations, 71
inspection of, 621
Pretreatment, 304
alternative technologies, 333–341
definition, for MHW/HPHW systems
lack of control, cause and effect problem, 174
requirements for MHW/HPHW systems, 186
using greensand, 326
using natural zeolite, 326
using synthetic resins, 326
Pretreatment equipment, see Water, pretreatment plant system
Pretreatment need
equipment for deep-well supply, 308
equipment for tropical surface water, 308
equipment for variable quality surface water, 309
Pretreatment processes, basic types, 307–314
Pressure aerators, 309–310
Pressure gauges, 81
Pretreatment using natural zeolite, greensand,
and synthetic resins, 326–332
iron and manganese removal using greensands, 321–328
Pretreatment using natural zeolite, greensand,
and synthetic resins (continued)
multifunctional water conditioners, 331–332
organic traps (organic scavengers), 330–331
softening by ion-exchange, 328–330
Primary air, 82
Primary circuit coolant water, treatment of, 477–478
Primary superheater tube bundle (WT), 47
Prime movers, 605
Priming, 155, 283, 284, 296, see also Surging
Priming control, as functional area requiring chemicals, 387
Problem-specific polymer, function of allorganics, 443
Problem-specific polymers, as adjuncts, 389
Problems with fuel oils, 671–673
Problems with solid fuels, 670–671
Process chemicals, causing foaming, 549
Process contaminants, 136, 141, 204, 218
processes, 651
Process contaminants and deposits, cleaning
processes, 651
Process contaminants control, as functional area requiring chemicals, 387
Process leaks, 202, 298–301
Process particulate pickup, 283
Product breakdown temperatures, of amines, 511
Product water, in ED technology, 374
Products for boosting alkalinity, 548
Professional Water Technologies, 371
Program primary support chemicals, 385, 389
Propenamide, 446
Propenoic acid, 446
Propylene glycol, 402
Propylene glycol monostearate, in cleaning formulations, 651
Protection of idle boilers (long-term offline), 608–612
waterside dry lay-up, 610–611
waterside wet lay-up, 608–609
Protection of standby boilers (short-term offline), 606–608
Protective colloid, 438
Proteinaceous foams, 550
Protonation of amines, 538
Pulse-echo pitch-catch technique, 622
Pulverized fuel, 16, 41
treatment formulation, 687
Pulverized fuel coal burners, 83
Pulverizer
bowl mill, 83
impact mill, 83
Pump
feedwater, 88–89
multistage centrifugal, 88
<table>
<thead>
<tr>
<th>Index</th>
<th>143</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pump (continued)</strong></td>
<td></td>
</tr>
<tr>
<td>single stage centrifugal, 88</td>
<td></td>
</tr>
<tr>
<td>steam-driven reciprocating, 88, 89</td>
<td></td>
</tr>
<tr>
<td>turbine, 88, 89</td>
<td></td>
</tr>
<tr>
<td>power requirements, 88</td>
<td></td>
</tr>
<tr>
<td>reciprocating, 89</td>
<td></td>
</tr>
<tr>
<td>Pure water</td>
<td></td>
</tr>
<tr>
<td>definition of basic pure water, 344</td>
<td></td>
</tr>
<tr>
<td>definition of very pure water, 344</td>
<td></td>
</tr>
<tr>
<td>Purge cycle, 16</td>
<td></td>
</tr>
<tr>
<td>Purification by electrodemineralization,</td>
<td></td>
</tr>
<tr>
<td>372–376</td>
<td></td>
</tr>
<tr>
<td>electrodeionization, 374–376</td>
<td></td>
</tr>
<tr>
<td>electrodialysis, 373</td>
<td></td>
</tr>
<tr>
<td>electrodialysis reversal, 373–374</td>
<td></td>
</tr>
<tr>
<td>Purification, by RO membrane process, 308</td>
<td></td>
</tr>
<tr>
<td>Purification of MU water</td>
<td></td>
</tr>
<tr>
<td>by ion-exchange, 345–359</td>
<td></td>
</tr>
<tr>
<td>by membrane technologies, 359–372</td>
<td></td>
</tr>
<tr>
<td>Purification processes, 304</td>
<td></td>
</tr>
<tr>
<td>Purification technologies for pre-boiler, 341–376</td>
<td></td>
</tr>
<tr>
<td>Purif. water, 352</td>
<td></td>
</tr>
<tr>
<td>Pyridazine, 504</td>
<td></td>
</tr>
<tr>
<td>Pyridines, in cleaning processes, 647</td>
<td></td>
</tr>
<tr>
<td>Pyrite, in scales, 646</td>
<td></td>
</tr>
<tr>
<td>Pyrocatechol, 506</td>
<td></td>
</tr>
<tr>
<td>from tannins, 405</td>
<td></td>
</tr>
<tr>
<td>Pymalgallic acid, 506</td>
<td></td>
</tr>
<tr>
<td>from tannins, 405</td>
<td></td>
</tr>
<tr>
<td>Pyrogallol, 237, 501, 506</td>
<td></td>
</tr>
<tr>
<td>from tannins, 405</td>
<td></td>
</tr>
<tr>
<td>in gas analysis, 693</td>
<td></td>
</tr>
<tr>
<td>QR-1086, 447</td>
<td></td>
</tr>
<tr>
<td>Quality management systems, 43</td>
<td></td>
</tr>
<tr>
<td>Quartz, 145</td>
<td></td>
</tr>
<tr>
<td>in scales, 645</td>
<td></td>
</tr>
<tr>
<td>Quaternary ammonium compounds, 517</td>
<td></td>
</tr>
<tr>
<td>Quebracho, 237, 444, 505</td>
<td></td>
</tr>
<tr>
<td>historical perspective, 392</td>
<td></td>
</tr>
<tr>
<td>Quebracho tannins, 171, 405, 484, 693</td>
<td></td>
</tr>
<tr>
<td>historical perspective, 393</td>
<td></td>
</tr>
<tr>
<td>Quercus sp. tannin, 405</td>
<td></td>
</tr>
<tr>
<td>Quick line</td>
<td></td>
</tr>
<tr>
<td>in fuel additives, 680</td>
<td></td>
</tr>
<tr>
<td>for lay-up programs, 610</td>
<td></td>
</tr>
<tr>
<td>Quinic acid, 506</td>
<td></td>
</tr>
<tr>
<td>from tannins, 405</td>
<td></td>
</tr>
<tr>
<td>Quinol, 499–501</td>
<td></td>
</tr>
<tr>
<td>Quinolines, in cleaning processes, 647</td>
<td></td>
</tr>
<tr>
<td>Quinone, 499</td>
<td></td>
</tr>
<tr>
<td>as catalyst, 505</td>
<td></td>
</tr>
<tr>
<td>Radiation, 47</td>
<td></td>
</tr>
<tr>
<td>Radiographic testing, 623</td>
<td></td>
</tr>
<tr>
<td>Radionuclides, 266</td>
<td></td>
</tr>
<tr>
<td>Rapid action intermittent BD arrangement,77–78</td>
<td></td>
</tr>
<tr>
<td>Rare-earth metals, as slag modifier, 682</td>
<td></td>
</tr>
<tr>
<td>Ratio</td>
<td></td>
</tr>
<tr>
<td>alkalinity to tannin, 407</td>
<td></td>
</tr>
<tr>
<td>cation to anion resin, 536</td>
<td></td>
</tr>
<tr>
<td>caustic to silica, 413</td>
<td></td>
</tr>
<tr>
<td>distribution of amines, 527</td>
<td></td>
</tr>
<tr>
<td>fuel/excess air, 673</td>
<td></td>
</tr>
<tr>
<td>of Na to PO₄, 474</td>
<td></td>
</tr>
<tr>
<td>oil/grease to millscale, in cleaning</td>
<td></td>
</tr>
<tr>
<td>processes, 652</td>
<td></td>
</tr>
<tr>
<td>of sulfonated styrene to maleic anhydride,451</td>
<td></td>
</tr>
<tr>
<td>silica content to caustic alkalinity, 585</td>
<td></td>
</tr>
<tr>
<td>silica to sodium oxide, 398</td>
<td></td>
</tr>
<tr>
<td>sodium to TDS in steam, 603</td>
<td></td>
</tr>
<tr>
<td>Reaction stage turbines, 114</td>
<td></td>
</tr>
<tr>
<td>Real-time remote monitoring, 132</td>
<td></td>
</tr>
<tr>
<td>Reboilers, 536</td>
<td></td>
</tr>
<tr>
<td>to reduce amine exposure, 533</td>
<td></td>
</tr>
<tr>
<td>Reciprocating FW pumps, 89</td>
<td></td>
</tr>
<tr>
<td>“Recommendations for Treatment of Water for Land Boilers,” 343</td>
<td></td>
</tr>
<tr>
<td>Reciprocation of scale and corrosion debris, 204, 296–298</td>
<td></td>
</tr>
<tr>
<td>Redox process, corrosion as, 647</td>
<td></td>
</tr>
<tr>
<td>Redox tendencies</td>
<td></td>
</tr>
<tr>
<td>effect of chelant or oxygen, 263</td>
<td></td>
</tr>
<tr>
<td>effect of chelants, 436</td>
<td></td>
</tr>
<tr>
<td>Reducing conditions, maintenance of, 150</td>
<td></td>
</tr>
<tr>
<td>Reduction of oxides, by hydrazine, 298</td>
<td></td>
</tr>
<tr>
<td>Reduction reactions, 149</td>
<td></td>
</tr>
<tr>
<td>Red-water, 398</td>
<td></td>
</tr>
<tr>
<td>Refinery gas, as fuel, 51</td>
<td></td>
</tr>
<tr>
<td>Refractory integrity, 617</td>
<td></td>
</tr>
<tr>
<td>Refractory surfaces, inspection of, 620</td>
<td></td>
</tr>
<tr>
<td>Refuse-derived fuel, 59</td>
<td></td>
</tr>
<tr>
<td>Regeneration, of ion-exchange resin bed, 329</td>
<td></td>
</tr>
<tr>
<td>Regenerative FW heating, 98</td>
<td></td>
</tr>
<tr>
<td>Reheater (WT), 44, 47</td>
<td></td>
</tr>
<tr>
<td>Reheaters, 71, 90–91</td>
<td></td>
</tr>
<tr>
<td>nondrinable, 608</td>
<td></td>
</tr>
<tr>
<td>Relative amine basicity cost effectiveness,526</td>
<td></td>
</tr>
<tr>
<td>Relative humidity, 690</td>
<td></td>
</tr>
<tr>
<td>Relative neutralizing capacity, of amines, 521</td>
<td></td>
</tr>
<tr>
<td>Relative volatility, of amines, 511, 526–530</td>
<td></td>
</tr>
<tr>
<td>Removal of copper/copper oxides, 641–643</td>
<td></td>
</tr>
<tr>
<td>Reodorants, for fuels, 671</td>
<td></td>
</tr>
<tr>
<td>Residual heat, 20</td>
<td></td>
</tr>
<tr>
<td>Residual oils, 685</td>
<td></td>
</tr>
<tr>
<td>Residual sulfite, sampling for, 605</td>
<td></td>
</tr>
<tr>
<td>Resin</td>
<td></td>
</tr>
<tr>
<td>acrylic bead, in multifunctional water conditioners, 332</td>
<td></td>
</tr>
<tr>
<td>ceramic bead, in multifunctional water conditioners, 332</td>
<td></td>
</tr>
<tr>
<td>gel type, 200</td>
<td></td>
</tr>
<tr>
<td>isoporous, 200</td>
<td></td>
</tr>
<tr>
<td>macroporous, 200</td>
<td></td>
</tr>
</tbody>
</table>
Resin breakdown, 197
Resin loss from softener, 197
Restorative preoperational passivation, 171
Restrictor tube, cleaning, 625
Resultant by-products of amines, 511
Return tube, blisters and deformation, 617
Reversal of potential, 150
Reverse osmosis, 199, 324, 360–372
application to reduce TDS, 162
automatic periodic membrane flush, 366
chemical for antiscaling/antifouling, 368–372
chemical treatments for RO antiscaling and antifouling duty, 368–371
chemical treatments for RO cleaning duty, 371–372
clean-in-place, 366
corrosion factors, 363
design considerations for, 364–366
energy recovery turbine systems, 366
high permeate TDS water reject system, 366
to limit silica, 294
membrane cleaners, 371
membrane cleaning processes, 372
membrane storage, 372
membranes
aramid type, 363
aromatic polyamide type, 363
cellulose acetate type, 363
thin film composite type, 363
permeate flush tank, 366
pretreatment requirements for RO, 367–368
primary components of RO, 361–364
programmable logic control, 366
pumps, 366
as purification technology, 342
Reversion, of phosphates, 400
Rippled magnetite, 508
Riser tubes (WT), 43, 46
RO, 51
Rodline, 51, 52, 85, 648
Rohm and Haas Company, 352, 404, 441, 662
Roof header (WT), 47
Roof tube (WT), 47
Rosin-amine ketone, in cleaning processes, 647
Rotor unbalancing, in steam turbine, 116
Ruptures, 259
Rust
in boiler deposits, 634
removal during cleaning, 640
Sacrificial anode, 167
Sacrificial zinc sheet anodes, historical perspective, 593
Safety issues, of amines, 511
Safety valves, 79
SAG® 10, 30, 555
Saline corrosion, 250
Salinity and adverse chemical reactions, control over, 169–170
Salinity in the boiler, limiting, 169
Salt cake, historical perspective, 393
Salt density index, 363
Salt splitting, 358
Salting rate, of softeners, 328
Salts
as combustion catalyst, 681
as fuel additive, 678
as slag modifier, 682
Sample coolers
see also Sampling coils
temporary, 602
Sample points, for superheated steam, 601
Sample probe, double-walled type, 602
Sampling coils (sampling pots/sample coolers), 93–94
Sampling and testing steam and condensate, 599–605
to sample for carryover and steam purity tests, 602–604
sampling steam and condensate in higher pressure boiler systems, 600–601
sampling steam and condensate in lower pressure boilers, 602
steam quality and purity and general sampling requirements, 604–605
superheated steam, using isokinetic multiphase nozzle, 601
Sampling for carryover and steam purity tests, 602–604
Sampling nozzle
multiphase, 601
single-port, 600, 602
Sampling pots, see Sampling coils
Sampling procedures for water and steam, 599
Sampling station, 111
Sand filters, 321–322
Sandwich polisher, design of resin bed, 353
Saponifiable oil, 549
Saponification
as cleaning processes, 637
of fats, as deposit binder, 154
of soaps, 205
Sarcosinates, 444
as iron chelants, 406
Satellite feeding stations, for amines, 535
Saturated steam, 600
Saturation point, of BW TDS, 74
Saturation ratio, in RO systems, 369
Save-all tank, 72, 93
Saw dust, as fuel additive, 678
Saybolt Seconds Universal, 83
Scale and corrosion debris transport, 296–298
Index

Scale control, as functional area requiring chemicals, 387
Scale and hardness control, nonchemical technologies for, 338–341
Scale heat conductivity, measurement, 623
Scale resolutization, 146
Scales, 218
amorphous, 144, 218
analysis of, 632–635
carbonate, 182
crystalline, 144, 218
eggshell thickness, historical perspective, 392
mineral salt, 144
removal by cleaning solvents, 645–647
Scaling
fouling and deposition, in boilers, 217–235
silicate, 37
Schinopsis tannin, 405
Schwebebett™ design, of resin bed, 352, 353
Scion®, 353
Scion-Hipo™, deionizer design, 353
Scope of BW treatment and control of steam/waterside chemistry, 134–140
Scotch marine boilers, 32–33, see also Boiler, fire tube, Scotch marine
Screens, 325
for condensate conditioning, 376
Scrubber
dry, 678
wet, 678
Seawater, as source for RO, 365
Seawater evaporator, 56
Seaweed, historical perspective, 393
Secodyne™, 318
Secondary air, 82
Secondary circuit working fluid, treatment of, 478
Secondary precipitation, 313
Sedimentation, 306
definition, 314
historical perspective, 390
Sediments, 73
Semipermeable RO membrane, 363
Sensible heat, 15, 97
Separation of steam and water, 7–10
Sequacel® HD, 449
Sequestrants
function of all-organics, 442
lignins as, 445
Sequestration, using phosphate, 419
Serpentine, 148, 214, 229, 412, 413
in boiler deposits, 634
in scales, 646
Settling period, of dry polymer, 320
Settling rate, of floc, 320
Shell and tube heat exchangers, 100
Shell floor, inspection for excessive sludge, 616
SHMP, 421, see also Sodium hexametaphosphate
Short cycle deionizer design, 353
Short-term overheating, 260–261
Siderite, 236
Sieves, 325
for condensate conditioning, 376
Silica, 217
amorphous, deposit in steam-condensate systems, 295
carryover, 276
cleaning in RO plants, 371
colloidal, 199
contaminant in steam purity, 603
control in supercritical boilers, 476
conversion in condensate polishers, 380
in fuel additives, 680
in higher quality water, 304
in scales, 646
in steam/condensate, 344
ionic, 199
limits in steam, 589
managing high levels in raw water makeup, 658
rejection rate with RO, 361
removal, 214
removal from water, 311
removal by RO, 369
testing in steam/condensate, 602
vaporous, in steam, 293–295
Silica adsorption, by magnesia addition, 309
Silica and magnesium, as mutual precipitants, 412
Silica and silicate deposition, 227–231
Silica in BW, maximum concentrations, 588
Silica control
as adjunct requirement, 389
with AVT programs, 475
as functional area requiring chemicals, 87
Silica deposit control agents, 360, 370
Silica deposition, 198
Silica deposits, 214
Silica dispersants, 162
Silica dissociation, 347
Silica gel, for lay-up programs, 610
Silica in steam, maximum concentrations, 588
Silica leakage, 198–199
into feedwater, 198:200
Silica levels, after ion-exchange, 359
Silica limitation processes, 294
Silica limits, 588
Silica micelles, 549
Silica polymer, for RO pretreatment, 371
Silica precipitants, 294
Silica reduction and removal technologies, 163
Silica removal, 162–163
by ferric/magnesium hydroxide absorption, 412
Silica removal (continued)
   by ion-exchange, 349
   need for, 162
Silica scaling, 440
Silica solubilization, 546
Silica volatiles, 154
Silica volatilization, 230
Silicate anions, 228
Silicate-based boiler compounds, 411–413
Silicate-based inhibitor, to prevent free hydroxyl ion, 241
Silicate chemistries, as anodic inhibitors, 388
Silicate ion, in steam, 294
Silicate precipitation, seeding points, 228
Silicate scale, 228
   eggshell thickness, 230
Silicate scaling, from hardness breakthrough, 661
Silicate zeolites, historical perspective, 391
Silicates, 145, 227–231, 395, 398–399, 635
   amorphous, in steam, 293
   in boiler deposits, 635
   in cleaning formulations, 649
   complex scales, 229
   contributor to stress-corrosion cracking, 240
   corrosion inhibitor, 183
   glossy, in steam, 293
   role in caustic-induced stress corrosion cracking, 466
   in scales, 646
Silicates and other common minerals, deposition by, 227–237
   deposits from inorganic salts and organics, 233–237
   iron oxide and other corrosion debris deposition, 231–233
   silica and silicate deposition, 227–231
Silicic acid, 380
   in steam, 294
   volatile, 116
Silicone-block copolymers, 552
Silicones, 554–555
   as antifoams, 551
Siloxane glycol/PVM copolymer, 555
Silt, in fuel oils, 672
Single gas analyzer, 693
Single-phase boiler, see Boiler, single phase
Sintering temperature, of slag, 682
Slag, 42
Slag deposits, 674
Slag modifiers, 682–683, 684
   examples, 682–683
   for fireside cleanliness, 611
   formulation, 687
   as fuel additives, 675, 680
Slagging, 673
   of furnace area, 681
   of superheater, 681
Sling psychrometer, 693
Slow rinse, of ion-exchange resin bed, 329
Sludge, 73, 176, 218,
   coarse magnetite, 178
   hematite, 178
   iron, 180
   in LP boiler vessel, 182
   managing problems in LP boilers, 657
Sludge blanket precipitation softening, 311
Sludge conditioners, 440
   as adjuncts, 85
   historical perspective, 392
   tannin as, 404
Sludge conditioning, via tannins, 388
Sludge control, as functional area requiring chemicals, 387
Sludge dispersants, 237
   tannins and lignin-based, 444
Sludge dispersion, of polymers, 413
Sludge fluidizer, function of all-organics, 442
Sludging
due to hardness breakthrough, 196
   general, 236
   grease, caused by oily surfaces, 298
Smaller steam turbine generators, 114–115
Smelt, 58
Smoke suppressant, 681
Smoke test set, 693
Smutting, 681
   acid, 680
   dry, 680
SNF S.A., 318
Soap
   as combustion catalyst, 681
   as slag modifier, 682
Soda ash, 30, 411
   in cleaning solutions, 652
   condensate corrosion induced by, 289
   historical perspective, 391
   as a softening agent, 311
Soda pulping process, 58
Sodalite, 229, 234
Sodaphos®, 422
Sodium
carryover, 276
   contaminant in steam purity, 603
   control in supercritical boilers, 476
   in fuel oils, 671
   in fuels, 673
   in higher quality water, 304
   in steam/condensate, 344
   levels in steam, 603
   testing in steam/condensate, 602
   Sodium acid sulfite, 487–488
   Sodium alginate, 444
   Sodium aluminosilicate zeolites, historical perspective, 391
   Sodium aluminate, 411
   historical perspective, 391
   Sodium aluminosilicate zeolites, historical perspective, 391
<table>
<thead>
<tr>
<th>Sodium-aluminum silicate, zeolite, 411</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium aluminum sulfate, in scales, 645</td>
</tr>
<tr>
<td>Sodium and silicate leakage, 198–199</td>
</tr>
<tr>
<td>Sodium bicarbonate, 226, 515</td>
</tr>
<tr>
<td>conductive corrosion induced by, 288</td>
</tr>
<tr>
<td>production, 357</td>
</tr>
<tr>
<td>Sodium bisulfite, 168, 371, 396, 487–488</td>
</tr>
<tr>
<td>as RO membrane cleaner, 371</td>
</tr>
<tr>
<td>breakdown in steam-condensate systems, 291</td>
</tr>
<tr>
<td>Sodium borate, 395</td>
</tr>
<tr>
<td>Sodium bromate, in processing, 645</td>
</tr>
<tr>
<td>Sodium carbonate, 226, 289, 411, 413, 545</td>
</tr>
<tr>
<td>in cleaning solutions, 652</td>
</tr>
<tr>
<td>historical perspective, 391</td>
</tr>
<tr>
<td>as a softening agent, 311, 312</td>
</tr>
<tr>
<td>Sodium carboxylates, 444</td>
</tr>
<tr>
<td>from hydrolyzable tannins, 406</td>
</tr>
<tr>
<td>Sodium carboxymethylcellulose, 444</td>
</tr>
<tr>
<td>Sodium cation ion-exchange softening, with ED, 374</td>
</tr>
<tr>
<td>Sodium compounds in fuel, 674</td>
</tr>
<tr>
<td>Sodium contamination, in condensate, 382</td>
</tr>
<tr>
<td>Sodium control, as functional area requiring chemicals, 387</td>
</tr>
<tr>
<td>Sodium-cyanide ion-exchanger, 161</td>
</tr>
<tr>
<td>Sodium cycle softening, 328–329</td>
</tr>
<tr>
<td>Sodium deposits, in clinker, 684</td>
</tr>
<tr>
<td>Sodium dihydrogen phosphate, 421</td>
</tr>
<tr>
<td>Sodium dodecyl sulfosuccinate, 543</td>
</tr>
<tr>
<td>Sodium disilicate, deposit in steam-condensate systems, 295</td>
</tr>
<tr>
<td>Sodium dodecyl sulfate, in RO cleaners, 372</td>
</tr>
<tr>
<td>Sodium-EDTA, in cleaning processes, 638</td>
</tr>
<tr>
<td>Sodium erythorbate, 61, 485, 486, 497–499</td>
</tr>
<tr>
<td>Sodium erythorbate and erythorbic acid, 497–499</td>
</tr>
<tr>
<td>Sodium ferrite, 249, 257</td>
</tr>
<tr>
<td>Sodium ferronate, 546</td>
</tr>
<tr>
<td>Sodium gluconate, 432</td>
</tr>
<tr>
<td>Sodium gluconate, 432</td>
</tr>
<tr>
<td>in cleaning processes, 640, 646</td>
</tr>
<tr>
<td>as passivator, 649</td>
</tr>
<tr>
<td>Sodium heptonate, 432</td>
</tr>
<tr>
<td>Sodium hexametaphosphate, 400, 421, 422</td>
</tr>
<tr>
<td>Sodium humate, 444</td>
</tr>
<tr>
<td>historical perspective, 393</td>
</tr>
<tr>
<td>Sodium hydrogen sulfite, 487–488</td>
</tr>
<tr>
<td>Sodium hydrosulfito resin cleaner, 349</td>
</tr>
<tr>
<td>Sodium hydroxide, 545</td>
</tr>
<tr>
<td>inadequate concentration of, 240</td>
</tr>
<tr>
<td>as adjunct, 389</td>
</tr>
<tr>
<td>buildup in boilers, 236</td>
</tr>
<tr>
<td>in cleaning processes, 641</td>
</tr>
<tr>
<td>in cleaning solutions, 652</td>
</tr>
<tr>
<td>Sodium hypoferrite, 249, 257, 546</td>
</tr>
<tr>
<td>Sodium hypophosphite, 452</td>
</tr>
<tr>
<td>Sodium ion-selective electrodes, 603</td>
</tr>
<tr>
<td>Sodium ions, 169</td>
</tr>
<tr>
<td>measuring in steam, 278</td>
</tr>
<tr>
<td>Sodium iron silicate, in scales, 645</td>
</tr>
<tr>
<td>Sodium lauryl sulfate, in RO cleaners, 372</td>
</tr>
<tr>
<td>Sodium leakage</td>
</tr>
<tr>
<td>into feedwater, 198–200</td>
</tr>
<tr>
<td>from polishers, 382</td>
</tr>
<tr>
<td>Sodium levels, after ion-exchange, 359</td>
</tr>
<tr>
<td>Sodium lignosulfonate, 444, 445</td>
</tr>
<tr>
<td>as decharacterizer, 485</td>
</tr>
<tr>
<td>Sodium mercaptobenzothiazole, 401</td>
</tr>
<tr>
<td>Sodium metabisulfite, 488–489</td>
</tr>
<tr>
<td>Sodium metaborate, 399</td>
</tr>
<tr>
<td>Sodium metaphosphate, 424</td>
</tr>
<tr>
<td>historical perspective, 393</td>
</tr>
<tr>
<td>Sodium metasilicate, in cleaning solutions, 652</td>
</tr>
<tr>
<td>Sodium metavanadate, 675</td>
</tr>
<tr>
<td>Sodium molybdate, 397</td>
</tr>
<tr>
<td>Sodium nitrate, 387, 395</td>
</tr>
<tr>
<td>in coil boilers, 595</td>
</tr>
<tr>
<td>conductivity guide, 595</td>
</tr>
<tr>
<td>historical perspective, 393</td>
</tr>
<tr>
<td>as oxidizer in cleaning processes, 641</td>
</tr>
<tr>
<td>Sodium nitrate inhibitor, 256</td>
</tr>
<tr>
<td>Sodium nitrite-based corrosion inhibitors, 580</td>
</tr>
<tr>
<td>Sodium oxide, as slag component, 682</td>
</tr>
<tr>
<td>Sodium polycrylamide-acrylate, historical perspective, 393</td>
</tr>
<tr>
<td>Sodium polyelectrolyte, historical perspective, 393</td>
</tr>
<tr>
<td>Sodium polymethacrylates, 446</td>
</tr>
<tr>
<td>Sodium polyphosphate, 399</td>
</tr>
<tr>
<td>Sodium polysilicates, 398, 412</td>
</tr>
<tr>
<td>Sodium pyrosulfite, 488–489</td>
</tr>
<tr>
<td>Sodium pyrovanadate, 675</td>
</tr>
<tr>
<td>Sodium salinity, control over, 169</td>
</tr>
<tr>
<td>Sodium salts, steam distilling, 295</td>
</tr>
<tr>
<td>Sodium silicates, 411</td>
</tr>
<tr>
<td>Sodium slip, 358</td>
</tr>
<tr>
<td>Sodium sulfate, historical perspective, 393</td>
</tr>
<tr>
<td>Sodium sulfite, 168, 483–487, 578</td>
</tr>
<tr>
<td>breakdown in steam-condensate systems, 291</td>
</tr>
<tr>
<td>catalyzed, 87</td>
</tr>
<tr>
<td>in coil boilers, 595</td>
</tr>
<tr>
<td>feeding, 487</td>
</tr>
<tr>
<td>historical perspective, 393</td>
</tr>
<tr>
<td>as primary support chemical, 389</td>
</tr>
<tr>
<td>Sodium tannates, 407</td>
</tr>
<tr>
<td>Sodium tetaborate, 399</td>
</tr>
<tr>
<td>Sodium tetramethylenediamine, 543</td>
</tr>
<tr>
<td>Sodium trimetaphosphate, 421</td>
</tr>
<tr>
<td>Sodium tripolyphosphate, 399, 422</td>
</tr>
<tr>
<td>Sodium vanadyl vanadate, 675</td>
</tr>
<tr>
<td>Soft water, definition, 217</td>
</tr>
<tr>
<td>Softened makeup, increased demand, 196</td>
</tr>
<tr>
<td>Softener</td>
</tr>
<tr>
<td>need for, 225</td>
</tr>
<tr>
<td>need for with HP steam boilers, 308</td>
</tr>
<tr>
<td>need for with LP steam boilers, 308</td>
</tr>
<tr>
<td>reduced operating capacity, 197</td>
</tr>
</tbody>
</table>
Softening
  by ion-exchange, 328–329, 346
  lack of capability in feedwater, 193–196
Softening need, example, 194
Sokalan® PA20-P A25, 446
Solid fuels, problems with, 670–671
Solubility limit, of BW TDS, 74
Solubilizer, function of all-organics, 443
Soluble poison, 477
Solubilizing programs, 658
Solution polymers, 316
Solvent degreasers, 649
Solvent extractable oily matter, 568
Solvent naphtha, for fuel oils, 686
Solvent sprays, in cleaning formulations, 650
Solvents
  for removing copper and copper oxides, 643–645
  for removing iron oxides, 637–641
  for removing organics, 649–651
  for removing scales, 645–647
Sonar effect, in nonchemical technology, 334
Soot
  in stack, 677
  inspection for, 620
Soot blowers, 73, 81–82, 611, 682
  inspection of, 620
Soot blowing, affecting steam sampling, 604
Soot deposition, 674
Soot emissions, dry, 678
Soot removers, 649
Sooting, 680
Sorbitan, 58
Sorbitan, 544
Sorbitan-based non-ionic surfactant treatments, 544
Sorbitan fatty acid esters, 544
Sorbitan monooleate, 684
Sorbitan tristearate, 544, 684
Sorbitol, 544
Soya-based filters, 537
Soyaalkyl-dimethylamine, 540
Space heating equipment, 132
Spalling, 259
  in FW heaters, 609
Sparge pipe, 18
Specific conductance to TDS conversion guide, 570
Specific humidity, 690
Specific ion electrode, 9
Specific usage additives, USDA, 484
Spherical stack solids, 673
Spheroidization, 261–262
Spinels, 642
Spiral wound cartridge, 363
Spiral wound RO elements, 364
Split stream dealkalization, 356
Spoilage, of fuels, 671
Sponge ball blasting, 624
Sponge Ball, Inc., 624
Spray atomizers, 91
Spray atomization water, 586, 589
  water quality limits, 591
Spray dryer desulfurizer, 678
Spray ponds, 309
Sprayed electrode boilers, 28–29
Spreading coefficient, of antifoams, 551
Square-wave generators, 334
SS/MA, 451, see also Sulfonated styrene
maleic anhydride
Stability of treated water, 313
Stabilization of unstable water, 202
Stabilizer, function of all-organics, 443
Stains, 176
Stand-alone online cleaning formulations, 628–629
Stand-alone programs, for online cleaning, 627
Standard hydrogen electrode, 150
Standard soap solution test, historical perspective, 392
Standby and idle boilers, management of, 606–612
Standby boilers (short-term offline), protection of, 606–608
Stannous chloride, in cleaning processes, 640
Starches, 237, 438
  as adjuncts, 386
Stay bolts, 29
Steam, 1
  carryover, 8
  delivery system, 45
  discoloration, 300
  dry, 8, 9
  extracted, 115
  header, 71
  high heat-content, 274
  live, 273
  moist, 9
  purity, 268, 275–284, 604
  quality, 274, 275–284
  superheated, 4
  throttle, 114
  valves, 71
  wet, 9, 282
Steam accumulator, 281
Steam analyzes, Larson-Lane type, 278
Steam and condensate equipment, inspection of, 621
Steam and condensate purity, 154
Steam and condensate systems, corrosive gases in, 284–293
  carbon dioxide carryover, 288–291
  other corrosive gases and related impurities, 291–293
  oxygen infiltration, 285–287
Steam and water problems affecting turbines, 115–116
Steam blanket, 146, 229, 259, 608
Steam bubble frothing, 296
Steam bubble nucleation, 6
Steam coils, 502
Steam-condensate recovery system, 45
Steam cycle, 86
Steam delivery system, 71
Steam demand, 274
Steam drums, 8, 41, 45
inspection of, 618
Steam dryers, 280
Steam flashing, 605
Steam flow restrictions, 281
Steam generation, 1–22
basics of, 4–10
separation of steam and water, 7–10
steam tables, 7
boiler plant efficiency, 14–22
energy, work, and power, 10–14
Steam generation bank tubes, 44, see also
Boiler bank tubes (WT)
Steam generator, see Boiler
Steam heated tracing lines, 19
Steam load swings, 281
Steam meter, inspection of, 621
Steam pH, with hydrazine, 492
Steam pressure efficiency, 17
Steam pressure reductions, 281
Steam purity
notes, 604–605
testing for, 603
Steam purity and steam quality, 275–284
genral sampling requirements, 604–605
necessity for steam sampling, 276–278
steam sampling, 277–278
steam–water separation effectiveness, 278–284
Steam quality, 604
notes, 604–605
testing for, 603
Steam raising plants, 67
Steam release velocities, 14
everly high, 115
Steam sampling, 276–278
in higher-pressure boilers, 600–601
in lower-pressure boiler systems, 602
Steam sampling points, 600, 601
Steam sampling/testing, 599–605
Steam saturation temperature, 103
Steam scrubbers, 280
Steam separaor–water storage drums, 573
Steam separators, 280
Steam sparge pipes, 305
Steam-to-steam heat exchanger, 60
to reduce amine exposure, 533
Steam stripping, 9
Steam superheating and delivery system, 47
Steam surging, 283
Steam system cycle, 132, 134
Steam tables, 7
with amines, 533
Steam trap efficiency, 10
Steam traps, 91–92
disc, 92
efficiency, 19
float thermostatic, 92
impulse, 92
inverted bucket, 92
thermodynamic, 92
thermostatic, 92
Steam turbine
backpressure, 113, 115
condensing, 113, 115
extraction, 115
high-pressure section, 113, 114
impulse stage type, 113, 114
induction, 115
intermediate pressure section, 114
large steam, 113
low-pressure section, 114
noncondensing, 115
reaction stage type, 113, 114
reheat condensing, 113
smaller generator systems, 114
water and steam problems, 115
Steam turbine-driven FW pumps, 89
Steam volatiles, vaporous silica and,
293–295
Steam washers, 280
limiting silica by employing, 295
Steam-water
different types employed, 137
separation of, 7
sublayer film, 143
Steam/water analyzer panels, 661
Steam-water circulation system, 44, 45–47
boiler steam-water circulation system,
45–46
steam superheating and delivery system, 47
Steam-water control limits, 138
Steam-water separation, 278–284
effect of boiler operating variables on,
280–282
factors affecting the quality of, 8
interface factors, 282–284
operating variables, 280–282
steam–water interface physicochemical
factors, 282–284
steam–water separation devices, 279–280
surging and carryover, 282–284
Steam-waterside chemistry, control of, 134
Steam-waterside problems and water
treatment objectives, 140–144
interrelationship of waterside problems
with boiler design and operation,
142–144
treatment objectives, 142
Boiler Water Treatment: Principles and Practice

Stearylamine, 536
Steel laths, as sacrificial anodes, historical perspective, 393
Steelworks waste heat boilers, 57, see also Boiler, waste heat, steelworks
Steric repulsion, function of all-organics, 442
Sticky films, 300
Stirling boiler, see Boiler, water tube, Stirling
Stockhausen, 318
Stoichiometric relationships, of hydrazine, 493
Stokers, 84
inspection of, 620
mass feed, 84
overflow stokers, 84
underfeed stokers, 84
Stop valves, 79
Storage of bagasse and similar process residues, 671
Straight tube NP steam generator, 66
Strainer technologies, 307
Strainers, 325
for condensate conditioning, 376
Stratification, 259
in feedwater tank, 111
of fuel oils, 672
Stratified packed-bed, design of resin bed, 352
Stress and high temperature-related corrosion, 254–262
chelant corrosion, 262–265
copper corrosion, 265
overheating effects and high-temperature corrosion, 259–262
stress corrosion cracking, 255–258
thermal fatigue cracking and corrosion fatigue, 258
Stress corrosion cracking, 255–258
caustic cracking, 255–256
cautious embrittlement, 255–256
cautious stress corrosion cracking, 255–256
hydrogen embrittlement and hydrogen damage, 256–258
Stress corrosion cracking mechanisms, 169
Stress rupture, 260
Strontium, 221
as slag modifier, 682
Styrene, 443
Styrene divinylbenzene, 327, 347
Subcooled liquid, 53
Submerged electrode boilers, 27–28
fixed water level, submerged electrode boilers, 28
variable water level, submerged electrode boilers, 28
Substantivity, of amines, 538
Suez-Lyonaisse, 441
Sulfur, in combustion chamber, 676
Sugar molecules, as tannins, 404
Sugar-phenols, from tannins, 405
Sugar refinery boilers, 59, see also Boiler, sugar refinery
Sugars, as process contaminants, 283
Sulfamic acid, in cleaning processes, 641, 646
Sulfate ions, 169
Sulfate leakage, 198
Sulfate salinity, control over, 169
Sulfate scale, historical perspective, 392
Sulfates, 217, 635
in boiler deposits, 635
cleaning in RO plants, 371
effect on nitrite feed rate, 396
in RO feedwaters, 370
in water supplies, 234
Sulfides, removal by slow heating, 646
Sulfite, 305, 498
Sulfite-based one-drum program formulation, 557
Sulfite/bisulfite, 208
Sulfite oxygen scavenger, 417
Sulfite pulping process, 58, 445
Sulfite/sulfite derivatives, as oxygen scavengers, 482
Sulfonate groups, 442
Sulfonated styrene maleic anhydride, 451
Sulfonated vinyl radical, 444
Sulfones, as biocides for fuel oils, 686
Sulfonic acid group, in ion-exchange resin structure, 327
Sulfur, 54
as combustant, 691
reaction producing sulfur dioxide, 691
Sulfur compounds, 673
Sulfur dioxide, 682
breakdown in steam-condensate systems, 291
in combustion chamber, 676
in steam-condensate systems, 284–285
from sulfite, 486
Sulfur gases
emissions of, 676
in acid rain, 675
Sulfur trioxide, 682
in combustion chamber, 676
Sulfurated ash deposits, 676
Sulfuric acid
in cleaning processes, 641
for RO pretreatment, 367
forming under pits, 250
from sulfur gases, 680
Sulfuric acid regenerant, 349
Sulfurous acid, breakdown in steam-condensate systems, 291
Superfloc™, 318
Superheat, degree of, 602
Superheater deposits, 90
Superheaters, 71, 90–91
  convection (WT), 44
  convection type, 90
  horizontal arrangement, 90
  interdeck arrangement, 90
  nondrainable, 608
  pendant arrangement, 90
  platen arrangement, 90
  radiant (WT), 43, 90
  secondary (WT), 47
  wet lay-up by flooding, 609
Superheaters and reheaters, 90–91
Superior®, nonchemical technology, 338
Supersaturation, 144
Surface acting agent, antifoam/defoamer
chemicals as, 549
Surface-acting properties, of process
contaminants, 550
Surface adsorption reaction, of hydrazine, 492
Surface cleaner, PEG as, 553
Surface condenser, 114
  operational problems, 117–119
  Surface shielding, in corrosion processes, 247
Surface (skimmer) BD arrangement, 76–77
Surface spreading action, of antifoams, 551
Surface tension, increase due to impurities, 283
Surfaceant antifoam/defoamer chemicals as, 549
Surfaceant properties, of amines, 543
Surfactants, in fuel additives, 680
Sur-gard®, 497
Surging, 33, 115, 154, 155, 183, 282, 284,
  294, 296
  from excess softener chlorides, 661
Surging control, as functional area requiring
chemicals, 387
Surging, steam–water interface
  physicochemical factors as, 282–284
Survival pressure
  of DEHA, 496
  of ethyborbate, 499
Suspended iron, 663
Suspended solids, 306
  calculations for BD requirements, 580
  in raw water, 304
Sweet water, 402
Synergism, using phosphate, 419
Symperonic® 1L2LFL, 552
Synthetic tannins, 388
Tag-out/lock-out rules, 599
Tagged polymers, 662
Tallow–based fillers, 537
Tallow propylenediamine, 540
Tallow alkyl-dimethylamine, 540
Tarm® 850–960, 446
Tank sludging, 672
Tannic acids, 505, 568
  historical perspective, 393
  sodium salts, 405
Tannin application notes, 406–410
Tannin-based corrosion inhibitors,
degradation of, 582
Tannin-based one-drum program formulation,
557
Tannin-based products, as oxygen scavengers,
483
Tannin blend concentrates, 405
Tannin blends, 171
Tannin chemistries, 405–406
Tannin Corporation (Peabody, MA), 445
Tannin extracts, historical perspective, 392
Tannin index/value, 407
Tannin programs, 388, 403–410
  tannin application notes, 406–409
  tannin chemistries, 405–406
  tannin program formulations, 409–410
Tannins, 168, 184, 208, 237, 283, 394, 395,
  438, 443, 444, 498, 505–506, 550
  mixing with amines, 485
  lignin-based sludge dispersants and,
  444–445
  liquid single types, 445
  multiblended inhibitors, 405
  natural, 404
  spray–fired, 445
  synthetic, 404
  thermal decomposition limits, 591
  wattle, 30
Tap water, as source for RO, 364
TAR, 237
TDS levels, in higher quality water, 304
Tea bush, 408
Technical supervisory service, 127
Telfon®, 534
Temperature
  condenser terminal difference, 118
  saturation, 4
Temporary hardness, 223, 311
Terminalia chebula, tannin, 405
Terminology
  boiler, 1
  boiler plant, 1
  steam generator, 1
  steam-raising plant, 1
Terpolymers, 442, 446, 447
  as adjuncts, 389
  use of to control iron fouling, 197
Tetradebate ligand, 431
Tetrahydro-p-isoxazine, 520
  1,3,4,5-Tetrahydroxy-cyclohexane-carboxylic
  acid, 405, 506
Tetrapolymers, 442
Tetrapotassium pyrophosphate, 123
Tetrasodium-EDTA, in cleaning processes, 646
Tetrasodium pyrophosphate, 422
Boiler Water Treatment: Principles and Practice

Tetrazines, 505
Texaco Corporation, 519, 520, 686
Thermal aging, of oxides, 297
Thermal breakdown, 219
inspection for, 620
of treatment chemicals, 237
Thermal conductivity, 148
Thermal cycling, 665
Thermal cycling stress, 258
Thermal decomposition, of fuels, 673
Thermal fatigue cracking and corrosion fatigue, 258
Thermal fluids, 1
Thermal gradients, effect at boiler surfaces, 468
Thermal oxidation, 91, 261
Thermal shock, 98
to ion-exchange resin, 327
Thermal sleeve, 601
Thermal stability of amines, 511, 530–531
Thermo-compression evaporator, see
Evaporator, thermo-compression
Thermodynamic steam traps, 92
Thermo-expansion FW regulator, 80
Thermohydraulic FW regulator, 80–81
Thermostatic steam traps, 92
Thin film composite polyamide cartridges, 365
Thinning of vertical tubes, condensate
corrosion producing, 289
Thiocarbamide, in cleaning processes, 643
Thios, in cleaning processes, 647
Thiomorpholine, in cleaning processes, 647
Thioare, in cleaning processes, 637, 642, 647
Thorium, 232, 62
Thorium, 233, 62
Threshold agents, 166, 176
function of all-organics, 443
Threshold effect, 398
function of all-organics, 443
by phosphate action, 400
of polymers, 413
Threshold mechanisms, 432
for RO pretreatment, 369
Threshold phosphate, 202
Throttling calorimeter, 9, 278
Tin, 210
Toluol, 686
Tolyltriazole, 395, 401
Top drum, inspection of, 618, see also Steam drum
Top water-wall headers (WT), 46
Total alkalinity, 546
requirements with phosphate, 420
Total hardness, definition, 223
Total organic carbon, 457
rejection rate with RO, 361
Total solids, control with AVT programs, 476
Total volatiles, of fuels, 670
Tough gel, in bead resin deep-bed polishers, 380
Tracer dye polymer, 662
Tracer dyes, 179, 662
Transgranular cracks, 465
Transport
of boiler water solids, 202, 203
of iron oxides, 662
of metal oxides, problems caused by, 297
of scale and corrosion debris, 204, 211,
285, 296–298
Transport agent, function of all-organics, 443
Transport-Plus™, 455
Transported iron, 663
Transported iron and copper oxides, 530
Transported metal, 508
Transported silt, 550
TRASAR®, 441
TRC® 233, 447
Treatment of NP primary circuit coolant water, 477
Treatment of NP secondary circuit working fluid, 478
Treatment processes, pre-boiler and post-
boiler, 303–383
Treatment programs, optimizing in HP
industrial boilers, 661–662
Tri-Act®, 544
Triaminoanilines, 505
Triammonium-EDTA
in cleaning processes, 638
oxidizer mix, in cleaning processes, 645
Tricalcium phosphate, 145, 422, 423
in boiler deposits, 635
historical perspective, 392
scale, 235
Trichloroethylene, in cleaning formulations, 650
Triethanolamine, 498
in cleaning processes, 644
Trichloromethanes
contaminant in steam-condensate systems,
291
removal by carbon filters, 323
removal of by membrane technology,
360
1,2,3-Trichloroxygenzene, 506
from tannins, 406
3,4,5-Trichloroxygenzene acid, 405, 506
Tri-bed, design of resin bed, 353
Trion-3™, 332
Triple bed, design of resin bed, 353
Triple condensate polisher, 380
Triple-membrane process, for high-purity
water, 374
Triple-membrane purification, 345
Trisep Inc., 361
Trisodium phosphate, 123, 399, 421
historical perspective, 392
in cleaning solutions, 652
Triton N101, 686
Troubleshooting boiler operations, 657–667
identifying high water losses in HW heating and other closed-loop systems, 659–660
managing high silica levels, in raw water makeup, 658
managing high sludge problems in lower pressure boilers, 657–658
optimizing treatment programs and control parameters in high-pressure industrial boilers, 661–665
significance of hardness breakthrough in lower pressure boilers, 660–661
significance of high iron levels when operating a chelant program, 658–659
Try cocks, see Gauge cocks
Tube bifurcation, 55
Tube failure, 168
Tube flare, inspection of, 619
Tube hanger, inspection of, 620
Tube heat transfer rate, measurement, 623
Tube rupturing, 257
Tube sheet, inspection, 617
Tuberculation, 246–247
Tubercules, as binding agent, 232
Tubes
bent, 41
inspection for dishing, 616
inspection for thinning, 617
inspection of deterioration, 616
inspection of leaks, 616
inspection of surface, 616
leaking in condenser, 118
Turbine and condenser operation efficiency, 20–22
Turbine efficiency, effect of condenser, 116
Turbine overspeed, 282
Turbine pumps, 89
Turbines, 71
extraction, 21
noncondensing, 21
operating efficiency, 20
reheat condensing, 21
Turboinn boilers, 623
Turbulent flow, in boiler water, 143
Turndown ratios, 16, 19
Tuyeres, 84
Tween, 545
Two-drums programs, 555
Two-phase boiler, see Boiler, two-phase
Two-phase nuckleate boiling, 465
Two-phase systems, fundamental problems, 140
Two-pipe heating system, 133
U value, 218
Ucon, 686
Ucon 50-HB-5100, 553
 Ultraclean Technology, 624
Ultrapurification, 324, 359
as purification technology, 342
Ultrasonic testing, 622
Unburned carbon, 677
Undersooting of rolled ends, 619
Undertie deposit corrosion, 248
Underfed stokers, 84
Uniform general corrosion, historical perspective, 393
Uniform rate corrosion, 245
Unihib 106-305, 449
Union Carbide Corporation, 519, 520, 553, 555, 686
United States Department of Agriculture, 484
Unshared electron pairs, due to basicity, 524
Unstable treated water, 202
Upcore design, of resin bed, 352
Upflow precipitation softening, 311
Uptake funnel precipitation softening, 311
Uranium232, 62
Uranium235, 62
Uranium238, 62
Urea, 684
in steam-condensate systems, 292
U.S. Department of Health, 484
U.S. Energy Federal Technology Alert, 333
U.S. Filter, 353, 375
Use of glycols, problems associated with, 177
Utility power boilers, 53–55
U-tube nanometer, 86
Vacuum deaerators, 108
Vacuum pumps, in condensers, 117
Valve
automatic non-return, 73, 80
blowdown, 73, 74
blowdown for coil boiler, 74
blowdown for firetube boiler, 74
blowdown for marine boiler, 74
blowdown for vertical firetube boiler, 74
blowdown for watertube boiler, 74,
blowoff, 73, see also Valve, blowdown
drum safety, 73
feed line check, 73
feed line stop, 73
outside stem and yoke, 79
pop type safety, 79
safety, 79
safety relief, 73
shut-off, 73
side-action lever, rapid opening, 75
slow-opening angle, 75
steam huddling chamber, 79
steam line stop, 73
stop, 73, 79
super-jet safety, 79
superheater safety, 73
Vanadate complexes, as fireside deposits, 676
Vanadium, 681
  in clinker, 684
  compounds in fuel, 674
  in fuels, 673
Vanadium pentoxide, 674, 675
  as fineside deposits, 676
  as slag component, 682
Vanadium sulfate, as slag component, 682
Vapor compression evaporator, see
  Evaporator, vapor compression
Vapor-phase amine, 526
Vapor phase inhibitors, 389
  as program primary support chemicals, 385
Vapor phase programs, 464, 474–476
Vaporizing oil burners, 83
Vaporous silica and other steam volatiles, 293–295
Variable water level, submerged electrode
  boilers, 28
Varnish, 205, 300
VCI materials, for lay-up programs, 610
Vented receiver, inspection of, 621
Vents, boiler, 80
Verna® TL-3, TL-4, TL-7, 451
Versene®, 432
Vertical boiler, see Boiler, fire tube, vertical
Vertical recirculating inverted U-tube NP
  steam generator, 66
Vinylbenzene, 443
Vinylformic acid, 446
Viscosity improver, 672, 685
Viscosity of fuel oils, 672
Vitamin C, 497
Vivendi, 353
VOC removal, using multifunctional water
  conditioners, 332
Volatile corrosion inhibitors, for wet lay-up, 609
Volatile neutralizing amine, with AVT
  programs, 475
Volatile organic scavengers, 483, 489, 511, 521
  with AVT programs, 474
Volatility, 521
  of amines, 511, 526–520
Volatility, relative volatility, and distribution
  ratio or partition coefficient, 526–530
Volcanic lake media, 309
Volumetric heat release rates, 14
VPI, 389, see also Vapor phase inhibitors
Vulcan Chemical Technologies, 318
Vyncke special-purpose boilers, 59
Walls, inspection of, 620
Wastage corrosion, 245
Waste heat and other special purpose boilers,
  56–59
  basic oxygen furnace boilers, 57
  black liquor recovery boilers, 57–58
Waste heat and other special purpose boilers
  (continued)
  carbon monoxide boilers, 57
  combined cycle boiler systems, 59
  enhanced oil recovery boilers, 58
  fluidized bed combustion boilers, 58
  steelworks waste heat boilers, 57
  sugar refinery boilers, 59
  Vyncke special-purpose boilers, 59
  waste-to-energy boilers, 59
Waste heat boiler, see Boiler, waste heat
Wastewater treatment system, 72
Waste-to-energy boilers, 59, see also Boiler,
  waste-to-energy
Water
  boiling by heat transfer, 4
  dipolar nature of, 2
  entrained, 9
  in fuel oils, 671
  pretreatment plant system, 69–70
  triple point of, 7
Water analysis records, 631
Water chemistry control limits, tables and
  supporting notes, 566–598
Water chemistry, control of, 157–158,
  559–598
Water column gauge glass, 73, 75, 82
Water columns, 82
Water conditioners
  multifunctional, 331–332
  multifunctional booster unit, 332
Water conditioning, see Water, pretreatment
  plant system
Water content, of fuels, 670
Water hammer, 5, 91, 183, 276
Water in steam, 604
Water levels, 281
Water losses
  excessive or uncontrolled, 180–182
  prevention of in MHP/HHP systems,
  186
  identifying in closed loop systems,
  659–660
Water meter, need for, 179
Water pretreatment plant system, 69–70
Water softening, need for, 160–161
Water-soluble surfactant, in cleaning
  formulations, 651
Water treatment capital equipment, need for,
  158–163
  need for deaerators and other equipment,
  161–162
  need for water softening, 160–161
  need for silica removal, 162–163
Water treatment management reviews,
  126–127
Water treatment for nuclear powered steam
  generators, outline of, 477–478
Water treatment practice, effective, 156
Index

Water treatment program management, 125–129
chemical treatment additions, 125
chemical treatment testing and interpretation, 125–126
full-service and outsourcing programs, 127–129
water treatment management reviews, 126–127
Water treatment programs
need for internal chemical types, 165
Water treatment recommendation
perspectives, 560–566
ABMA Commercial BW Requirements and ASB BW Guide, 563–565
ASME Code, 561
BS2486, 562–563
McCoy BW, 565–566
Water tube boiler plant sections, 43–45
water tube convection-pass section, 44
water tube exit gas section, 45
water tube furnace section, 43–44
Water tube boilers, 39–61
high-purity steam generation, 60–61
steam-water circulation system, 45–47
types of WT boiler, 47–59
cogeneration boilers, 52–53
coil boilers, 49
industrial WT boilers, 49–52
marine boilers, 55–56
utility power boilers, 53–55
waste heat and other special-purpose boilers, 56–59
water tube boiler plant sections, 43–45
Water tube convection-pass section, 44
Water tube exit gas section, 45
Water tube furnace section, 43–44
Water tube steam generators, 50–52
Water-jet electrode boilers, 28–29
Water-tent appearance checks, 120
Water vapor in air, 689
determination, 693
Water-wall headers, inspection of, 618
Water-wall tubes (WT), 43, 45, see also Membrane wall tubes
Water Wizard, 332
Waterline evaporation, 250
Waterside dry lay-up, 610–611
Waterside fouling, 194
Waterside problems
interrelationship with boiler design/operation, 142
in hot water heating and low-pressure steam systems, 180–185
excessive water loss, 180–182
lead and lag boiler operation, 184–185
maintaining inhibitor levels and controlling BD and surging, 182–184
Waterside problems (continued)
limiting potential for, 156–172
controlling corrosion, 167–172
effective water treatment practice, 156–158
limiting deposition, 163–167
need for water treatment capital equipment, 158–163
in MHPW and HPHW systems, 185–189
Waterside and steamside problems, 131–301
basics of, 131–172
contamination, 154–155
corrosion, 149–153
deposition, 144–148
fouling, 153–154
fundamental steam-waterside problems and water treatment objectives, 140–144
hot water and steam system cycles, 132–134
limiting potential for waterside problems, 156–172
system of BW treatment and control of steam/waterside chemistry, 134–140
boiler section specifics, 217–271
boiler scaling, fouling, and deposition, 217–237
nuclear powered steam generators, corrosion in, 265–267
other forms of corrosion, 262–265
passivation and common corrosion problems, 237–254
stress and high temperature–related corrosion, 254–262
hot water heating and low-pressure steam boiler specifics, 173–189
problems of corrosion in hot water and LP steam heating systems, 178–180
problems associated with use of glycols, 177
other waterside problems, 180–185
problems with heating coils, 175–177
waterside problems in MTHW and HTHW systems, 185–189
post-boiler section specifics, 273–301
corrosive gases in steam and condensate systems, 284–293
oil and process contamination, 298–300
scale and corrosion debris transport, 296–298
steam purity and steam quality, 275–284
vaporous silica and other steam volatiles, 293–295
pre-boiler section specifics, 191–215
feedwater contamination from makeup water, 193–203
feedwater contamination from returning condensate, 203–206
Waterside and steamside problems
(continued)
overview of pre-boiler section waterside problems, 192
problems associated with final feedwater blend, 205–215
Waterside surfaces, operational control of, 599–667
boiler cleaning, 623–657
boiler inspections, 612–623
managing standby and idle boilers, 606–612
sampling and testing steam and condensate, 599–605
troubleshooting notes, 657–667
Waterside wet lay-up, 608–69
Wattle tanin, 237, 405
Waxes, 685
Weld defect problems, 174
Wet chemistry analysis, 622
Wet desulfurization system, 54
Wet lay-up
of boiler auxiliaries, 609
by cascading BD, 609
programs, 606
protection of waterside, 608–609
Wet steam, 604
Wetback boiler, see Boiler wetback
Wetness/dryness degree of in steam, 604
Wetting agents, in cleaning formulations, 650
Wheatstone bridge, 623
Wick boiling, 14
Wire drawing, 76
Wood flour, as fuel additive, 678
Wood fuel, 17
Wood, as fuel, 51
W.R. Grace, Inc., 432
WT boilers, inspection of, 618–621
fiendside inspections, 620–621
waterside inspections, 618–619
Wustite, 233
X-ray diffraction, 622
Xenon, in air, 689
XTM, 375
Xonolite, 229
Yellow metal protection, 395
Zeolites, 326
historical perspective, 391
scale, 411
softening, 391
treatment, 308
Zero enthalpy, 2
Zero solids treatment programs, 464,
474–476, 478, 546
ZetapTM, 318
Zinc, 210
Zinc anodes, 167
with nontoxic technology, 334
Zinc oxides, 146
in corrosion debris, 296
transport of in condensate, 231, 232
Zinc sludge, as fuel additive, 678
Zinc transport, 212