POWER STATION ZERO DISCHARGE
COOLING TOWER - "Friend or Foe."
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(Use text viewer that displays extended ASCII characters)
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COOLING TOWER SYSTEMS
Basic Principles

In Power Stations, water is recirculated between the condenser and cooling towers to dissipate waste heat. What appears to be a simple process, in reality, is dynamic and complex. Substantial transfer of material and energy occurs. The process is constantly changing, consuming, and discharging.

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 ¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦
  ¦¦¦¦¦EVAPORATION¦¦¦¦¦
   ¦¦¦¦¦¦¦¦¦&¦¦¦¦¦¦¦¦¦
    ¦¦¦¦¦¦DRIFT¦¦¦¦¦¦
     ¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦
       ¦¦¦¦¦¦¦¦¦¦¦¦
        ¦¦¦¦¦¦¦+<------+
Windage ¦¦¦¦¦¦¦¦¦      ¦
<------¦         ¦     ¦
       ¦ COOLING ¦     ¦
       ¦  TOWER  ¦ CONDENSER
Makeup ¦         ¦     ¦
------>¦¦¦¦¦¦¦¦¦¦¦     ¦
       +---------+     ¦
            +--[PUMP]--+
```

Evaporation in the Cooling Tower transfers the waste heat to the environment at ambient conditions. The quantities of HEAT and EVAPORATION can be estimated by knowing the MASS FLOW and TEMPERATURE DROP of the recirculating water. (The heat capacity of water = 1 BTU per pound per degree F; 1 gallon = 8.33 pounds).

EXAMPLE:

With:
30,000 G @ Delta T = 10 F

Then:
BTU/MIN = 2,502,000

Since evaporation consumes 1,000 BTU/LB, the MASS RATE (in pounds) equals TOTAL HEAT RATE/1000 (2,502 LBS/MIN above). This equals 300 gpm Evaporation Rate (2,502/8.33). Makeup is added to the Tower to account for evaporation and other losses.

WATER LOSSES occur from the system (Drift, Windage, Blowdown, sampling, condenser leakage). In many plants, cooling water is consumed for ash quenching, scrubber makeup, area losses, etc.).

TOWER MAKEUP is supplied mostly from fresh water. However, wastewaters are often directed to the system. These include plant drains, boiler blowdown, demineralization wastes, etc.

MAKEUP = Evaporation + Losses - Recycled Wastes.

Short term variations occur (tower basin level fluctuation, batch recovery of waste streams, load swings, and periodic withdrawals). The recirculating system is a large "fly wheel" as it responds to many changes.

Since EVAPORATION IS PURE WATER VAPOR, dissolved salts from the INPUT concentrate in the Tower. The degree of concentration is limited by losses that occur (salts are lost from the system by several means as referenced above). The ultimate salinity that results is further influenced by chemical additives, air stripping of volatiles, dust, bio-reactions, precipitation, and dilution.

Conventionally, the term CYCLES is used to describe the concentrating effects of salinity in cooling tower systems.

CYCLES = MAKEUP/BLOWDOWN
(For expediency by some, although inexact, the conductivity ratio is being used).

However, CHEMICAL PROCESSES alter the

composition of the SALINITY. Therefore, the term "Cycles" is generally of little meaning in modern systems. These PROCESSES (pH control, chemical additives, stripping, bio-reactions, sidestream treatment, etc.) increase salinity and change the nature. In sophisticated systems, Cycles is of little value for controlling operations.

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CONVENTIONAL      ¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦
   TOWER           ¦¦¦¦¦EVAPORATION¦¦¦¦¦
   SYSTEM           ¦¦¦¦¦¦¦¦¦&¦¦¦¦¦¦¦¦¦
                     ¦¦¦¦¦¦DRIFT¦¦¦¦¦¦
                      ¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦
                        ¦¦¦¦¦¦¦¦¦¦¦¦   +15 degrees
                         ¦¦¦¦¦¦¦+<---------------+
                         ¦¦¦¦¦¦¦¦¦        pH=8   ¦
  Volatiles & Windage<--¦         ¦              ¦
       Airborne Input-->¦ COOLING ¦ +--[Filter]->¦WASTE
                        ¦  TOWER  ¦ ¦            ¦ HEAT
          TOTAL MAKEUP  ¦         ¦ ¦       +---------+
Fresh water>----------->¦¦¦¦¦¦¦¦¦¦¦ ¦       ¦CONDENSER¦
            ¦    ¦¦¦¦   +---------+ ¦       +---------+
Boiler ---->¦    ¦¦¦¦        ¦      ¦     Cooled ¦
            ¦    ¦¦¦¦        ¦----[PUMPS]------->+
Drains ---->¦    ¦¦¦¦        ¦
            ¦    ¦¦¦¦        ¦
DM Waste--->+    ¦¦¦¦        +----->BLOWDOWN DISPOSAL
                 ¦¦¦¦        ¦
CHEMICALS Added->---+        +----->Misc. Plant Uses
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ZERO DISCHARGE & COOLING TOWERS

It is desirable to allow the water in the cooling tower to concentrate to a high level for several reasons. First, water use is reduced. Second, wastewater discharge is minimized. Third, chemical use can be reduced.

To protect equipment (condenser, tower, etc.) and the environment from corrosion and/or fouling, the concentration of specific impurities in the recirculating water must be controlled. Further, the recirculating water must be maintained at specific pH, free from biological activity, and low in suspended solids.

Some impurities may be allowed to concentrate to high levels with little concern. These include natures' soluble minerals (sodium, potassium and sulfate). Chloride concentration must be looked at for each individual case as they may be corrosive with systems using stainless steel materials.

Other impurities must be restricted in concentration. The dominant impurities that must be limited are CALCIUM and SILICA. These can plate out on piping and other surfaces, causing equipment damage or expensive maintenance.

As calcium concentrates in water, it can react with carbonate to form a hard scale on piping. Silica can plate out as a glass like material (nearly impossible to remove). Calcium Carbonate will precipitate more fully at higher temperatures (such as in condenser tubes).

The primary method to avoid these conditions is to control the recirculating water pH. This is accomplished with sulfuric acid addition to the Tower. High quality design, equipment, and instruments should be used for pH control. Operation and maintenance of this system must be diligent.

The pH of the recirculating water should be kept stable (just below 8.3). A reasonable target is 8.1 (with a range of 8.0 to 8.2 pH).

This pH range is significant as all carbonates are converted to harmless bicarbonate and CO_2 below 8.3 pH. Therefore, little chance exists for the formation of calcium carbonate scale. Another beneficial action occurs in the tower at this controlled pH (the air flow strips impurities from the water).

The cooling tower is an effective stripper due to the high air flowrate and large surface area provided for the evaporation and heat removal. Properly arranged, the tower strips out the CO_2 and bicarbonate. Stripping to about 100 parts per million alkalinity can be achieved.

WCA ZERO DISCHARGE

Calcium and silica can be extracted utilizing Sidestream Treatment to provide ultimate assurance. Also, the system is kept free of biological growth which otherwise can promote corrosion and fouling.

With controlled pH, low alkalinity, and sidestream treatment, the potential for scaling or fouling is virtually eliminated.

BIOLOGICAL CONTROL

A Bromine (or chlorine) residual is maintained in the recirculating water to retard the incubation, growth and propagation of microbes. Frequently (weekly or as needed), short term spikes of chlorine bleach are added to "shock" any microbes that coexist with the low level residual. (Avoiding sunlight, shock treatment at night is most effective).

Bromine is the environmentally attractive chemical choice, safest for personnel, and of modest cost. Chlorine gas is effective and low-cost, but safety and environmental considerations restrict its' use. Proprietary organic based biocides are available from vendors. These are expensive and can produce unwanted side effects. Therefore, their use should be avoided. Experiments with ozonation may someday result in practical application.

Other methods for controlling biological growth include removing the microbes from the system and killing them by exposing them to pH shock. These capabilities are included with the WCA SIDESTREAM TREATMENT PROCESS.

With controlled pH, low alkalinity, and sidestream treatment, the potential for scaling or fouling is virtually eliminated.

In Essence, keep the water clean and at the proper pH!

CORROSION CONTROL

Several methods are employed "in unison" to minimize the corrosion of plant equipment. With suitable materials of construction and good control of the recirculating water, corrosion issues are minimized (to long term effects). Corrosion "coupons" should be maintained in the recirculating water to estimate these rates (typically 1 to 3 mils per year) or to detect the potential for short term pitting or localized problems.

The first line of defense to minimize corrosion is proper pH control as described previously. The second necessary strategy is to control biological activity, to restrict suspended solids buildup, and to prevent deposits from occurring. IN ESSENCE, KEEP THE WATER

CLEAN AND AT THE PROPER pH!

Conventionally, a small amount of phosphate derivative is added to the recirculating water for "umbrella" corrosion protection. These levels should be maintained within a strict range to provide the wanted "effects" yet to avoid unwanted side effects and costs. Other chemical additives should be avoided.

SCALE & DEPOSIT PREVENTION

Scale and deposits can occur from calcium, silica, iron, manganese, suspended solids, organics and microbial action. The best prevention against scaling and deposition is to keep these components from building up in the recirculating water.

In conventional tower systems, blowdown is used to purge the recirculating water to keep the impurities below troublesome limits. Large quantities of dispersants are added to the system. This procedure is inefficient as the amount of blowdown can be substantial. The blowdown required can be estimated based on the quality of the fresh water supply, the evaporation rate, and other system Inputs and Losses. Measurements are made during operation to establish the actual rates.

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WCA ZERO DISCHARGE¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦
   TOWER SYSTEM    ¦¦¦¦¦EVAPORATION¦¦¦¦¦
  (Single Stage)    ¦¦¦¦¦¦¦¦¦&¦¦¦¦¦¦¦¦¦
SIDESTREAM TREATMENT ¦¦¦¦¦¦DRIFT¦¦¦¦¦¦
                      ¦¦¦¦¦¦¦¦¦¦¦¦¦¦¦
                        ¦¦¦¦¦¦¦¦¦¦¦¦   +15 degrees
                         ¦¦¦¦¦¦¦+<---------------+<------+
                         ¦¦¦¦¦¦¦¦¦      pH=8     ¦       ¦
              Windage<--¦         ¦              ¦       ¦
                        ¦ COOLING ¦   +<---------¦WASTE  ¦
                        ¦  TOWER  ¦   ¦          ¦ HEAT  ¦
          TOTAL MAKEUP  ¦         ¦   ¦     +---------+  ¦
Raw Water-------------->¦¦¦¦¦¦¦¦¦¦¦   ¦     ¦CONDENSER¦  ¦
            ¦    ¦¦     +---------+   ¦     +---------+  ¦
Boiler BD-->+    ¦¦     +<---¦--------¦ Cooled   ¦       ¦
                 ¦¦     ¦ [PUMPS]--------------->+       ¦
Drains ---->+    ¦¦     ¦       +--------------+         ¦
            +------------------>¦WCA SIDESTREAM+-[Pump]->+
DM Waste--->+    ¦¦+----------->+--------------+
                 ¦¦¦¦   ¦             +-->Solid Disposal
CHEMICALS Added->---+   +----------->Misc. Plant Uses
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ELIMINATING BLOWDOWN SAVES MONEY

Blowdown in conventional designs can cause several problems and result in high costs. First, a high volume of water consumption is experienced. Disposal of the waste is often difficult. Chemical additive costs are high due to the purging. Environmental concerns may prevent this practice.

ZERO DISCHARGE & SIDESTREAM PRINCIPLES:

To minimize wastes & consumption while maintaining high quality water, the WCA SIDESTREAM SYSTEM is employed. In the basic design, a portion of the recirculating water is treated to:

1. Extract unwanted calcium & silica.
2. Kill microbes.
3. Remove solids, metals, colloids & organics.
4. Treat and recover other waste streams from the plant.

Several options are available to integrate all water systems and chemical uses. Total Management and optimization of the processes & technology can be achieved.

The SIDESTREAM TREATMENT PROCESS can eliminate wastes, reduce consumption & chemical costs, enhance operation, and accommodate Environmental Regulations. The Total Costs must be assessed. Frequently, this is the lowest cost option. Sometimes, there is no choice. Fresh water may be limited and waste disposal may not be possible. Regulations may disallow conventional practices.

ZERO DISCHARGE (Single Stage Design):

In nearly all designs, the SIDESTREAM PROCESS will extract sufficient quantities of calcium and silica from the recirculation water such that no Blowdown from the plant is required for this purpose. Losses from the recirculating system limit the salinity rise. Losses are assimilated within the plant by ash quenching, scrubber makeup, drift and windage. Further losses occur from disposal of the dewatered solids, sampling, condenser in-leakage, and internal station evaporation.

For plant locations with a low TDS water supply (such as in New England), a Single Stage Design is sufficient. Internal losses by the mechanisms mentioned above are sizable in comparison to the raw water input such that the recirculation water salinity stays within reasonable bounds.

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WCA ZERO DISCHARGE     ¦¦¦¦¦¦¦¦¦¦¦¦¦   +15 degrees
  ADVANCED SYSTEM        ¦¦¦¦¦¦¦+<-------------<--------+
  (Double Stage)         ¦¦¦¦¦¦¦¦¦      pH=8  ¦         ¦
              Windage<--¦         ¦           ¦         ¦
                        ¦ COOLING ¦   +<------¦------->+¦
                        ¦  TOWER  ¦   ¦       ¦  HEAT  ¦¦
          TOTAL MAKEUP  ¦         ¦   ¦     +---------+¦¦
Raw Water-------------->¦¦¦¦¦¦¦¦¦¦¦   ¦     ¦CONDENSER¦¦¦
            ¦    ¦¦     +---------+   ¦     +---------+¦¦
Boiler ---->+    ¦¦     +<---¦--------¦ Cooled      ¦  ¦¦
                 ¦¦     ¦ [PUMPS]-------------------¦  ¦¦
DM Waste-------------->+¦       +--------------+    ¦  ¦¦
Drains-----------------¦¦------>¦WCA SIDESTREAM+--->+  ¦¦
                 ¦¦+----------->+--------------+    +<-+¦
                 ¦¦¦¦  ¦¦             +-->Solids    ¦   ¦
CHEMICALS Added->-+-->+¦+---------->Misc. Uses  +------+¦
+<----------------------+           +<----------¦XCHNGR++
¦  +-----------+  +--->-----------------------+ +------+
+->¦WCA REACTOR+------>¦BRINE TOWER EVAPORATOR+---->+
   +-----------+       +----------------------+
      +--->Solids Disposal  +--->Salt Disposal
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Western U.S. raw water TDS content can be several times higher than that of New England. In this case, though calcium and silica can be controlled in the circuit, TDS may rise to high levels. Then, additional purging of salts is required.

ADVANCED SYSTEM

The Double Stage design provides ENHANCED SALT PURGING by blowing down from the primary tower system to a Secondary Evaporation Circuit (BRINE TOWER, EVAPORATOR/CRYSTALLIZER, etc.).

The BRINE TOWER design is cost effective. Here, purge water is treated by the WCA Reactor to extract most traces of calcium and silica. The remaining salts are soluble. In this form, the fluid is concentrated to several times that of sea water. Waste is reduced to a manageable level. In the West, a solar pond is ideal for final evaporation of the residual. In many cases, internal plant uses (ash quenching, etc.) consume the residual.

The Brine tower materials (plastic, etc.) avoid corrosion and fouling. Evaporation is driven by waste heat from the condenser similar to the action of the Primary Tower. A plate and frame heat exchanger (or "split condenser") is employed to isolate the "Secondary Loop" from the "Primary" recirculating flow.

The "Secondary" Tower circuit is small compared to the "Primary" Tower circuit such that costs and maintenance are moderate. Chemical additives prevent corrosion and scaling.

In extreme circumstances, the EVAPORATOR CRYSTALLIZER version is employed where other methods fail to provide sufficient "Salt Purging" from the system. Electric power is consumed to drive a vapor compressor which provides the motive energy to evaporate the waste fluid. Salt crystals are formed and extracted with a centrifuge.

This option in design of Zero Discharge systems may be expensive, complex, and costly to operate. It is employed where other options are inappropriate.

Alternate INTERMEDIATE CONCENTRATING PROCESSES such as reverse osmosis and electrodialysis have been used in some plant designs to reduce the size and cost of the Evaporator Crystallizer. Generally, membrane processes are sensitive to fouling, add cost, and complicate the system. It is desirable to avoid their use as a waste concentrating unit. However, some special applications can make these additions practical.

RESTRICTING INPUT SALINITY to the power station water system is the most effective and common sense method to minimize the complexity and costs of achieving ZERO DISCHARGE.

SALINITY INPUT to the system comes from many sources:

1. With the raw water supply.

2. From chemicals used in makeup demineralization.
3. From conditioning chemicals added to system.
4. Plant drains, spills and waste streams.

There are several design and operating measures to restrict the salinity input:

1. Use a high quality raw water supply.
2. Treat the raw water supply.
3. Design an efficient makeup system.
4. Minimize use by recycling.
5. Minimize chemical additives.
6. Manage drains & spills.
7. Intelligent automation.
8. "Expert Systems" software.
9. Comprehensive Training.
10. Operate according to design intent.
11. Maintain equipment and controls.

RAW WATER SUPPLY - Often, there is little choice in selecting the water supply. When there is, selectively employ the raw supplies for the most appropriate uses.

Provide the makeup demineralizers with the highest quality source to achieve best efficiency (reduces regenerant waste, boiler additives and blowdown).

TREAT RAW WATER - In some cases, it is necessary to treat the supply before use. TDS may be reduced by precipitating calcium, silica, and alkalinity. This also removes suspended solids, colloids and organics.

DESIGN AN EFFICIENT MAKEUP SYSTEM

The makeup system efficiency influences the Power Station in many ways, including "Zero Discharge" objectives. It is well known that high quality water is required for boiler operation. However, the impact on waste is often overlooked.

Ion exchange designs are effective in producing a high quality product. However, they produce regeneration chemical wastes. Internal recovering schemes should be considered. In some cases, the use of reverse osmosis before ion exchange should be considered strictly for waste minimization.

MINIMIZE WATER USE - RECYCLE!

Each water subsystem within the station should be classified for the input quality requirement. Waste streams from some can be the supply to others. Some wastes contain chemicals that are needed elsewhere. Cation exchanger wastes contain acid which is useable in the cooling tower. Anion exchanger wastes contain caustic which is useable in the sidestream treatment process. Similar opportunities and benefits are numerous.

DRAINS AND SPILL MANAGEMENT

Ideally, the concept of "Wastewater Collection Drains" should be eliminated from power station design and operation. Instead, the concept of "Recycle Collection" and "Spill Containment" is a more thoughtful approach.

Discharges from subsystems should be directed to the "Recycle Collection" system. Open floor lines, thought of as Spill Containment, should be designed to collect and contain accidents and non standard events.

Spill containment should be isolated by area sumps. Liquids entering these sumps should be evaluated automatically (pH and conductivity). Based on analysis, the contents should be directed to the appropriate reuse system. Where necessary, the contents should be given special handling and disposal.

The containment sumps should be monitored by the Station computer. If the frequency of sump use becomes excessive, an alarm should signal the operator for investigation.

INTELLIGENT AUTOMATION

Often, systems become "over automated". Maintenance may be excessive and therefore neglected. "Key Items" requiring control are overlooked. This can produce the worst of results - a complex system that can't be kept working and that doesn't produce meaningful results.

Automation can be developed at reasonable cost. Often, this is the lowest cost alternative and the best investment choice.

This is accomplished with Process and I&C Engineering teamwork. Process Descriptions, Material and Energy Balances and P&ID's are the essential first step of design. Physical design such as civil and mechanical must be subject to process and control review. Equipment procurement requires similar confirmation.

EXPERT SYSTEMS SOFTWARE

EXPERT SYSTEMS software is becoming available to assist operators with complex decisions, tedious mathematics, logic, data logging and trend analysis. The computer tools are rapidly improving. "Expert Systems" should be commonplace in the near future.

OPERATOR TRAINING AND FOLLOW-UP

Complex and expensive facilities must be operated and cared for in an efficient manner. Significant decisions must be made constantly. Success of the venture ultimately is in the hands of operations.

Huge pay back is achieved through equipping the operating personnel with classroom and hands on training. Follow-up is valuable to assess the success of the training, to answer questions, and to fine tune instructions.

OPERATE PER DESIGN INTENT

Sometimes, systems are not operated according to the design. There can be many reasons for this. First, the design or installation can be faulty. Second, the training may be inadequate. Third, misguided or incomplete advice may have been given by vendors or outside consultants. Fourth, operations may lack the discipline and dedication.

Unresolved design and operating deficiencies can be costly and hazardous. Resolution achieves big rewards.

MAINTENANCE

The lowest cost and least time consuming option for operating complex facilities involves proper repair, preventative maintenance and good housekeeping. This obvious conclusion is too often neglected.

To manage these interrelated subsystems; experience, automation, trouble free design, and intelligible operator interface is required. Computerization is ideal for the many technol ogy intensive calculations and "cause & effect" decision making. This removes unnecessary and unreasonable burden from Operations. This technique also provides a single optimized "Game Plan" under one source of control.

Cooling Towers can be your biggest ally for achieving "Zero Discharge" in power stations. Complex issues can be made economic by using experience, knowledge, and common sense design.

Environmental limitations require power stations to consider improved water systems. Cooling Towers can be a big Ally in achieving significant improvements. The techniques and experience are growing rapidly to meet these needs.