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Horace R. Corbin, P.E.

Give Us Your Tough Issues
And Your Biggest Goals.
We'll Get Right To The Heart Of It

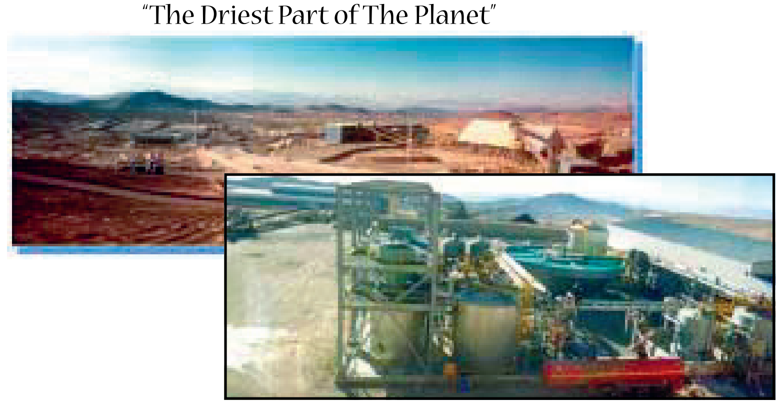
Projects

Horace and associates assist clients on major projects throughout the United States and in many foreign countries. Mr. Corbin, chemical engineer, has 40 years experience in chemical, refinery, pharmaceutical, electric power generation (nuclear and fossil), mining, pulp and paper, electronics, food processing, water, and wastewater engineering.

Horace has several innovations to his credit involving germanium, technetium, tire manufacturing, acid production, nuclear power, reverse osmosis, high strength organic waste, power plants, environmental permitting, process design, Zero Liquid Discharge and systems control.

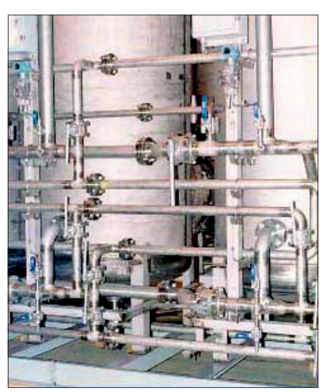
Horace has published many articles including those for the American Chemical Society, TAPPI, Power Magazine and Chemical Processing Magazine.

"The Driest Part of The Planet"



Copper Mining On Top of The World...
The Andes Mountains, Zaldivar, Chile.

"We employ modern tools, talented people, innovation and dedication to enhance our services for our clients. We are devoted to maintaining leadership in these areas."



Technetium Separator

Technetium Exists
Only in the Stars....

Created by stellar nuclear reactions, it doesn't exist naturally on this earth.

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Driest Part of the Planet

Copper Mining at 13,000 feet... Without a drop of rain in 40 years, the Atacama high desert plateau in the Andes mountains in northern Chile is considered the driest part of the planet. It has the appearance similar to the surface of the moon. This area is the reserve of the major source of the worlds' copper ore. As luck would have it, modern techniques for copper electrowinning require high volumes of ultra pure water. WCA, Inc., as part of the team with several other organizations (Placer Dome, Fluor Daniel, BHP, Minera Escondida and others) are solving these mining production challenges.First, locate saline water in a volcanic aquifer, then pump it 60 kilometers horizontally and a mile straight up to the mountain (a considerable feat). Once at the mine, desalinate it to ultra pure water. The water system must also provide for the potable and sanitary needs of the miners.Add "fast track" scheduling to multi-lingual design, construction and operation. Link the engineering teams from many locations throughout the world over the Internet. Computerize the operation to achieve the necessary efficiency and reliability. Convert your ocean going cargo containers to living quarters at 13,000 feet elevation.That's what it's like at the driest part of the planet!

Technology Consulting Worldwide Chemical Process, Water, Waste, Production, Environmental, Research, Development, Consulting, Plant Design, Supply, Automation, Control, Instrumentation, Data Communication, Project Management

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Technetium Exists Only in the Stars....

Created by stellar nuclear reactions, it doesn't exist naturally on this earth. Yet, uswca.com technology and equipment are helping to eliminate this nasty pollutant from a U.S. Department of Energy facility.

Since the end of the Cold War, disarming Soviet Union nuclear weapons is creating radioactive Technetium wastewater - uswca processes and decontaminates the wastewater. Ultimately, the radioactivity is isolated (for a few thousand years) in solid concrete. The Technetium contaminant is separated from the wastewater and converted into a solid form by using special absorbing and reactive metal media.

Elemental Technetium, discovered in 1937, has about 19 radioactive isotopes with atomic masses ranging from 90 to 108. Some isotopes decay rapidly. The isotope 95m_Tc has a half life of 61 days. This rapidly decaying isotope is used as a tracer in the medical diagnosis of certain human ailments. Other isotopes have a half life measured in thousand of years. The isotope 97_Tc has a half life of 2.6 million years. This is troublesome.

Technetium was the first element to be produced artificially. Searches for the element in terrestrial materials has been without success. However, Technetium has been found in the spectrum of S-, M-, and N-type stars.

Corbin Consulting has assisted with many projects. Each one has an interesting technical, commercial and/or manufacturing story.

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Aerobic & Anaerobic Biological Wastewater Treatment

Many wastewaters are purified of soluble organic contamination by utilizing the metabolic functions of microorganisms.

Specials machines maintain precise conditions so that specific cultures thrive. These cultures feed on the wastes and purify the water. Two basic processes are employed.

The Aerobic process grows microbes requiring the presence of dissolved air (oxygen) in the water. This is normally accomplished with open chambers and air blowers. The Anaerobic process grows microbes that cannot exist with dissolved air in the water. So, the reactors are closed to the atmosphere. The plants can be large or small.

Treatment Plants are custom designed for each specific application. The nature and quantity of the wastewater are the largest factors influencing design configuration. A small size system is shown on the right.

Clarification

Treatment plants are composed of multiple unit operations, arranged in a coordinated manner to ensure performance and to minimize costs. A complete instrumentation and control system is required in modern day facilities.

Digestion

With attention to design detail and with proper training of personnel, the facilities can be easy to operate and to maintain.

Aeration

To protect the environment and to achieve regulatory compliance for wastewater discharge, many tools and considerable experience are available.

Oil Water Separation

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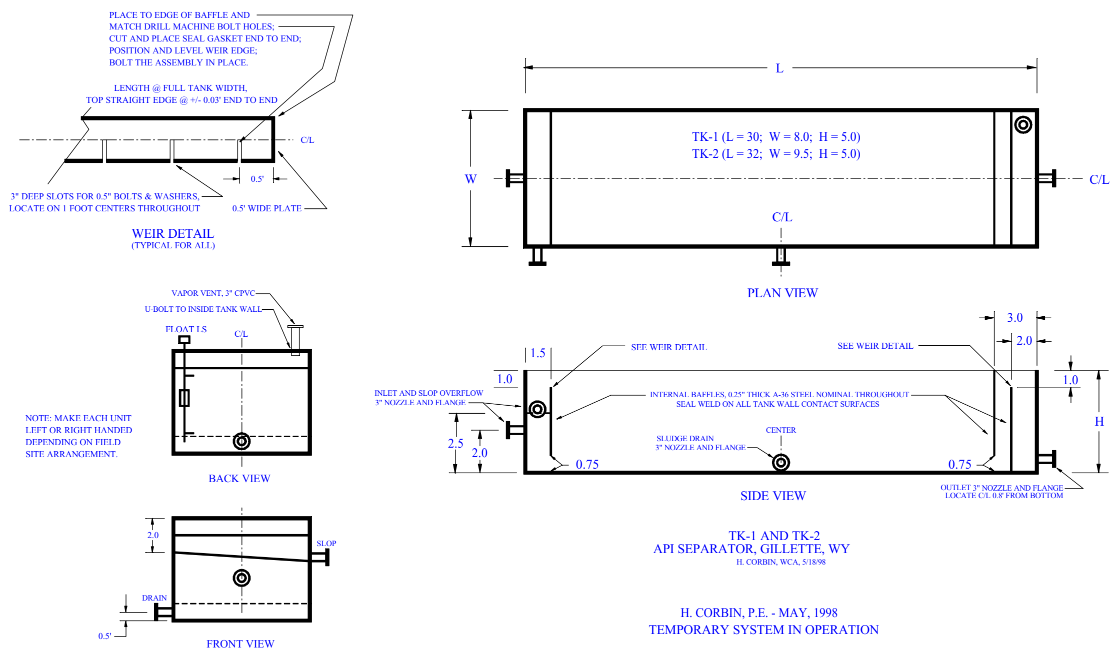
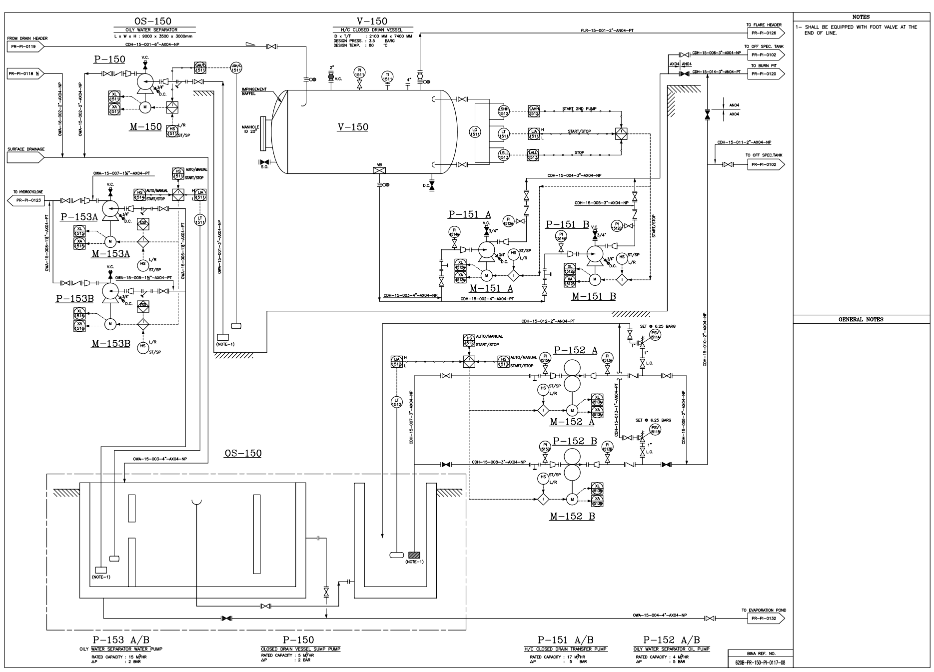
Summer 2010

One of the world's largest environmental disasters is occurring in the Gulf of Mexico, 5,000 feet below the surface of the ocean with oil gushing into the sea and on to beaches. Officials seem paralyzed to respond. Solving the ruptured drilling rig pipe is for sure a tremendous challenge.

However, mitigation seems forestalled though a massive effort is ongoing to assess the blame. Many of the world's experts have not been requested to assist, or even allowed.

Most times, the solutions to the most challenging problems start with the basics.





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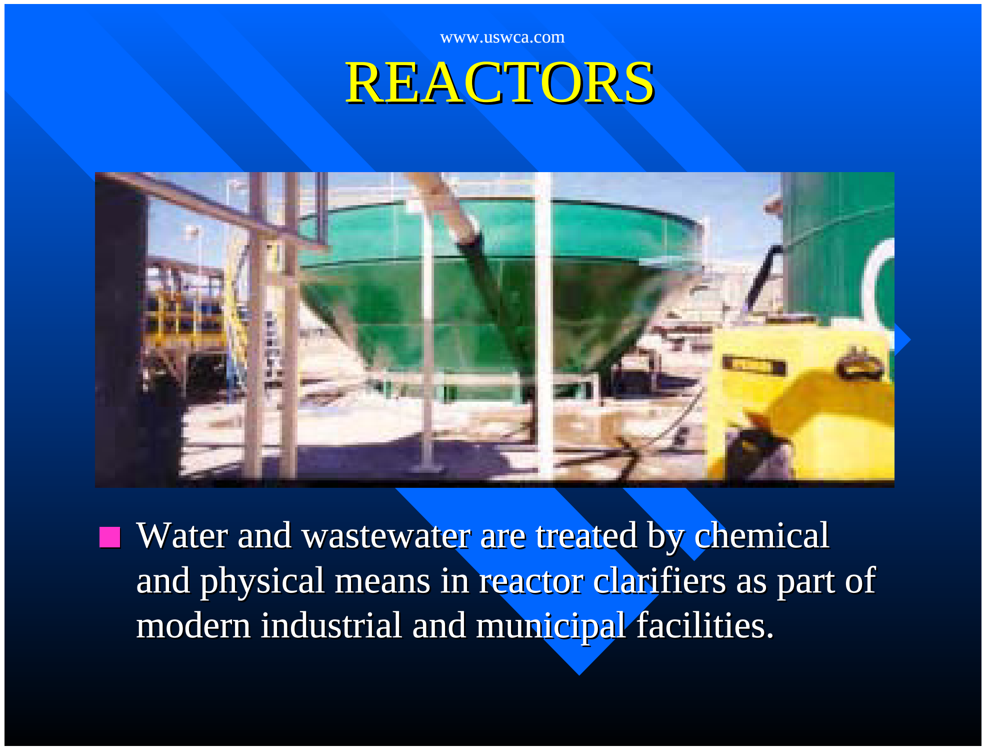

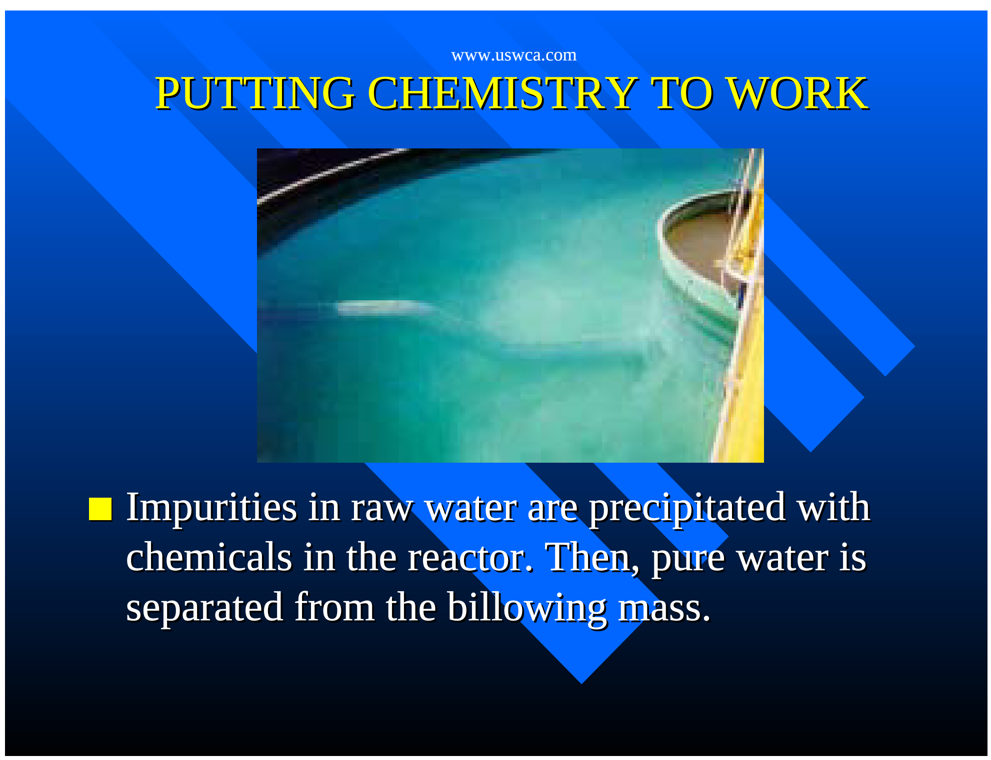

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Copper Mining

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UP, UP AND AWAY

- Copper mines in northern Chile are high in the Andes Mountains, hundreds of miles from...well.

WCA Engineers

LUNAR LIKE

- Not a drop of rain in 40 years, the Atacama high desert plateau is considered the driest part of the planet.

WCA Engineers

HUNGRY, VERY HUNGRY

- Tons of ore are moved in seconds over distances of miles.

WCA Engineers

PROCESSING COPPER

- Copper is dissolved from crude ore then converted to pure solid plate in electrowinning facilities.

WCA Engineers

MILES AND MILES

- Processing facilities cover huge areas at the Chilean copper mines.

WCA Engineers

REACTORS

- Water and wastewater are treated by chemical and physical means in reactor clarifiers as part of modern industrial and municipal facilities.

WCA Engineers

STACKS AND STACKS

- Reverse Osmosis membrane stacks remove the salt from high pressurize water.

WCA Engineers

TOUGH GUYS

- Copper mining in the Andes is not for the timid or frail. Highly skilled men from around the world master the challenge.

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Professional Profile
Horace R. Corbin, P.E.

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Horace Corbin is the owner of Corbin Consulting and of Watchung Communications, Inc. Company profiles are available at www.uswca.com and at www.goleader.com. Mr. Corbin has 40 years of business, engineering, and publishing experience. He has directed and served on many engineering projects involving nuclear energy, electric power generation, mining, refining, pharmaceutical, chemical, potable water, sewage, industrial waste, air pollution control, solid waste, "SuperFund"cleanup, pulp & paper, fiber optics and food & beverage processing throughout North America, South America, Europe, the Middle East and the Far East.

Mr. Corbin is a registered professional engineer and a newspaper publisher in New Jersey. He has practiced professional engineering in several states including New York, New Jersey, Pennsylvania, California, Florida and Texas.

EDUCATION: Mr. Corbin is a chemical engineering graduate from Drexel University and elastomer technology from the University of Akron. He has many business, management and technical continuing education courses to his credit. He has authored several articles for publications including *Power Magazine*, *Chemical Processing*, American Power Conference, TAPPI and the American Chemical Society. He has lectured at many business and trade associations.

WORK HISTORY: Mr. Corbin was employed by Mobil Oil, Dupont, Exxon Research and Engineering, Graver Water Co., R. F. Weston Consulting Engineers and Degremont. He served in several capacities including research, development, design, management, sales and marketing. For the past 20 years, he owns and operates engineering consulting, newspaper and Internet publishing companies.

ENGINEERING PROFICIENCY: Mr. Corbin provides consulting for project development, economic review, Due Diligence, Expert Witness, concept & process design, instrumentation, control, communication networks, information management, training, documentation and troubleshooting for industry, government, authorities, financiers, architects, engineers, constructors and developers.

SYNOPSIS OF PAST WORK: In the 1970's, Mr. Corbin commissioned several nuclear power plant facilities in the U.S. and Sweden involving radwaste treatment, reactor cleanup, fuel pool cleanup and condensate polishing. He commissioned advanced phosphorus removal for the EPA and designed water reuse techniques for pulp and paper. He led technology transfer from Germany for electromagnetic filtration of nuclear reactor core water, applied the use of reverse osmosis for high pressure boilers and developed new techniques for tire, inner tube and chemical production. In the 1980's on New York City's sewage treatment plant upgrades, Mr. Corbin served in retrofitting the headworks, inlet bar screens and digester screens, which comprise some of the world's largest sewage treatment facilities. Also during this era, Mr. Corbin teamed with Exxon Engineering in developing air pollution oxidation treatment and catalyst fines removal processes, which are now the standard for the world's refinery operation. In the 1980's and 1990's, Mr. Corbin developed and implemented Zero Liquid Discharge technology for several dozen power stations and trash incinerators in the northeast, Florida, southwestern U.S. and California. In the 1990's, Mr. Corbin created advanced water systems for the world's largest copper mines located in Escondida and Zaldivar, Chile. In the 2000s, Mr. Corbin is focusing on senior level consulting for law firms and major corporations in expert testimony, business development, "Going Green" initiatives, environmental issues, market economics and productivity.

Mr. Corbin served on teams for many varied projects including potable water and sewage systems, village water and sewage systems, hospital wastes, toxic wastes, advanced tertiary systems, sterilization, anaerobic and aerobic food & pharmaceutical wastewater treatment, SuperFund cleanup, potable water systems with ozone, power plant cooling, germanium recovery for fiber optics manufacturing, oil/water separation in refining and steel making, technetium removal in weapons disarmament and luxury hotel utility systems. Mr. Corbin pioneered the use of computers, instruments, controls and networks to manage and optimize complex facilities and to coordinate regional operations.

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ZLD

Cedar Bay 1994
Crystallizer
2 Evaporators

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Crystallizer
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TECHNICAL REPORT - ZERO DISCHARGE CONSIDERATIONS
December 2, 1991 - WATER CONTROL ASSOCIATES, Inc.

INTRODUCTION

As of 1991, WCA has engineered and supplied eight (8) Zero Discharge Systems since 1986 with others currently under design. The Systems are innovative, work well, and cost effective. Four of these plants are in New England (Ocean State in Rhode Island for Ebasco/Bechtel/G.E., 2 in New Hampshire, 1 in Maine). WCA is currently engineering what may be the largest and most complex system in the world (Cedar Bay - Jacksonville, Fla.).

An innovative installation to date is in Delano, CA (in operation for 1 & 1/2 years). WCA is engaged to double the Delano size for a second power block currently underway. It is "Advanced", which means practical & economic, innovative process design and application, "state-of-the-art" automation and controls, low parasitic power and chemical requirements, straight forward operation and maintenance, optimum environmental sensibility; (essentially "smart" steel with chemical engineering and operations "know how"). WCA incorporated several proprietary features in the system which make this possible.

For Delano Unit 1, WCA's customer was ABB & Schneider Engs. through the developer, Thermo Electron of Waltham, MA. On Unit 2, ABB is supplying the turbine generator, UE&C Boston provides general engineering, and WCA is supplying the water system direct to Thermo Electron. Other systems are in various stages with divisions of ABB, Bechtel, Schneider, Simons Eastern, Ebasco, General Electric, Westinghouse and others.

WCA provides Professional Services, permitting assistance, construction management, contract operations and maintenance in the specialty of Zero Discharge. WCA compliments the efforts of others as part of the team. This arrangement has produced excellent results; effective Project and Cost Management; satisfied owners, operators, and suppliers.

When providing design/supply contracts, WCA uses "Top-of-the-Line" components from suppliers who include Netszch, Komline Sanderson, Infilco Degremont, Allen Bradley, Duriron, Goulds, instrument and control suppliers, resin suppliers, R.O. components, Alfa Laval, Marley, Milton Roy, vessel and fabricating shops, and many others.

A Zero Discharge System includes several subsystems such as:

1. Reverse Osmosis for Makeup Demineralization.
2. Sidestream Treatment of the Cooling Tower.
3. Secondary Waste Reactor.
4. Waste Brine Concentrator (evaporative tower or mechanical).
5. Crystallizer (steam, mechanical or submerged combustion).
6. Solids and Salt Slurry Dewatering.
7. System Integration and Control.

ZLD - Delano, CA 1990

- Water and wastewater are treated by chemical and physical means in reactor clarifiers as part of the power station facility.

8. Chemical Optimization and Reuse.

TECHNICAL DISCUSSIONS:

THE WATER SUPPLY - Detailed raw water source(s) analyses are required for system design. Is more than one supply to be utilized? Is City water or well water to be used for boiler makeup and NOx suppression requirements? Is river water, other surface water, well water, or recovered wastewater to be used for cooling tower makeup? The analyses of all sources are to be determined.

RAW WATER PRETREATMENT - In general, it is not necessary to pretreat cooling tower makeup from most water sources. It is usually more effective (technically and economically) to employ sidestream treatment of the cooling tower. In extreme cases, both pretreatment of the makeup and sidestream treatment are required for optimum cooling tower operation in Zero Discharge Systems.

High hardness supplies, high turbidity surface waters and recovered wastewaters (such as secondary STP effluent and industrial effluents) used as cooling tower makeup generally require pretreatment. Pretreatment and/or Sidestream Treatment may be recommended when applicable.

As a precursor to reverse osmosis and ion exchange, water supply pretreatment is required. For City waters, this pretreatment may be limited to pH adjustment, chlorine removal and polishing filtration. For other supplies, elaborate pretreatment may be required including clarification, sand filtration, acidification, degasification, activated carbon, and cartridge filtration. WCA will advise the nature of pretreatment required based on the supply characteristics.

PARASITIC POWER - It is environmentally (and economically) unproductive to expend extensive parasitic power (connected and operating) for the operation of evaporators and crystallizers in Zero Discharge Designs. WCA recommends avoiding (or minimizing) this, wherever possible, with alternate design techniques.

Parasitic power consumption is environmentally undesirable. Substantial environmental releases occur from parasitic power generation (thermal, air, water and solid waste). Electric power generation is energy inefficient. Therefore, the best Environmental Plan strongly favors minimizing the parasitic load. Waste energy reuse and direct energy conversion are favored in WCA designs when energy consumption becomes necessary. Prior to this, every design effort is made to minimize this requirement.

Power stations have an abundance of waste energy which can be used for wastewater concentration at little cost and with environmental sensibility. The condenser is the primary source. Waste extraction steam, boiler blowdown and others can be applied as supplement when and if required.

CHEMICAL USE MINIMIZATION - Avoiding the use of chemicals is a paramount factor in Zero Discharge Design. INPUT = OUTPUT + ACCUMULATION. When chemicals must be used, discriminating application, integration, control, and reuse are invoked to realize efficiency.

To avoid buildup in the system, releases to the environment, and equipment malfunction; synthetic organic chemicals must be largely excluded from the plant (polymers, dispersants, antiscalants, organic biocides, etc.). Only "natural earth" inorganic chemicals (acid, caustic, lime, soda ash, MgO, etc.) are recommended. The benefits of this policy have been well established.

"RESTRICTED CHEMICAL USE" procedures required by Zero Discharge operation may be unfamiliar to many due to past conventions and chemical supplier recommendations. WCA provides detailed process and operating specifications to simplify implementation and to optimize performance.

BOILER MAKEUP TREATMENT - As a first step, designs using reverse osmosis for boiler makeup and NOx suppression are recommended. The R.O. effluent is polished by Mixed Bed ion exchange. Acid and caustic use is reduced by ~95% compared to that of "standalone" conventional ion exchange. Waste quantities are reduced correspondingly. Waste neutralization is not employed. If possible, on-site ion exchange regeneration should be entirely avoided.

Otherwise, small regeneration wastes that result are reused; by keeping them separate and by feeding them as reagents to other processes within the wastewater and cooling tower system. The R.O. reject, relatively dilute, is used as cooling tower makeup. By employing the above techniques, about half of the Zero Discharge Brine Management problems are avoided in most cases.

COOLING TOWER & CONDENSER CONSIDERATIONS - When suitably designed and controlled, the cooling tower is the most effective and sensible appliance for achieving Zero Discharge. No parasitic energy is consumed. Chemical use is minimized. The environmental impact is minor and is the lowest of all other alternatives.

As example: By applying Sidestream Treatment, plants in New Hampshire, Maine, and California operate without Tower Blowdown, expend no parasitic energy, and consume the minimum of chemicals.

At these installations (without the use of R.O.), the circulating water TDS is maintained at ~12,000 mg/l (sodium sulfate). Corrosion and fouling rates are very low. Chemical additives and environmental impacts are at a minimum. Materials of construction for the condenser, cooling tower, and piping are standard (typically admiralty brass and copper/nickel tubes). Titanium condenser tubes are used for severe duty applications. This permits high circulating water TDS operation in excess of 40,000 mg/l.

STACKS AND STACKS

- Reverse Osmosis membrane stacks remove the salt from high pressurize water.

In difficult applications, 316 SS tubes are not recommended due to the potential for chloride stress crack corrosion. One such example is where hot, bypass condenser service must be used during turbine dump, offline operation.

SIDESTREAM TREATMENT - Water supplies low in TDS make Zero Blowdown possible in cooling tower operation. Sidestream treatment acts as a kidney to the circulation loop. Calcium, silica, alkalinity, suspended solids, and microbial action are stripped from the system. Harmless sodium salts rise in limited fashion within the system to acceptable levels. Chemical additives are largely unnecessary.

Reference article abstract (Horace Corbin, Chemical Processing Magazine, August 1991).

COOLING TOWER CYCLES OF CONCENTRATION - This commonly used term is imprecise. Without further examination, design, environmental, and operating oversights can arise. Modeling of the specific circulating water parameters is required. These parameters include:

CIRCULATING WATER PARAMETERS

PARAMETER	DETECTION
1. Biological Activity	Algae growth
2. Viruses & Microbes	Laboratory Analyses
3. Suspended Solids	Mass Measurement
4. Chemical Organics	Chemical Oxygen Demand
5. Biodegradable Organics	BOD5
6. Metal Contaminants	Laboratory Analysis
7. Acidity/Causticity	pH & Alkalinity
8. Scaling Salts	Ca & SiO_2 Measurement
9. Soluble Salts	Ion Measurement

Each parameter has a distinct environmental and operating impact. The "mix" results in a synergistic and composite effect. The simplistic concept of "Cycles of Concentration" is of little assistance for precise engineering and operation. Detailed control of each parameter and the composite is required.

"Cycles" compares circulating water characteristic to that of the inlet water. Other significant influences are at work in the dynamics of operation. These include:

DYNAMIC FACTORS INFLUENCING CIRCULATING WATERS

1. Air Impurities Imparted to the System. 2. Residuals Resulting from Treatment Chemicals. 3. Biological Action. 4. Air Stripping of CO_2 and volatile organics. 5. Chemical Scaling. 6. Chemical Corrosion. 7. Chemical and Chemical/Physical Fouling. 8. Wastewaters Added to the System. 9. Impurities from the Makeup Supply. 10. Impurities purged by Blowdown, Drift, and Windage. 11. Effectiveness of Treatment Techniques. 12. Effectiveness of Control Systems.

DESIGN & CONTROL CONDITIONS FOR CIRCULATING WATERS
Extensive operating data and measurements have been collected and analyzed by WCA over the last several years. The design and control of the "Mix of Parameters" for circulating waters can now be precisely established for new plants to minimize water consumption, reduce wastes, assure reliable operation, prevent scaling and corrosion, and minimize impacts to the environment.

The design and operating window is summarized below:
CIRCULATING WATER DESIGN PARAMETERS (controlled with Sidestream Treatment)

PARAMETER	TARGET	RANGE
pH, S.U.	8.2	8-8.3
Ca, ppm	700	1000 max.
Mg, ppm	50	0-200
SiO2, mg/l	100	150 max.
HCO3, ppm	140 (fixed by pH)	
CO3, ppm	0 (fixed by pH)	
SS, mg/l	<20 (successfully maintained in all cases)	
Conductivity,	mmhos (no target limit, 25,000 database max.)	
Metals, mg/l	<.3 (successfully maintained in all cases)	
BOD5	<10 (higher values not observed)	
COD	no discovered limit up to 750 mg/l	

Nearly complete microbe and virus sterilization is maintained by the action of sidestream treatment (high pH shock kill and chem/physical removal) plus the use of inorganic bromine residual. This technique also eliminates algae and slim growth.

Notes: Organic treatment additives to the system are disallowed. Sulfuric acid is added for precision pH maintenance. No evidence of scaling or fouling has been detected with the above conditions after several years of observation. Corrosion coupons displayed rates less than 1 mil per year.

CASE STUDY (Plant A and Plant B):

At the time of design for the above plants, Zero Discharge technology was not mature. Experience and operating data were limited. The Engineers for the above projects chose different paths. Now, over a years' operating data are now available from each Plant to compare the successes of the different paths. Both plants achieve Zero Discharge.

From a chemical processing point of view, the plants are of similar size. Plant B is 30Megawatts compared to Plant A at 250 Megawatts per Unit. However, the Plant B water supply is several times higher in TDS. As such, the Zero Discharge operations are comparable.

PLANT A:

REACTORS

- Water and wastewater are treated by chemical and physical means in reactor clarifiers as part of modern industrial and municipal facilities.

At Plant A, Zero Discharge Water Systems (two stations) are equipped with 3 Evaporators, 3 crystallizers, 3 electro-dialysis concentrators, makeup ion exchange and pretreatment, waste neutralization, greensand filters for wastewater iron removal and sidestream treatment. The connected parasitic load exceeds 2 MegaWatts. The installed cost at Plant A for the water and wastewater facility was ~$20 million.

The operation of Plant A proves to be complex and expensive to maintain & operate. Continuous difficulty is experienced with evaporator and crystallizer fouling and mechanical failure. The EDR membranes are sensitive and foul.

The Plant A operating staff is overloaded with duties to keep the EDR, Evaporator, and Crystallizer operational along with the rest of the equipment. The water staff comprises 24 operators plus management, laboratory, and chemistry personnel.

UPGRADES TO PLANT A:

WCA demonstrated operation of Plant A for over a month using sidestream treatment and ion exchange improvements to maintain the circulating water below 4000 TDS while achieving Zero Discharge without the use of the EDR, evaporators or crystallizers. Modifications are now underway to make many of these provisions permanent.

From this work, it has been demonstrated that the use of reverse osmosis would be of significant benefit for the production of boiler water makeup and NOx suppression water while improving the Zero Discharge performance.

Membrane processes such as EDR are sensitive to fouling when used for wastewater concentration in Zero Discharge systems. Membrane processes are best applied on the clean waterside such as a precursor to ion exchange to improve chemical efficiency and reduce waste generation.

In power stations supplied with good quality water supplies, vapor compression brine concentrators (evaporators) are (may be) unnecessary, and the costly and difficult operating requirements can be avoided. Similarly, the use of crystallizers can be minimized.

PLANT B:

At Plant B, the WCA system employs ion exchange for boiler makeup production, chemical & waste reuse, sidestream treatment, a secondary waste reactor, a brine concentrating tower, and a 4 gpm evaporative pond. Connected parasitic load is ~150 HP. The water and wastewater facility including the evaporation pond was ~$2.5 million installed.

The system has operated reliably since startup. The circulating water is maintained at 20,000 mmhos with low corrosion and no fouling. The plant chemist operates the complete water system with assistance at night by a utility operator.

UPGRADES TO PLANT B:

To increase the capacity of the system to accommodate a second generating unit, reverse osmosis is being added for boiler makeup production. The current production of demineralized water by ion exchange generates approximately 50% of the station brine waste. This waste will be eliminated by 90% upon installation of the R.O.

Additional automation is being installed such that one operator can handle the added water duties created by the second generating station. Remote monitoring and technical servicing by telephone modem will be installed to connect the plant control system with WCA headquarters. This avoids the need to increase the size of the technical staff at Plant B.

PLANT A AND PLANT B CONCLUSIONS:

1. Both plants will benefit greatly with the addition of Reverse Osmosis treatment prior to ionexchange.
2. Plant B operates reliably with little manpower, maintenance, parasitic power, and chemical consumption. The sidestream techniques, chemical recovery, secondary waste reactor and Evaporative Tower are reliable and rugged. The brine waste volume resulting is small. Crystallizer processing is avoided by use of the evaporation pond. The control system and automation for integrating the system proves to be very important to the success. Additional control improvements and remote servicing provisions will be added.
3. Plant A is difficult to operate and maintain. Manpower requirements are excessive. Parasitic loads and chemical consumption are high. Electrodialysis, vapor compression evaporation and crystallization cause great difficulty and expense. Many of the techniques from Plant B will be installed at Plant A to improve circumstances.
4. A reliable and rugged crystallizing process is required for Zero Discharge operation. Where climatic and land conditions permit, evaporative ponds are ideal. Mechanically driven crystallizers appear unsatisfactory for the application.

BRINE MANAGEMENT CONSIDERATIONS:

Zero Discharge Systems require reliable and rugged methods for brine management and disposal. Four general methods exist: PREVENTION, DIVERSION, CONCENTRATION and CRYSTALLIZATION.

BRINE PREVENTION: The most effective management technique is to minimize brine production. The highest quality raw water source, proper use, and efficient preparation provides direct prevention. Proficient inter-plant processing (cooling tower operation, demineralized water production, chemical minimization, chemical reuse, and recovery) provide additional prevention. Applying automation, integration and processing "know-how" achieves significant results.

Where raw water supplies are good, PREVENTION TECHNIQUES in combination with NATURAL SYSTEMS LOSSES are sufficient to meet the complete brine management and disposal requirements in many applications to achieve Zero Discharge.

BRINE DIVERSION: Many processes within a power station can be arranged to consume brine laden wastewaters. These include ash quenching, dry flue gas scrubber injection water, ash treatment and spraying, interstitial water displacement of dewatered sludges and area wide washdown evaporation. With design integration, diversion is an important factor for brine management.

With PREVENTION and DIVERSION, most stations can achieve Zero Discharge without the need for CONCENTRATION AND CRYSTALLIZATION.

BRINE CONCENTRATION: Waste streams can be concentrated up to approximately 17%by weight salt by a combination of methods. Further concentration is not possible with these methods as sodium salt crystallization occurs which fouls the equipment. In the dilute concentrating range (up to 3-4% TDS) reverse osmosis and electrodialysis have been used. To achieve the higher levels of concentration, evaporation techniques are required.

Reverse Osmosis and Electrodialysis are membrane separation processes using electric energy to achieve the results. The details of these processes are not covered within this text. The processes are well understood and considerable data are published for the reader to explore, if desired.

In Zero Discharge Systems, membrane processes are sensitive to fouling and scaling when concentrating wastewaters. Dependable operation may not be possible. Therefore, their use is generally not recommended for this application. Membrane processes are best applied in clean water systems such as for demineralized water production.

EVAPORATORS are being used with reasonable success for brine concentration in Zero Discharge applications. Two basic evaporator methods are being used: Vapor Compression (falling film, slurry recirculation) and Evaporative Towers. Other evaporator types are available, such as multiple effect, steam driven units. These are not used in Zero Discharge System due to technical and cost limitations. The reader is referred to the CHEMICALENGINEER'S HANDBOOK by Perry for further detail.

EVAPORATIVE TOWERS: The simplest brine concentrating method is the Evaporative Tower. This system is similar to a conventional cooling tower. The waste stream is circulated within the tower system over packing and contacted by ambient air drawn through the system with fans. Heat is applied to the circulating water through a plate exchanger powered by station condenser waste heat. Higher temperature waste energy (steam, condensate, boiler blowdown, or combustion gas) can be applied as a supplement to increase the capacity of the system.

FROM THE TOP

- Four of these pressure vessels filter 2500 gpm of clarified water (about 500 M3/hr.).

Water vapor evaporates and exits with the exhaust air as a function of the relative humidity relationship. Feed is added to maintain level in the tower basin. The circulation fluid is monitored to control the conductivity (dissolved salt). A bleed stream of concentrate results.

Prior to entering the tower, the feed is processed by a reactor to strip calcium, magnesium and silica from the stream which prevents scaling. The pH within the tower is maintained between7 and 8 pH by acid addition. In this manner, the stream can be concentrated up to 17% by weight salt.

WCA has applied this system for use in Zero Discharge Systems. The installed and operating cost is low. Energy consumption is low as waste condenser heat is the primary source. The system is reliable, effective and requires little attention.

VAPOR COMPRESSION EVAPORATION: Waste streams can be concentrated to 17% salt and the pure water recovered as condensate by using the "Vapor Compression, falling film, slurry recirculation Evaporator.

The liquid within the unit is seeded and maintained with ~8% calcium sulfate crystals (to avoid scaling). This liquor is kept in constant circulation by pumping to the top of a vertical tube exchanger section. Liquor coats the tubes and falls to the main body for pumping.

A vapor compressor provides the energy input which is exchanged to the liquor. Boiling vapors are the input to the compressor. The heated vapors condense and are recovered after transferring energy to the fluid.

This system is expensive, difficult to operate, requires maintenance for scale removal and is a high energy consumer. When it's important and economically viable to recover the water vapor, the system has greater application in Zero Discharge Systems.

CRYSTALLIZATION: Two general crystallization processes exist: PASSIVE and FORCED. Both have limits of applicability, operation, and high cost.

A solar evaporative pond, the primary Passive technique, is a reliable method for crystallization where climatic and land conditions permit. Most sites are limited and cannot employ this method.

The remaining option for brine management is FORCED CRYSTALLIZATION. Two basic versions exist: VAPOR RELEASE and VAPOR RECOVERY. Within each version, options for energy type and application vary. The most prevalent energy types include electric, fuel combustion, and steam.

VAPOR RELEASE FORCED CRYSTALLIZATION: Kilns, incineration, spray driers, and submerged combustion units are common examples.

KILNS are used in the chemical industry where the production of a valuable product is the primary goal. High temperature gas (several hundred degrees) is contacted with brine liquor in a rotating vessel to drive off the moisture and to capture the dried product. Due to the high energy cost and high equipment cost, kilns are generally not applicable to Zero Discharge systems.

INCINERATORS are used to destruct liquids and solids by injection at direct contact with a high temperature flame. Toxic organic compounds are often destroyed by this method. Incinerators consume very high energy and are generally not applicable to liquids which create a solid residue by-product such as in Zero Discharge Systems.

SPRAY DRIERS contact the atomized waste liquid with high temperature and high velocity gas to evaporate the moisture. Solid residues are carried within the gas stream to a bag filter for removal. Spray driers have some applicability to Zero Discharge System although they are expensive, suffer high energy cost, and are difficult to maintain.

SUBMERGED COMBUSTION CRYSTALLIZATION is the most used method of the past in the chemical industry. The outstanding feature of this device is its' low equipment cost, ease of operation and resistance to scaling. A clean burning fuel is required as the combustion products come in direct contact with the brine and are discharged to the atmosphere. Energy consumption is moderately high (~2000 BTU's per pound of water evaporated).

The fuel (such as natural gas, propane, or LPG) is burned with excess air compressed under low pressure within a chamber. The hot combustion gas product exits and sparges below the liquid surface in a vat to cause evaporation. Direct energy transfer occurs and crystalline solids form between the liquid-gas interface. Scaling is not possible with this technique.

Due to its' simplicity and non scaling nature, SUBMERGED COMBUSTION CRYSTALLIZATION may grow in its use for Zero Discharge Systems where a clean fuel source is available. In power stations, natural gas or propane are commonly available.

VAPOR RECOVERY FORCED CRYSTALLIZATION:

Several methods exist and the reader is referred to the "CHEMICAL ENGINEERING HANDBOOK by Perry, for detail. The processes can be conducted under atmospheric pressure and under vacuum. Atmospheric operation is most common.

Two energy driver methods (steam and vapor compression) have been used in Zero Discharge Systems with some success.

Vapor compression units offer the convenience of using electric power. A compressor (ratio of ~1.5) creates heat which is exchanged to the liquid to drive evaporation. The water vapor evaporated feeds the inlet of the compressor, is raised in temperature, flows through a heat exchanger, is condensed and is recovered. Crystals develop in the evaporator body and are extracted for disposal.

Vapor compression is limited to the maximum temperature rise of the compressor (~18degrees). In wastewaters, calcium chloride often exists which creates a boiling point elevation of up to 40 degrees. When this occurs, the motive force of the compressor cannot overcome the boiling point rise. The unit stalls (ceases to operate).

To overcome the boiling point rise effect, steam can be used in the heat exchanger rather than compressed vapor energy to drive the crystallizer evaporation. This improves the flexibility of the process. The convenience of electric connection is lost.

Vapor recovery crystallizers are costly, can be difficult to operate & maintain, and can scale. Where vapor recovery is important, the steam driven method provides superior flexibility compared to vapor compression. When steam is not available, care must be exercised in reviewing the stalling effect of boiling point rise with vapor compressor applications.

Vapor Recovery Forced Crystallization equipment is subject to operating and control difficulty from: scaling, heat transfer fouling, foaming and carryover, high boiling point rise, corrosion, and high energy consumption.

The most important consideration in Crystallizer choice in Zero Discharge Systems is operating reliability and low maintenance. Energy consumption is a secondary consideration.

MATERIAL BALANCE OVERVIEW:

WCA’s practice is to model the system calculations with personal computers. Inputs and operating parameters are varied to calculate the impacts.

Example Discussion:

Producing 140 gpm of ion exchanged water produces about 4 pounds of chemical waste (acid & caustic) per pound of inlet TDS removed plus the original salt mass of the supply. This is equivalent to the salt load of evaporating 700 gpm of water in the cooling tower. Using R.O. eliminates 95% of the chemical waste. The supply TDS mass remains but is manageable through addition to the tower. As an overview, R.O. use eliminates about 40 to 50% of the power station salt load.

The cooling tower evaporates approximately 600 gpm. If sidestream treatment were employed and no tower blowdown employed, the circulation water would equilibrate approximately as follows:

TOWER CYCLING AT ZERO BLOWDOWN:

MU = Evap + Drift + Windage (Blowdown = zero). Assuming Drift + Windage = 20 gpm; MU TDS = 100; then:

MU = 600 + 20
Cycles of Concentration = 620/20 = 30.67
Circulation TDS = 30.67 x 100 = 3067 mg/l.

A completely closed tower as above is easily achieved when using sidestream treatment. Sidestream treatment and misc. waste streams add some chemical load. Even so, there is a wide berth for increase without impact. So the question becomes: "Is there really a problem during normal operation when the system is designed as above?".

SPECIAL ISSUES OF COAL PILE RUNOFF:

Given design; that once every 100 years, storm flow will generate collected wastewater that must be disposed of in 5 days at 120 gpm. During other years, storm flow will be considerably less. The storm flow comprises yard and coal pile runoff.

The coal pile runoff is the important polluter. However, it is well known that coal pile runoff is only of high strength during the first displacement phase within the pile. After which, the wastewater becomes dilute since the mechanisms of waste leaching become limited.

Essentially, the first 10% or so of the waste is strong. Afterwards, the quality improves rapidly. The actual amount of pounds of pollution to deal with is relatively small.

Coal pile runoff contains typically acidity, sulfate TDS, iron, aluminum and other metals. The metals are easily removed and the acidity corrected by feeding the stream to the sidestream treatment system and back to the cooling tower.

When this is practiced for 5 days, the mathematics show that the circulating water TDS will rise temporarily (by perhaps double the normal level). Continued operation will eventually restore TDS to near normal conditions. This temporary rise may gives little technical concern and little environmental concern. The evaporator alternatives with the parasitic loads otherwise must be contemplated.

Temporary salt load can be extracted with standby equipment comprising a concentrating tower and submerged combustion crystallizer at modest equipment and low annual energy expense. The operation of this equipment will be required only occasionally.

The connected electric load and all other complications of the alternatives are avoided. The submerged combustion crystallizer would be energized by propane or other fuel already onsite for boiler restarts.

ABOUT WCA:
WCA is a unique firm of chemical, mechanical, and construction engineers dedicated to the design, management, and supply of Advanced Systems for water, wastewater, operations, and service. WCA provides complete System Engineering and Supply; fabrication of specialty

components; procurement & customizing of standard components; design, programming &supply of the controls, instruments and automation; construction assistance; training; commissioning; and maintenance, operations assistance and service.

Regards,

Horace R. Corbin

Horace R. Corbin, P.E.

CORBIN Consulting

CONTACT US

If you have a challenging job that needs to get done, contact us (908) 232-4407. Regards.

Horace R. Corbin, P.E. press@goleader.com