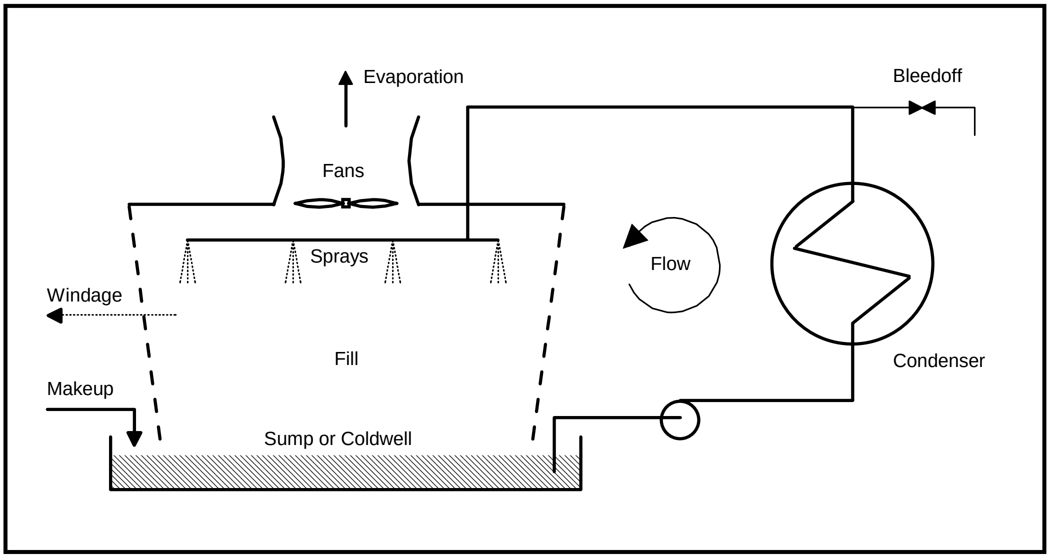

C-TOWER

Cooling TOWER calculations
Version 5.0 for Excel

M A R V I N S I L B E R T and A S S O C I A T E S
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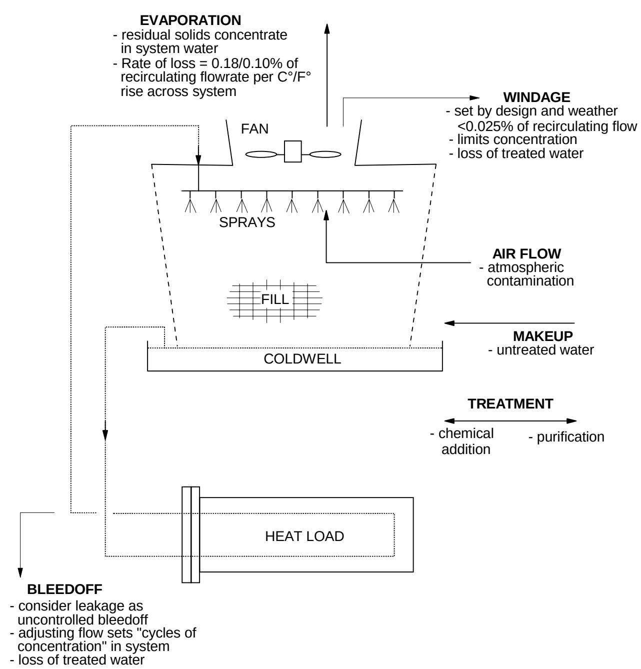
C-tower

Cooling-**WATER** calculations

C-tower is a contraction of **C**ooling **T O W E R** water and chemical consumption calculations. C-tower does all the calculations needed to estimate the use of water and chemical treatment products within a cooling tower. This latest version has added the ability to calculate usage and costs associated with a short-term feed to the recirculation line as well as corrections for the percentage of active materials within a given product. C-tower can work with US, metric or imperial units or any combination of them and any currency. C-tower uses several very common calculations from the open literature, many of which are used by the various water-treatment suppliers and consultants. To fully interpret the results, it should be noted that conditions within a cooling tower may differ from those on which the calculations are based due to factors such wind speed and humidity. The calculations do give a reasonable average over the year; however, the authors can assume no responsibility for any decision based upon the results of the calculations.

Cooling Tower Dynamics

Water is our most common cooling medium for industrial and HVAC systems. A simple once-through system takes its water from the source (*e.g.*, a river); circulates it across the equipment to remove heat and returns the warmed water to the source. With major systems, this requires vast quantities of water. When it is not available and/or too expensive to purchase, the water can be reused and recycled through evaporative cooling. Instead of discarding the returning warmed water, it passes through a tower, similar to that shown below.



As the finely dispersed droplets cascade over the **fill** (a *packing* that provides a large surface area), the warmer molecules evaporate and go off to the atmosphere leaving behind a cooled liquid that collects in the **coldwell** from which it can be recycled to cool the process again. Fresh water is added only to make up for the evaporation and system losses. Typically, the make-up requirements are only a few percent of the flowrate and the water may reside in the system for several hours. The chemistry of the recirculating water is more complex than for once-through cooling and is based upon the factors shown below.

a. The water that leaves as evaporation is pure water. The solids remain behind and the water in the system will become more and more concentrated as evaporation continues. To compensate for this concentrating effect, a small controlled **bleedoff** must be established to drain some of the solids-laden water from the system. Fresh make-up must be brought in to replace the water lost though bleedoff.

b. **Drift** or **windage** are droplets of *treated* water carried by the wind and lost from the system. The quantity lost is dependent upon wind conditions and tower design. Some typical values for different tower designs are shown below.

Type of Cooling Tower	***Windage Range***
spray pond	1 - 5%
natural-draft tower	0.2-1.0
induced-draft towers	0.02 - 0.3
forced-draft towers	0.02 - 0.3

c. In addition to the controlled bleedoff, there will be an uncontrolled bleedoff or **leakage**. The final system chemistry will be achieved does not discriminate between the two; it is dependent upon the total value of all sources.

The ultimate concentration reached within the circulating water is measured in **cycles of concentration** or as a **concentration ratio** or $\mathbf{C_r}$. The two terms are synonymous. The ratio is a measure of the concentration of a given species in the concentrated water compared to the concentration of that species in the original make-up. The species, most commonly used, is chloride as it tends to be soluble and easily measured. As an example in a system where the chloride in the makeup is 30 mg/L and 120 in the coldwell:

$$\text{COC or } C_r = \frac{120}{30} = 4.0$$

The use of chloride may give misleading results where chloride can be carried in the atmosphere *e.g*. towers located near the sea or operated in the winter near a salted highway.

Treatment of open-recirculating systems tends to be much more complicated then for a once-through system due to the rather dynamic nature of their operation. Pure water is lost to the atmosphere by evaporation leaving behind a residue. At the same time the scrubbing action of the sprays picks up gases (including oxygen and other gases from the neighbourhood, *e.g*., H_2S near an oil refinery) and debris from the atmosphere. High concentrations of some species can lead to scaling. Treatment requires establishing control of microbiological life, suspended material and corrosion. The fact that only a relatively small volume is being discarded and the operation is somewhat closed, allows for more expensive formulations.

The required chemical dosage is related to the water used within the system. The dynamics are dependent upon losses of treated water as well as losses of untreated water. Evaporation removes heat from the water by allowing those molecules with the highest kinetic energy *i.e*. temperature to escape. Water that is lost is pure and carries no treatment as the treatment products stay behind. The loss of water by evaporation, as a percent of the total, is directly related to the temperature difference across the tower. As a rough approximation, the rate of evaporation is approximately 1% of the recirculation rate for each 10 F° of rise between the outlet and inlet across the tower.

$$\%E = \frac{\Delta T}{10} \quad \text{or} \quad E = \text{Recirculation Flowrate x } \frac{\Delta\text{T}}{1000}$$

In the real world, a corrections is needed for factors such as wind, relative humidity, *etc*. Multiplying the %E by 0.85 works out to a reasonable long-term approximation. If the climate is particularly moist, the value may go down to 0.65; if it is very dry, it may go up to 1.0-1.2.

$$\%E = \frac{0.85x\Delta T}{10} \text{ in F}^\circ = \frac{0.85 \text{ x } \Delta \text{T}}{5.55} \text{ in C}^\circ$$

As described above, the concentration ratio is measured from ratio of the concentration of chloride (or some other species) between the tower clearwell and the make-up:

$$C_R = \frac{[\text{Cl}_{\text{Clearwell}}]}{[\text{Cl}_{\text{Make-up}}]}$$

To maintain a balance within the system, it follows that the total chloride in the make-up must equal the total chloride in the losses, *i.e*. $\%M \times [\text{Cl}_{\text{Make-up}}] = \%L \times [\text{Cl}_{\text{losses}}]$. Rearranging gives:

$$\frac{\%M}{\%L} = \frac{[\text{Cl}_{\text{Losses}}]}{[\text{Cl}_{\text{Make-up}}]} \quad \text{or} \quad \frac{[\text{Cl}_{\text{Clearwell}}]}{[\text{Cl}_{\text{Make-up}}]}$$

where the concentration of chloride in the losses is the concentration in the clearwell and the total losses of concentrated material include planned blowdown, unplanned blowdown (leakage) and windage, *i.e*. $\%L = \%B + \%W$. Coupling the above:

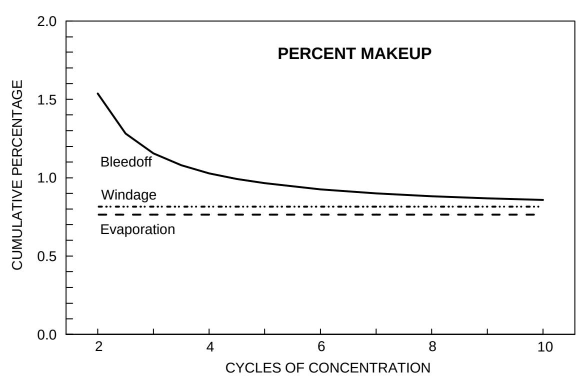
$$C_R = \frac{\%M}{\%L} = \frac{\%M}{\%B + \%W} \text{ with the total make-up } \%M = \%E + \%B + \%W$$

- **Evaporation losses** are fixed by the ΔT across the system with some variation related to the weather, *e.g*., the losses will be dependent upon the ambient temperature, the relative humidity and wind. The higher the ΔT, the higher will be the number of cycles to which the tower water can be concentrated for a fixed bleedoff and windage rate.

- **Windage losses** are set by the design of the cooling tower. The cooling tower is usually sold with a windage specification. This may vary over a wide range as the ambient wind speed increases. The lower the windage loss, the higher will be the number of cycles to which the tower water can be concentrated for a given ΔT and bleedoff rate.

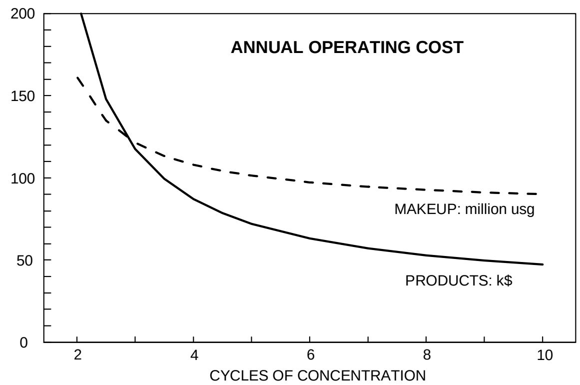
- **Bleedoff** is not fixed as are evaporation and windage. The bleedoff can be adjusted within a fixed range. If the flow is not metered, the bleedoff flowrate can be calculated from the concentration ratio and the evaporation rate:

$$\%B = \frac{\%E}{(C_r\text{-}1)} - \%W$$



As the bleedoff is reduced, the concentration ratio increases. When the bleedoff reaches zero, the ultimate concentration will be limited by the windage. In a typical HVAC application, where the ΔT is low, the maximum ratio attainable may be 4-8. In an industrial application, where the ΔT is high, it may go over 20 cycles. As the ratio rises, so also do the concentrations of scale forming species and the need for a program to control them.

As shown in the graph, the **water makeup requirements** decrease rapidly with the first few cycles of concentration, but much less so with further cycling up of the tower. There is little change once 5 cycles have been reached. On the other hand, chemical costs continue to drop as the products are concentrated within the system. **Product consumption** is directly related to the losses of treated water from the system, not the makeup added to the system. Evaporation losses do not remove the treatment products as do bleedoff and windage.



It is interesting to note that the **volume** held within the system is not always accurately known. Some estimates take the volume of the sump or clearwell and add 25–50%. Others assume it to be 6–10 times the recirculating rate. An accurate value can be obtained by a tracer method where a known amount of an easily measured substance is added and the concentration measured once it is well mixed. It is useful to work with some estimate and get an idea of some time-based operating parameters, particularly when trying to estimate the dosages of chemical products..

a. **Time per cycle:** This is the length of time for water to make the complete loop through the system, This is given by the relationship:

$$t = \frac{\text{volume}}{\text{flowrate}} = \frac{\text{V}}{\text{E}}$$

If the flowrate is in gallons or litres per minute, t will be in minutes.

b. **Retention time:** This is an oversimplified indication of the length of time for an impurity to be removed through the bleedoff system. For this application, the term bleedoff means bleedoff plus windage and losses. This is given by the relationship:

$$t = \frac{\text{volume}}{\text{bleedoff rate}} = \frac{\text{V}}{\text{B+ W}}$$

If the bleedoff is in gallons or litres per minute, t will be in minutes.

c. **Holding time index (HTI):** This is a more realistic approach to the retention time recognizing that all material is not removed as it passes the bleedoff valve. This is given by the relationship:

$$t = 0.693\,\frac{\text{volume}}{\text{bleedoff rate}} = 0.693\,\frac{\text{V}}{\text{B+ W}}$$

As with the above calculation, if the volume is in gallons or litres and the flowrate in gallons or litres per minute, t will be in minutes. The 0.693 term is ln 2, *i.e*., this is the same type of half life as would be calculated for a nuclear system.

d. From the above timing, it is possible to calculate product dosages. For continuously fed products such as inhibitors and dispersants, the following relationship applies.

$$\text{Continuous Feed} = \frac{\text{desired ppm x MU}}{C_r \text{ x 120 x X}}$$

For a feedrate in	with *MU* in	X=
lb per day	US gallons per day	1000
kg "	US gallons per day	454
kg "	litres per day	120

For slug-fed products such as biocides, the calculation is independent of the concentration ratio and following relationship holds.

$$\text{Slug Feed} = \frac{\text{desired ppm x V}}{\text{120 x X}}$$

For a feedrate in	with V in	X=
lb per slug	US gallons	1000
kg "	US gallons	454
kg "	litres	120

To destroy alkalinity, the addition of sulfuric acid can be calculated from:

$$\text{Acid Feed} = \frac{\text{ppm of alkalinity removed x MU}}{\text{120 x X}}$$

For a feedrate in	with V in	X=
lb per slug	US gallons	1000
kg "	US gallons	454
kg "	litres	120

Chemical Treatment

Biological Control: The tendency for biological activity and fouling can be effectively controlled. Chlorine is usually added as a shock dose, usually at night. It can be added as Cl_2 or as hypochlorite depending upon the size of the system. The hypochlorite should be sodium as opposed to calcium (HTH) as the calcium would add to the system's scaling potential. Bromination, is also becoming an accepted procedure when the pH run >8. Alternatively a number of proprietary biocides can be used. These include iso-thiazalones, carbamates and quaternary products. Unlike chlorine, which oxidizes cell walls, the use of the proprietary products can lead to the development of an organism that adapts to the biocide. It is common to alternate biocides to kill off any bacteria that may have adapted.

Corrosion Control: The most effective corrosion inhibitor is chromate which acts as an anodic inhibitor forming a stable γ-iron oxide film. With increasing consciousness of the environment, chromates were first reduced from the 150 mg/kg region to the 30-50 mg/kg region by blending with zinc. Environmental legislation has now ruled out the use of chromates and the newer formulations utilize blends of biodegradable organics such as phosphonates and azoles.

Scale Control: Scaling tendencies can be reduced through pretreatment of the water with techniques such as softening or reverse osmosis, but the cost for their application is high. It is much more common to change the nature of the scale through the use of scale modifiers such as polymaleic and polyacrylic acids or phosphonates. The scale formed tends to stay suspended long enough to be removed by either the blowdown or a filtration system.

The overall treatment program would include product formulations to cover all three areas and would be accompanied with a daily testing program to measure its effectiveness. It must be pointed out that as the operation of the tower leads to accumulations of contaminants in the water, good control of these materials can prevent severe corrosion or fouling of the heat-exchange surfaces. Four approaches can be taken to ensure adequate control:

1. Increase bleedoff to remove solids and prevent their concentrations from going too high. Unfortunately this approach also increases the quantities of water and treatment products used and tends not to be cost effective.

2. Utilize heavier dosages of treatment products to prevent deposition possibly with the incorporation of an acid-feed system to keep the carbonate equilibrium system in the more soluble bicarbonate form. This approach can be very costly and is counter to good environmental practice.

3. Provide filtration either on the basis of full flow or a side stream to remove the impurities as they collect and prevent their overconcentration. This is the preferred approach as it can maintain a clean system and thus tends to avoid or at least reduce the long-term fouling of heat transfer surfaces. It also does not add to the environmental load produced by the system.

   There has been a controversy as to the type of filtration required. A typical side-stream sand filter may take several hours to filter the entire system and is capable of removing particles down to 5-10 µm. The full flow strainer can filter the entire system every 5-15 minutes, but is limited to particles down to 50 µm. The debris from the atmosphere will contain a mixture of particles of a wide range of sizes. If the treatment program contains a dispersant, it will keep the fine particulate material suspended for several hours. This is long enough to keep it suspended until it is removed by either the sand filter or the bleedoff system.

4. Soften the water to minimize the scaling potential. This can be either on the basis of treating makeup or a continuous side stream. There are a number of industrial plants that use feed from other parts of the plant to accomplish this goal. Softening, with ion-exchange resins, is appropriate where the number of cycles does not get higher than 5-6. While hardness-producing cations are removed, they can not be totally eliminated. The resins do not remove the bicarbonates. The trace of hardness leaking through will eventually concentrate enough to give a possible scaling problem. Softening with a clarifier will also reduce the bicarbonates and allow higher cycling.

Notes on the operation of C-tower

C-tower is an Excel spreadsheet. It can be loaded as any other spreadsheet. There are no macros. It's operation is almost self-explanatory. Inputs can only be entered in the Setup and Input worksheets and only into the unprotected cells that are indicated by their blue colour.

Worksheet	**Notes**
C-tower	Introduction to C-tower with some notes
Setup	Unit systems: US, Imperial, traditional and SI Metric are available and can be used in combination. There are three categories; one each for the flow & volume, product cost and water cost. All calculations will be entered and reported in the selected choice. Currency: The tables and graphs can handle any currency, but will truncate the name to the first seven (7) characters if the name is longer. Range: The range for the Cycles of Concentration scale on the x-axis of the graphs and the column heading for the graphs and tables can be entered along with the number of decimal places used on the x-axis for the graphs
Input	Data can be entered into the appropriate locations on the various tables. Note that data can be entered only into unprotected cells, which are coloured blue. To change the units go to the setup screen. **Operational Data** Table labels: Enter the text that will be the title for the various worksheets. System volume is the total volume of system including pipework and sumps. If you do not have a volume, a good rule of thumb is to set the volume at six times the recirculation rate. Recirculation rate is the total flow rate between system and cooling tower. Operation is the number of equivalent full-time days of operation per year. ΔT is the temperature difference between the cool water feed from tower and warm water returned from system. Windage on most modern cooling towers is 0.025% or lower. Use this or the manufacturer's value if available. An arbitrary cut-off has been set to stop the calculations from cycling higher, once the bleedoff becomes less than windage. A zero value will allow cycling higher. Enter your limit in the setup screen. An evaporation coefficient of 0.85 provides a reasonable average over a year; other values may be used based upon local weather conditions or experience. The Heat Load is calculated from the ΔT and flowrate in the appropriate units based upon the temperature scale selected. Alkalinity for acid addition: Enter the alkalinity of the makeup water and the maximum to be allowed in the recirculating water. W-index calculate the sulfuric

Worksheet	Notes
	acid feedrate required to keep from exceeding the selected value. (see also acid feed, below.) **<u>Product Data</u>** Provisions are included to enter the product name, its cost, the percentage of active material and the frequency of addition. Continuously fed chemical products: Enter the ultimate steady-state concentration in mg/L (ppm). If the product is used for only for a part of the year, enter the number of days per year over which it is used; otherwise, leave the time blank as any value entered here will over-ride the operating time value. The calculation averages the short-term addition and gives the equivalent value for the full year. Acid Feed: Enter the cost per kg/lb for sulfuric acid and the concentration. 93% is the most common industrial grade. Slug-fed chemical products: Enter the ultimate concentration in mg/L (ppm), the cost per kg/lb, product name and number of times per week that they will be boosted. The weekly and annual additions will be calculated. The input page calculates the timing parameters that can be used to assess the number of additions per week. **<u>Water Data</u>** Enter the actual purchase cost for water. In some regions, that value might also include a sewage component. Where water is pumped directly from the source, e.g., from a lake or river using plant equipment, an equivalent in-house cost, such as electrical load should be used.
Daily	This spreadsheet provides the daily water and product consumption. The product additions and costs will be in the units selected in the setup screen for the operating parameters, products and cost entered on the input.
Annual	This spreadsheet provides the annual water and product consumption. The product additions and costs will be in the units selected in the setup screen for the operating parameters, products and cost entered on the input.
Comparison	This spreadsheet gives the water and product consumption against a pre-set Cycles of Concentration value which can be entered in the setup screen. The units are in units of percentage change with a negative value meaning less and a positive value meaning more.
Relative	This worksheet gives the relative contribution of water and product s to the overall cost of treating the system.
Workspace	This worksheet is blank and allows the user to copy graphs or tables from other worksheets to prepare a customized report.

Technical Support

FAQs

This section is a summary of questions that have popped up over the years. Users are encouraged to supply additional questions as the user is the one with the questions. The developer tends to see things in their sleep and can miss some critical points.

1. **How do I establish a cut off for the maximum number of cycles in a tower?**
   While the theoretical limits may appear quite high, the tower is operated in the real world. C-tower allows you to set a cut off based upon the bleedoff related to windage. The default is 50% of the windage. Allowing the tower to cycle higher is really meaningless.

2. **Why doesn't C-tower plot graphs of everything?**
   The answer to that is simply an effort to avoid graph fatigue. Hard numbers are available for everything. The ones that are plotted tend to be those that can give a useful overview. If you think we left one out, let us know and it may be added to a future upgrade.

3. **Can I really believe 50-60 cycles of concentration?**
   No. That's really theoretical. Even the windage numbers quoted by the manufacturers must be questioned under some wind conditions. Measurements that indicate such numbers should be investigated for realistic causes, *e.g.*, being too near a highway overpass or too close to a neighbour who's emissions can end up in the cooling tower sump.

4. **You may contact us at the following addresses:**

   Mail: Marvin Silbert and Associates
   23 Glenelia Avenue, Toronto, Ontario, Canada, M2M 2K6
   Telephone: 1-416-225-0226
   Fax: 1-416-225-2227
   E-mail: marvin@silbert.org
   WWW: http://www.silbert.org

Sample Output

The pages that follow are printouts of the various worksheets showing the inputs and outputs.

C - t o w e r

Water INDEX calculations, version 5.0 for Excel, (C) 1990, 94, 99, 2006

Developed by: **MARVIN SILBERT and ASSOCIATES**

C-tower uses several calculations from literature. To fully interpret the results, it should be recognized that actual conditions within a cooling tower may differ from those on which the calculations are based due to factors such wind speed and humidity. Although the calculations do give a reasonable average over the year, the author can assume no responsibility for any decision based upon the results of the calculations.

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Enter User's Affiliation here

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Instructions:

Setup	This tab provides the set-up parameters and the units to be used for all the calculations. Those cells in column "I" marked in blue allow input to meet the users needs. Column "J" will show the units as they will be used, based upon the values selected.	
	I7	Insert the currency to be used. A symbol or up to 7 characters can be used.
	I12 to I15	Select the units for the system parameters
	I8 and I20	Select the number of cycles of concentration used for the comparison graphs and the number of decimal points displayed in the title. The value is selected from the data. If that one isn't in the table, it will take the next lower value.
	I23	Select a practical cut-off for the calculated maximum number of cycles of concentration. Selecting 0% may not be realistic.
	I27 and I28	Set the plot parameters and the start, step and maximum will display. The graphs use 11 points. It may be necessary to juggle the values in I27 and I28 to get a rational spread.
Input	Enter the plant and system identification and the water and product information in the blue spaces. This information will be used in the subsequent worksheets.	
	D3 and D4	Plant name and sample location. Used for titles on the individual worksheets.
	D7 and D8	Volume and flowrate in units selected in Setup.
	D9	Days of operation in a year.
	D10	Temperature rise in C° or F° as selected in Setup.
	D11	Windage as supplied by tower manufacturer or estimated.
	D12	Evaporation coefficient appropriate to area. If in doubt use 0.85.
	J7 and J8	Alkalinity in make-up and maximum allowed in system. Sulfuric acid will be added as needed.
	C16 to C23	Desired concentration of product in mg/L (ppm). Continuously-fed products are in C16-C18 and slug-fed in C20-C23.
	D16 to D24	Cost of products (D16-D23) and water (D24) in units selected in Setup.
	E16 to E23	Names of treatment products
	F16 to G23	Percentage of actives in the products and their names.
	H16 to H18	Number of days continuously fed product is used, if not full time. Calculates average. Leaving it blank uses value in D9
	H20 to H23	Number of times slug-fed products are added per week. Calculates weight in each slug.
Daily	This page calculates the water consumption and product usage and their costs on a daily basis	
Annual	This page calculates the water consumption and product usage and their costs on a daily basis	
Comparison	This page compares the water and chemical consumption, the timing and the costs vs. the number of cycles of concentration selected in I18 on the setup worksheet. The comparison is not made only for the slug-fed products as the slug fed are independent	
Relative	This page compares the proportion of the costs from treatment products with the cost of water.	
Workspace	This page is a blank worksheet that can be customized by the user. Tables and/or graphs can be copies from the other worksheets and combined to form a customized report sheet.	

For more info: **MARVIN SILBERT and ASSOCIATES**
23 Glenelia Avenue, Toronto, ON, Canada, M2M 2K6
Tel: **1-416-225-0226,** *FAX:* **1-416-225-2227,** *e-mail:* **software@silbert.org**

	A	B	C	D	E	F	G	H	I	J	K
1											
2			**SETUP instructions:**	**Enter appropriate values ONLY in the blocks provided below and**							
3				**on the input page. The input cells have blue fonts.**							
4				**Do not enter values in any other location.**							
5											
6											
7			CURRENCY	Enter currency name up to 7 char.					**$**	$/lb	
8											
9											
10											
11			MEASUREMENT UNITS	1	2	3	4	5			
12			- Treatment products sold by:	kg	lb	-	-	-	**2**	lb	
13			- Water sold by:	US	Imperial	m³	-	-	**1**	$/1000 usg	
14			- Temperature	C°	F°	-	-	-	**2**	F°	
15			- Volume and flow	US	Imperial	Litres	m³	kg	**1**	000 usgpm	
16										000 usg	
17											
18			CYCLES OF CONCENTRATION	For comparison table and graphs. Uses the					**4**	4.00	
19				next lower value if not in the "lookup" table.						is available	
20			- Decimal places	Used for titles on comparison plots.................					**1**	4.0	
21											
22											
23			MAXIMUM CYCLES			When bleedoff is		....	**50**	% of windage	
24			OF CONCENTRATION			Maximum COC will be.......			> > >	12.00	
25											
26			SET COC RANGE FOR TABLES AND GRAPHS								
27			- Start value	Goes to 1.50 if no value entered.....................					**2**	2.00	
28			- Step size	Goes to MAXIMUM if no value entered...........					**0.5**	0.50	
29			- Stop value	Maximum COC plotted will be.........................					> > >	7.00	
30											

C-tower: Cooling-Tower Water & Chemical Consumption Calculations

PLANT: **XYZ Manufacturing Inc.**

SYSTEM: **Mould Cooling**

SYSTEM PARAMETERS

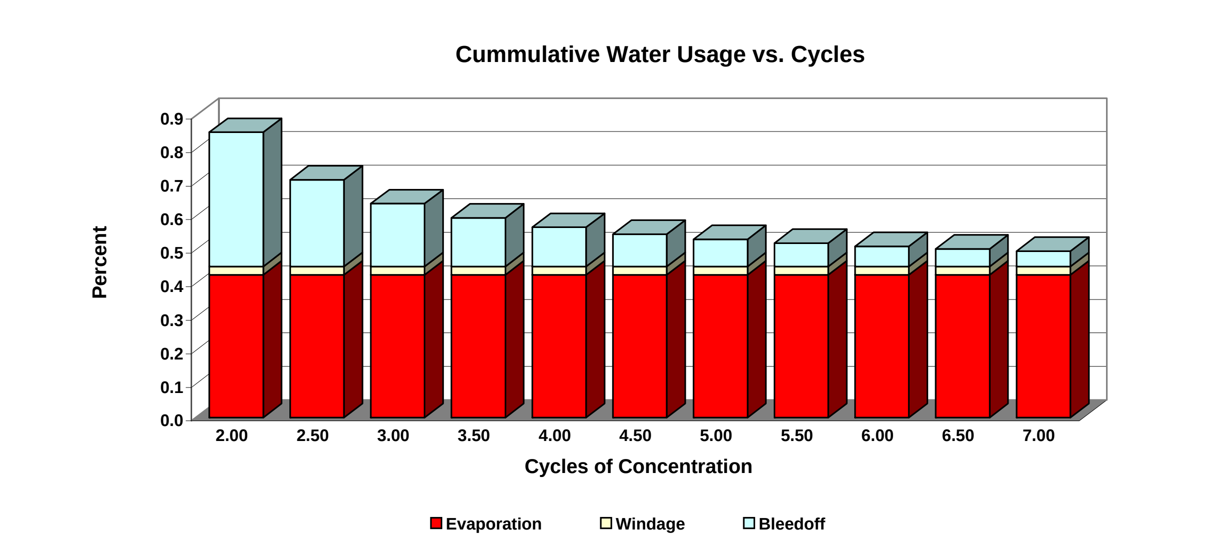
Total Volume	350	000 usg	Alkalinity Present in Make-up	100	ppm
Recirculation Rate	75	000 usgm	Max Alkalinity in System	500	ppm
Operation	365	days/year			
Delta T:	5	F°	Heat Load	3.1E+06	BTU/min
Windage	0.025	Percent	Cycle Time	4.7	min
Evap'n Coefficient	0.85		Max Concentration Ratio	12	COC

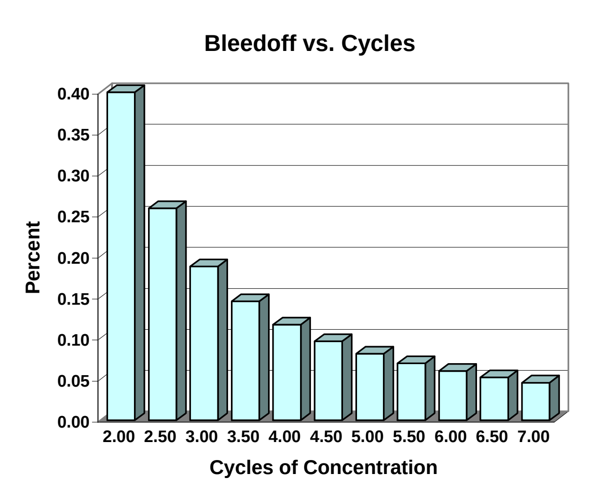
CHEMICAL PRODUCTS

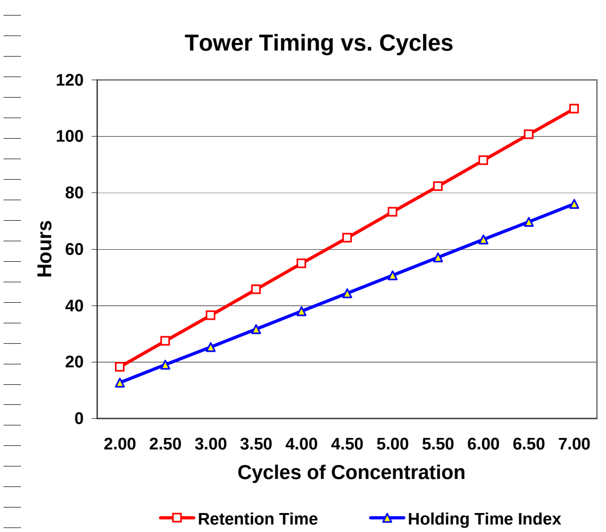
	mg/L	$/lb	Product	%	Active		Frequency		Dosage
Continuous	150	5.00	ABC-123	100	ABC		days/yr	150.0	mg/L
	35	7.50	DEF-456	100	DEF		if not	35.0	average
	15	5.00	GHI-789	100	GHI		full time	15.0	over year
		0.25	H2SO4	93	H2SO4				
Slug Fed	5	1.00	JAVEX	12	Chlorine	2	/week @	121.5	lb/slug
	1	7.00	DISP-11	100	ASDFG	1		2.9	
	75	7.00	BIO-1	100	XYZ	1		218.8	
	100	6.00	BIO-2	100	QWERTY	1		291.7	
Water:		3.00	$/1000 usg						

WATER CONSUMPTION

Cycles of Conc.		2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	
Rate of	Evap'n	318.8	318.8	318.8	318.8	318.8	318.8	318.8	318.8	318.8	318.8	318.8	usgpm
	Windage	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	
	Bleedoff	300.0	193.8	140.6	108.8	87.5	72.3	60.9	52.1	45.0	39.2	34.4	
	Make-up	637.5	531.3	478.1	446.3	425.0	409.8	398.4	389.6	382.5	376.7	371.9	
	Losses	318.8	212.5	159.4	127.5	106.3	91.1	79.7	70.8	63.8	58.0	53.1	
Percent	Evap'n	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	Relative to
	Windage	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	Recirc.
	Bleedoff	0.40	0.26	0.19	0.15	0.12	0.10	0.08	0.07	0.06	0.05	0.05	Rate
	Make-up	0.85	0.71	0.64	0.60	0.57	0.55	0.53	0.52	0.51	0.50	0.50	
Retention Time		18.3	27.5	36.6	45.8	54.9	64.1	73.2	82.4	91.5	100.7	109.8	hours
Holding Time Index		12.7	19.0	25.4	31.7	38.0	44.4	50.7	57.1	63.4	69.8	76.1	







C-tower: Cooling-Tower - Daily Water & Chemical Consumption

PLANT: **XYZ Manufacturing Inc.**

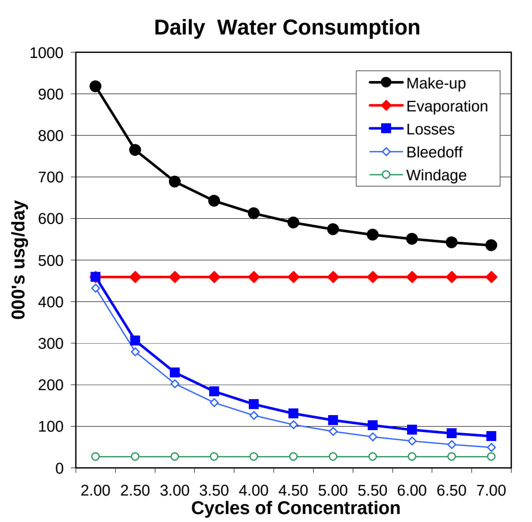
SYSTEM: **Mould Cooling**

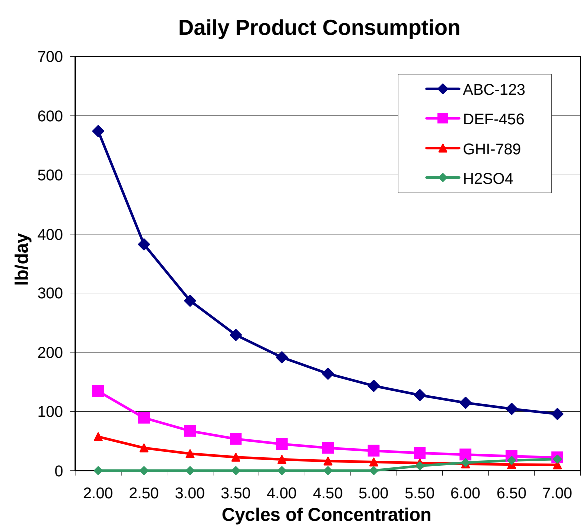
Daily Water Consumption

Cycles of Concentration		2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	
Rate of	Evaporation	459.0	459.0	459.0	459.0	459.0	459.0	459.0	459.0	459.0	459.0	459.0	000's usg/day
	Windage	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	
	Bleedoff	432.0	279.0	202.5	156.6	126.0	104.1	87.8	75.0	64.8	56.5	49.5	
	Make-up	918.0	765.0	688.5	642.6	612.0	590.1	573.8	561.0	550.8	542.5	535.5	
	Losses	459.0	306.0	229.5	183.6	153.0	131.1	114.8	102.0	91.8	83.5	76.5	

Daily Product Consumption

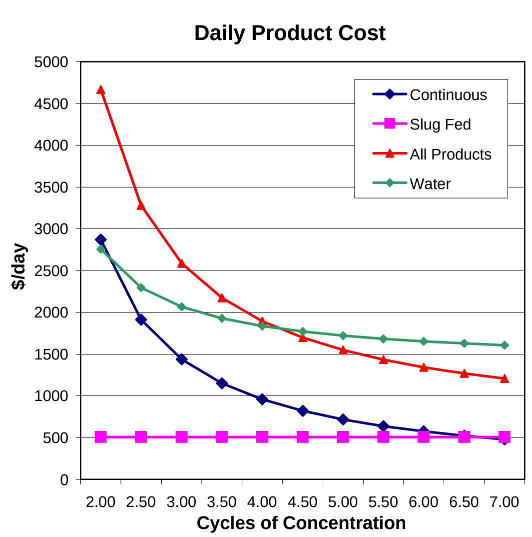
Cycles of Concentration		2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	
Continuous	ABC-123	574.0	382.7	287.0	229.6	191.3	164.0	143.5	127.6	114.8	104.4	95.7	
	DEF-456	133.9	89.3	67.0	53.6	44.6	38.3	33.5	29.8	26.8	24.4	22.3	
	GHI-789	57.4	38.3	28.7	23.0	19.1	16.4	14.4	12.8	11.5	10.4	9.6	Consumption
	H2SO4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	13.7	17.3	19.6	lb/day
Slug Fed	JAVEX	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	
	DISP-11	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	
	BIO-1	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	
	BIO-2	41.7	41.7	41.7	41.7	41.7	41.7	41.7	41.7	41.7	41.7	41.7	

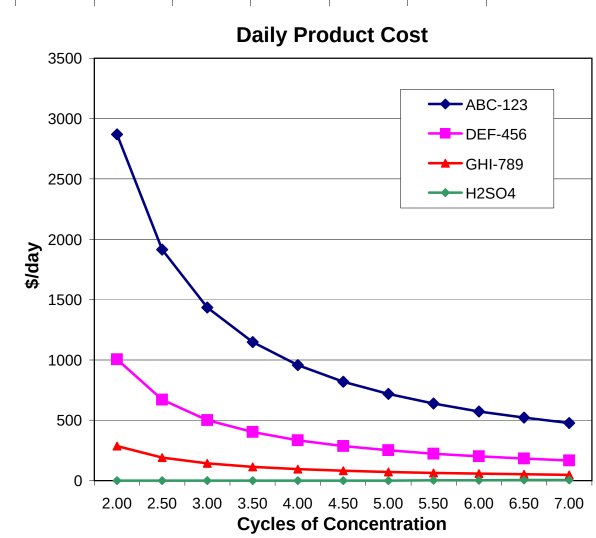




Daily Product Cost

Cycles of Concentration		2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	
Continuous	ABC-123	2870.0	1913.3	1435.0	1148.0	956.7	820.0	717.5	637.8	574.0	521.8	478.3	
	DEF-456	1004.5	669.7	502.3	401.8	334.8	287.0	251.1	223.2	200.9	182.6	167.4	Individual
	GHI-789	287.0	191.3	143.5	114.8	95.7	82.0	71.8	63.8	57.4	52.2	47.8	costs in
	H2SO4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	3.4	4.3	4.9	$/day
Slug Fed	JAVEX	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	
	DISP-11	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	
	BIO-1	218.9	218.9	218.9	218.9	218.9	218.9	218.9	218.9	218.9	218.9	218.9	
	BIO-2	250.2	250.2	250.2	250.2	250.2	250.2	250.2	250.2	250.2	250.2	250.2	
Totals	Continuous	4161.5	2774.3	2080.8	1664.6	1387.2	1189.0	1040.4	926.9	835.7	761.0	698.5	
	Slug Fed	506.7	506.7	506.7	506.7	506.7	506.7	506.7	506.7	506.7	506.7	506.7	Total costs in
	All Products	4668.3	3281.1	2587.5	2171.4	1893.9	1695.8	1547.1	1433.6	1342.5	1267.7	1205.2	$/day
	Water	2754.0	2295.0	2065.5	1927.8	1836.0	1770.4	1721.3	1683.0	1652.4	1627.4	1606.5	
	Total	7422.3	5576.1	4653.0	4099.2	3729.9	3466.2	3268.4	3116.6	2994.9	2895.1	2811.7	





C-tower:	Cooling-Tower - Annual Water & Chemical Consumption

PLANT: **XYZ Manufacturing Inc.**

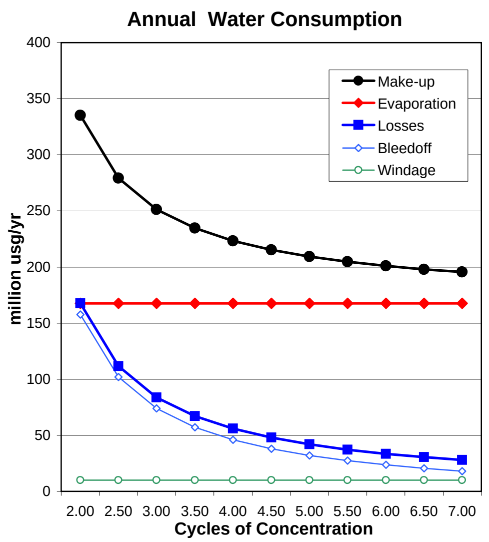
SYSTEM: **Mould Cooling**

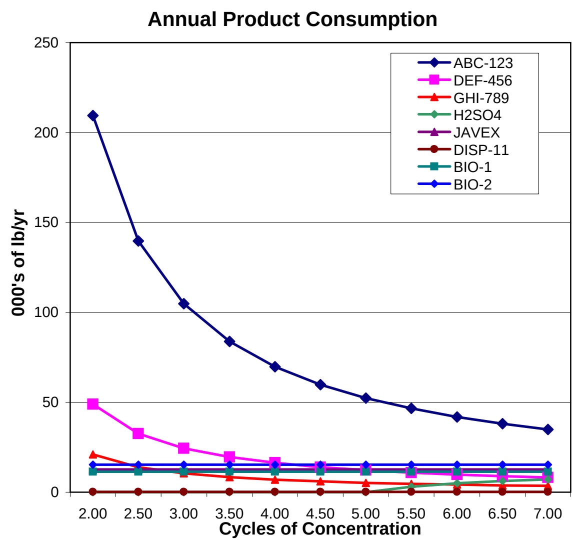
Annual Water Consumption

Cycles of Concentration		2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	
Rate of	Evaporation	167.5	167.5	167.5	167.5	167.5	167.5	167.5	167.5	167.5	167.5	167.5	million usg/yr
	Windage	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	
	Bleedoff	157.7	101.8	73.9	57.2	46.0	38.0	32.0	27.4	23.7	20.6	18.1	
	Make-up	335.1	279.2	251.3	234.5	223.4	215.4	209.4	204.8	201.0	198.0	195.5	
	Losses	167.5	111.7	83.8	67.0	55.8	47.9	41.9	37.2	33.5	30.5	27.9	

Annual Product Consumption

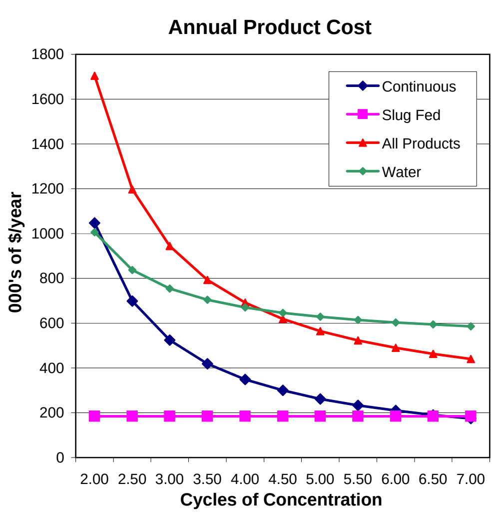
Cycles of Concentration		2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	
Continuous	ABC-123	209.5	139.7	104.8	83.8	69.8	59.9	52.4	46.6	41.9	38.1	34.9	
	DEF-456	48.9	32.6	24.4	19.6	16.3	14.0	12.2	10.9	9.8	8.9	8.1	
	GHI-789	21.0	14.0	10.5	8.4	7.0	6.0	5.2	4.7	4.2	3.8	3.5	Consumption
	H2SO4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	5.0	6.3	7.2	000's of lb/yr
Slug Fed	JAVEX	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	
	DISP-11	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	
	BIO-1	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4	
	BIO-2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	

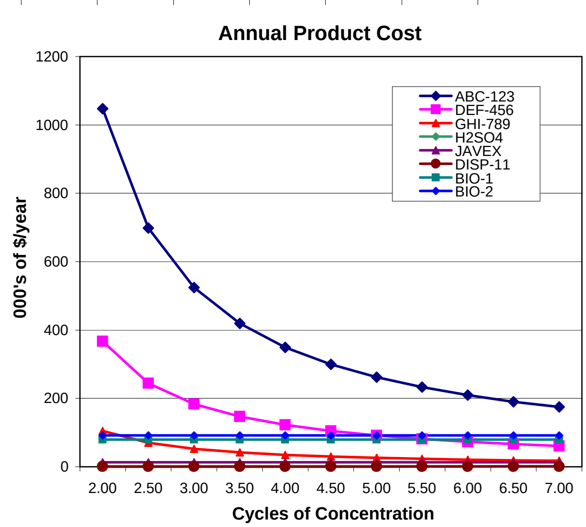




Annual Product Cost

Cycles of Concentration		2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	
Continuous	ABC-123	1047.6	698.4	523.8	419.0	349.2	299.3	261.9	232.8	209.5	190.5	174.6	
	DEF-456	366.6	244.4	183.3	146.7	122.2	104.8	91.7	81.5	73.3	66.7	61.1	Individual
	GHI-789	104.8	69.8	52.4	41.9	34.9	29.9	26.2	23.3	21.0	19.0	17.5	costs
	H2SO4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	1.3	1.6	1.8	000's of $/year
Slug Fed	JAVEX	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	
	DISP-11	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	
	BIO-1	79.9	79.9	79.9	79.9	79.9	79.9	79.9	79.9	79.9	79.9	79.9	
	BIO-2	91.3	91.3	91.3	91.3	91.3	91.3	91.3	91.3	91.3	91.3	91.3	
Totals	Continuous	1519.0	1012.6	759.5	607.6	506.3	434.0	379.7	338.3	305.0	277.7	254.9	
	Slug Fed	185.0	185.0	185.0	185.0	185.0	185.0	185.0	185.0	185.0	185.0	185.0	Total costs
	All Products	1703.9	1197.6	944.4	792.5	691.3	619.0	564.7	523.3	490.0	462.7	439.9	costs
	Water	1005.2	837.7	753.9	703.6	670.1	646.2	628.3	614.3	603.1	594.0	586.4	000's of $/year
	Total	2709.1	2035.3	1698.3	1496.2	1361.4	1265.2	1193.0	1137.6	1093.1	1056.7	1026.3	





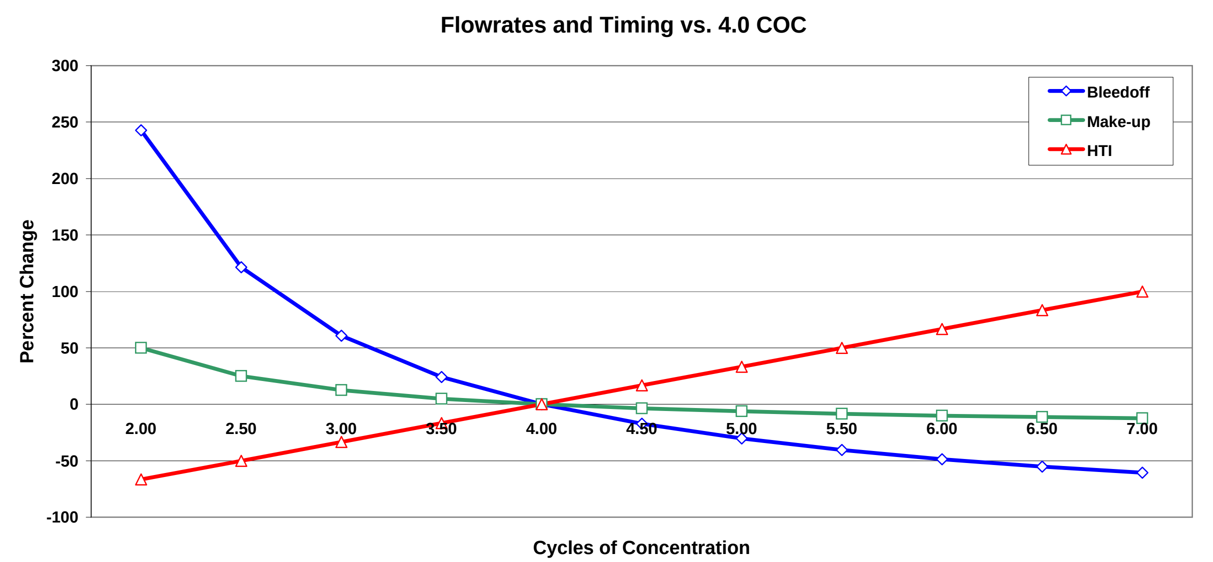
C-tower: **Cooling-Tower - Water & Chemical Consumption Comparisons**

PLANT: **XYZ Manufacturing Inc.**

SYSTEM: **Mould Cooling**

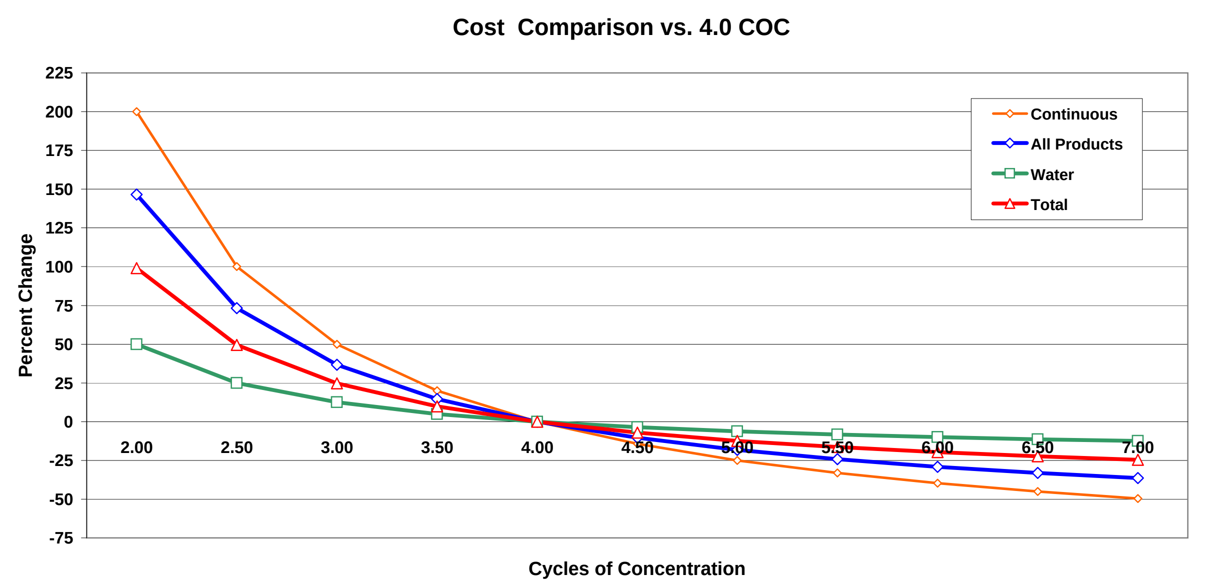
Flowrates and Timing vs. 4.0 COC

Cycles of Concentration		2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	
Rate of	Evaporation	0	0	0	0	0	0	0	0	0	0	0	
	Windage	0	0	0	0	0	0	0	0	0	0	0	
	Bleedoff	243	121	61	24	0	-17	-30	-40	-49	-55	-61	% Change
	Make-up	50	25	13	5	0	-4	-6	-8	-10	-11	-13	
	Losses	200	100	50	20	0	-14	-25	-33	-40	-45	-50	
Retention Time and HTI		-67	-50	-33	-17	0	17	33	50	67	83	100	



Cost Comparison vs. 4.0 COC

Cycles of Concentration		2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	
Cost	Continuous	200	100	50	20	0	-14	-25	-33	-40	-45	-50	
	Slug Fed	0	0	0	0	0	0	0	0	0	0	0	
	All Products	146	73	37	15	0	-10	-18	-24	-29	-33	-36	% Change
	Water	50	25	13	5	0	-4	-6	-8	-10	-11	-13	
	Total	99	49	25	10	0	-7	-12	-16	-20	-22	-25	



C-tower: Cooling-Tower - Relative Cost

PLANT: **XYZ Manufacturing Inc.**
SYSTEM: **Mould Cooling**

COMPARISON AGAINST TOTAL COST

Cycles of Concentration		2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	
Totals	Continuous	56.1	49.8	44.7	40.6	37.2	34.3	31.8	29.7	27.9	26.3	24.8	
	Slug Fed	6.8	9.1	10.9	12.4	13.6	14.6	15.5	16.3	16.9	17.5	18.0	%
	All Products	62.9	58.8	55.6	53.0	50.8	48.9	47.3	46.0	44.8	43.8	42.9	
	Water	37.1	41.2	44.4	47.0	49.2	51.1	52.7	54.0	55.2	56.2	57.1