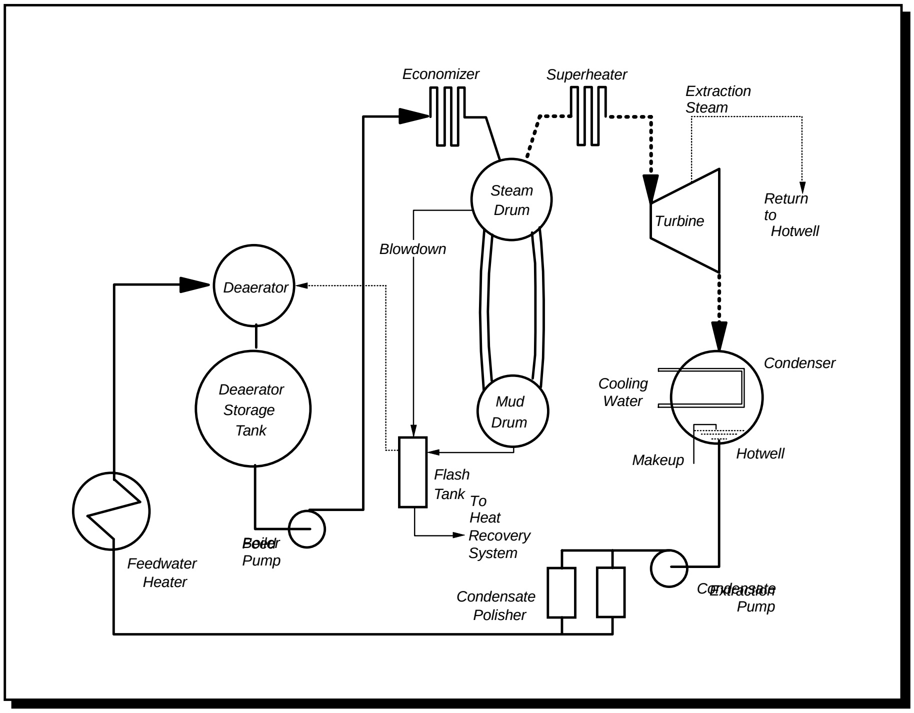


# Boil-Bal

**<u>Boil</u>er <u>Bal</u>ance Calculations**
**Version 2.0 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**
23 Glenelia Avenue, Toronto, Ontario, Canada, M2M 2K6
Telephone: 1-416-225-0226
FAX: 1-416-225-2227
Internet: marvin@silbert.org

# C-tower

**C**ooling-**WATER** calculations

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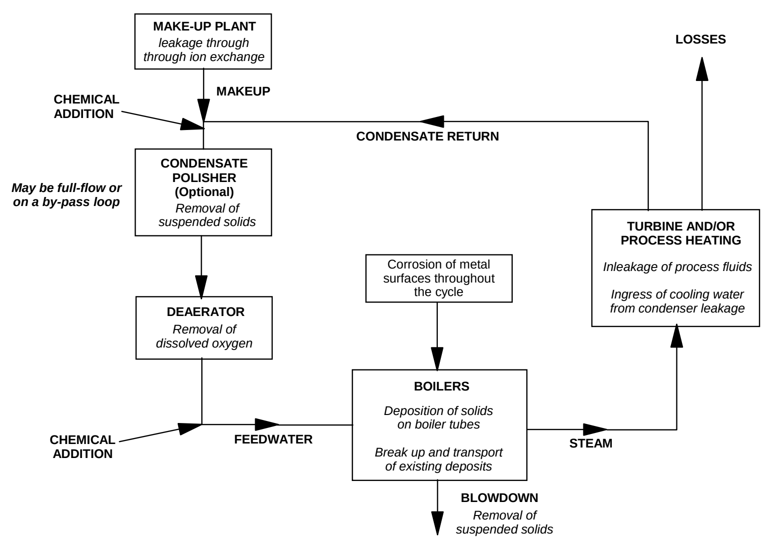
**Boil-Bal** calculates the use and balance of water and energy within a boiler system. This latest version includes the ability to calculate the water and energy savings achievable by adding a flash tank and heat-exchanger to recover the residual heat present in the boiler blowdown. Boil-Bal works with US, metric or imperial units or any combination of them and any currency. Boil-Bal 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 actual conditions within a boiler may differ from those on which the calculations are based. The differences are most pronounced at start-up or when changing load. While the calculations have been shown to give a reasonable approximation in many applications, MS&A can assume no responsibility for any decision based upon the results of the calculations.

## Boiler Mass Balance

The boiler cycle can be depicted as a simple loop. The figure shows both the water balance and the routes where contaminants are brought into or removed from the system. As steam is taken away from the boiler, the solids remain behind and concentrate. The total amount of solids in the boiler is dependent upon the quantity of solids brought in with the makeup or returned with the condensate. This quantity can be reduced, but not eliminated by external treatment. Two components of the mass balance in the boiler can be manipulated to limit the concentrating effect.




**BOILER WATER MASS BALANCE DIAGRAM**
**Showing water flows and sources of impurities**

- **Blowdown:** A small flow of concentrated water is taken from the boiler to prevent over–concentration of solids. The makeup brings in fresh water. The balance between the two, results in a steady-state concentration. A higher blowdown rate results in a lower concentration of impurities, but also removes more energy. Lowering the blowdown rate reduces the energy penalty, but can not achieve as low a concentration of solids. Blowdown can be continuous or intermittent. Its control can be a simple manual valve, or highly automated with control based upon the signal from an on-line conductivity meter. Typically, blowdown rates are less than 1% in the electrical generation plants. They may go to 5% in industrial utilities where condensate is returned and much higher if it isn't.

- **Condensate Recovery:** When the steam has done its work, it condenses back into a liquid. This condensate is pure water with essentially no solids. If it can be returned to the boiler, it eliminates the demand for makeup bringing new solids with it. In electrical generating stations more than 98% of the condensate is returned. In industrial plants, the percentage varies. It is not unusual to find systems where no condensate is returned. When it is returned, there is always a concern that returned condensate may include impurities from condenser leakage or hydrocarbons leaking from process heat exchangers. On-line monitors are available for detecting condenser leakage or hydrocarbons in water.

Blowdown losses and condensate recovery are the major effects that govern the overall behaviour of the system. Blowdown that is lost is also energy that is lost. Well designed systems may also contain a flash tank that recovers energy from the blowdown by routing the flashed steam back to the deaerator. Further energy recovery can be achieved by passing the hot liquid through heat exchangers to heat the incoming feedwater. Lost condensate must be replaced. The best way to do so it is bring it back. Plants with high rates of condensate recovery, also have low blowdown rates. This should be an incentive to designers as they can reduce the need for a blowdown energy recovery system if they use good quality make-up and a high condensate recovery.

## Performing a Mass Balance

If a solid component, e.g., phosphate is added to a boiler, it should stay in solution. The only mechanisms for its removal are deposition or blowdown. In a properly controlled system, there should be no deposition and a mass balance should indicate that the mass of material added through pumps s balanced by the mast of material discharged through blowdown.

- The weight added through the pumps is usually calculated from the concentration in the day tank times the drawdown in the tank.

- The weight lost through blowdown is usually calculated from the measured concentration in the blowdown times the blowdown flowrate.

There is one problem. It's not common to include instrumentation to measure the blowdown flow due to the difficulties inherent with the two-phase flow that may occur in the line. The alternative is to calculate it from the routine analyses used to monitor the boiler's performance. Many plants assume some arbitrary flowrate based upon the number of turns on the valve, but that may not really mean anything. Calculations tend to be more reliable with boilers that operate with a measurable level of dissolved solids rather than those using ultrapure water.

As an example, data will be used from a typical industrial boiler supplied with softened make-up. 60,000 lb/hr of steam is supplied to heat a process. 20% of the steam (i.e. 12,000 lb/hr) is lost and the remaining 80% (i.e. 48,000 lb/hr) is returned as condensate. These flows are fixed by the systems design. A number of simple relationships become apparent from the mass balance:

| | |
|---|---|
| FW = MU + CR | Feedwater flow is the sum of makeup and condensate return. |
| FW = BD + S | Feedwater flow is also the sum of blowdown and steam flow. |
| MU = BD + L | Makeup replaces blowdown and losses |
| S = CR + L | Steam produced is the sum of return and losses. |

From these relationships, the following information can be derived and will cover essentially all the calculations necessary to cover a boiler mass balance calculation.

**Cycles of concentration** can be evaluated relative to either feedwater or makeup concentration. A subscript indicates which. The most common species is chloride as it tends to be easily measured and remains in solution in the boiler at operating temperatures. In order to make the necessary calculations, it is necessary to measure chlorides in the makeup, feedwater, blowdown (i.e. in the boiler) and returns (i.e. in the condensate).

$$COC_{MU} = \frac{Cl_{BD}}{Cl_{MU}} \quad \text{and} \quad COC_{FW} = \frac{Cl_{BD}}{Cl_{FW}} \quad \text{where:} \quad \frac{COC_{MU}}{COC_{FW}} \times 100 = \%MU$$

The percentage of Condensate Returns (CR) can then be determined from the four chloride values:

$$\%CR = 100 \times \frac{Cl_{MU} - Cl_{FW}}{Cl_{MU} - Cl_{CR}}$$

A few additional variations of the above equations relate:

| | | | |
|---|---|---|---|
| **MAKEUP** to condensate returns: | %MU | = | 100 - %CR |
| **BLOWDOWN** to feedwater flow and steaming rate: | BD | = | FW - S |
| **FEEDWATER** to steaming rate and blowdown: | FW | = | $\frac{100 \times S}{100 - \%BD}$ |
| **LOSSES** to makeup and blowdown: | L | = | MU - BD |

The calculation[1] is based upon measured levels of chloride in the boiler. Taking as an example a boiler fed by softened water. The measured chloride values through the system are:

$$Cl_{MU} = 30, \quad Cl_{FW} = 6.5, \quad Cl_{BD} = 300, \quad Cl_{CR} = 0.1$$

From this the cycles of concentration can be calculated:

$$COC_{FW} = \frac{300}{6.5} = 46.2 \quad \text{and} \quad COC_{MU} = \frac{300}{30} = 10$$

along with the percentages of the various streams:

$$\%CR = 100 \times \frac{30 - 6.5}{30 - 0.1} = 78.6\%$$

$$\%MU = 100 - \%CR = 100 - 78.6 = 21.4\%$$

$$\%BD = \frac{\%MU}{COC_{MU}} = \frac{21.4}{10.0} = 2.14\%$$

$$\%L = \%MU - \%BD = 21.4 - 2.14 = 19.3\%$$

[1] The percentages and flows are presented to three significant figures.

The individual flows for a 60,000 lb/hr steaming rate can be calculated from the percentages:

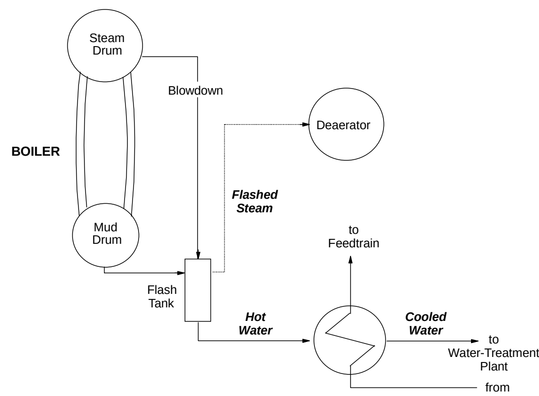
$$FW = \frac{S \times 100}{100 - \%BD} = \frac{60{,}000\ \text{lb/hr} \times 100}{100 - 2.14} = 61{,}300\ \text{lb/hr}$$

| | | | |
|---|---|---|---|
| MU = | %MU × FW | = 21.4% × 61,300 | = 13,100 |
| BD = | %BD × FW | = 2.14% × 61,300 | = 1,310 |
| CR = | %CR × FW | = 78.6% × 61,300 | = 48,200 |
| L = | %L × FW | = 19.3% × 61,300 | = 11,800 |

If more condensate could be recovered, it would result in less blowdown and need less make-up.

## Blowdown Energy Recovery

While blowdown can minimize the overconcentration of impurities in a boiler, it is common to find plants skimping on blowdown flow. The reason is that it contains energy and that is going to be lost unless a recovery system is installed. The boiler used as an example in Section 1 can also serve to demonstrate the calculations. For the sample calculations that follow, the following operating parameters will be used:




**Blowdown Recovery Options**

| | *US/Imperial units* | *SI metric units* |
|---|---|---|
| *steam is produced at a pressure of* | *100 psig/114.7 psia* | *791 kPa* |
| *steam production is* | *60,000 lb/hr* | *7.56 kg/s* |
| | *$1.44 \times 10^6$ lb/day* | *$6.5 \times 10^6$ kg/day* |
| *the blowdown rate is 2.17%* | *$3.1 \times 10^4$ lb/day* | *$1.4 \times 10^4$ kg/day* |
| *the make-up water temperature is* | *60°F* | *15.6°C* |
| *the fuel cost is* | *$7.40/10^6 BTU* | *$7.00/GJ* |
| *the boiler efficiency is* | *70%* | |

The thermodynamic data has been taken from a standard set of steam tables. It should be noted that the tables are based upon absolute pressure and that the 100 psig will be found by looking up 114.7 psia. The symbol conventions used in the following calculation are:

$H_{f\text{-}P/T}$ Enthalpy of liquid water for the specified pressure/temperature
$H_{fg\text{-}T}$ Latent heat of evaporation for the specified pressure or temperature

Energy lost = blowdown flow × [enthalpy of boiler water - enthalpy of make-up]
= blowdown flow × [$H_{f\text{-boiler pressure}} - H_{f\text{-make-up temperature}}$]

US/Imp = $3.1 \times 10^4$ lb/day × [$H_{f\text{-}114.7\ psia} - H_{f\text{-}60°F}$]
= $3.1 \times 10^4$ lb/day × (309 - 28) BTU/lb = $8.8 \times 10^6$ BTU/day

SI units = $1.4 \times 10^4$ kg/day × [$H_{f\text{-}791\ kPa} - H_{f\text{-}15.6°C}$]
= $1.4 \times 10^4$ kg/day × (718 - 65) kJ/kg = 9.3 GJ/day

Energy cost = Energy lost × energy cost × (100 ÷ efficiency)

US/Imp = $8.8 \times 10^6$ BTU/day × \$7.40/$10^6$ BTU × (100 ÷ 70) = \$93/day

SI units = 9.3 GJ/day × \$7.00/GJ × (100 ÷ 70) = \$93/day

A well designed recovery system would include two components to recover energy. While either or both can be used, the best recovery will be achieved from applying both.

**Flash Tank:** The first stage to recover energy from the blowdown is to have the high-pressure water flash to steam that can be fed back into the process, usually into the deaerator. Assume the deaerator is operated at 239°F. The first stage is to measure the percentage of the blowdown that is flashed to steam and use this to calculate the energy that can be recovered.

$$\%\ \text{flashed steam} = 100\,\frac{\text{Enthalpy of water in boiler - Enthalpy of water at deaerator outlet}}{\text{Latent heat of evaporation at deaerator outlet}}$$

$$\text{US/Imp} = 100\,\frac{H_{f\text{-}114.7\ psi} - H_{f\text{-}239°F}}{H_{fg\text{-}239°F}} = 100\,\frac{(308\text{-}209)\ \text{BTU/lb}}{953\ \text{BTU/lb}} = 10.4\%\ \text{or}\ 0.104$$

$$\text{SI metric} = 100\,\frac{H_{f\text{-}791\ kPa} - H_{f\text{-}115°C}}{H_{fg\text{-}115°C}} = 100\,\frac{(718\text{-}482)\ \text{kJ/kg}}{2216\ \text{kJ/kg}} = 10.4\%\ \text{or}\ 0.104$$

Once the percentage that flashes to steam is known, it is possible to calculate the energy that can be recovered by feeding that flashed steam back into the process.

Energy recovered = blowdown flow × % flashed steam ×[$H_{g\text{-flashed steam}}$ - $H_{f\text{-make-up}}$]

US/Imp = $3.1 \times 10^4$ lb/day ×10.4% × [$H_{g\text{-}239°F}$ - $H_{f\text{-}60°F}$]

= $3.1 \times 10^4$ lb/day × $0.10^4$ × (1160 - 28) BTU/lb = $3.6 \times 10^6$ BTU/day

SI metric = $1.4 \times 10^4$ kg/day ×10.4% × [$H_{g\text{-}115°C}$ - $H_{f\text{-}15.6°C}$]

= $1.4 \times 10^4$ kg/day × $0.10^4$ × (2699 - 65) kJ/kg = 3.9 GJ/day

Energy cost = Energy lost × energy cost × (100 ÷ efficiency)

US/Imp = $3.6 \times 10^6$ BTU/day × \$7.40/$10^6$ BTU × (100 ÷ 70) = \$39/day

SI metric = 3.9 GJ/day × \$7.00/GJ × (100 ÷ 70) = \$39/day

**Heat Exchanger:** This water is still hot and some additional savings can be achieved by passing it through a heat exchanger to boost the temperature of the incoming makeup or feedwater. If the temperature can be reduced to 90°F the additional energy recovered will be:

Energy recovered = blowdown flow × [1 - flashed steam] ×[$H_{f\text{-D/A outlet}}$ - $H_{f\text{-HX outlet}}$]

US/Imp = $3.1 \times 10^4$ lb/day ×[1 - 0.104] × [$H_{f\text{-}239°F}$ - $H_{f\text{-}90°F}$]

= $3.1 \times 10^4$ lb/day × 0.896 × (208 - 58) BTU/lb = $4.2 \times 10^6$ BTU/day

SI metric = $1.4 \times 10^4$ kg/day ×[1 - 0.104] × [$H_{f\text{-}115°C}$ - $H_{f\text{-}32°C}$]

= $1.4 \times 10^4$ kg/day × 0.896 × (482 - 134) kJ/kg = 4.4 GJ/day

Energy cost = Energy lost × energy cost × (100 ÷ efficiency)

US/Imp = $4.2 \times 10^6$ BTU/day × \$7.40/$10^6$ BTU × (100 ÷ 70) = \$44/day

SI metric = 4.4 GJ/day × \$7.00/GJ × (100 ÷ 70) = \$44/day

## Notes on the operation of Boil-Bal

Boil-Bal is an Excel spreadsheet. It can be loaded as any other spreadsheet. There are no macros. It's operation is almost self-explanatory. To avoid errors, enter information only into the cells marked in yellow. The entered data will be indicated by their blue colour.

| **Worksheet** | **Notes** |
|---|---|
| C-tower | Introduction to Boil-Bal with some operational notes |
| Setup | This worksheet sets up the units to be used for all the calculations. The appropriate values will display when the units are selected.. |
| Input | Enter the plant and system identification and the water and product information. This information will be used for identifying the system in the subsequent worksheets. If you do not want a title or note to appear, enter a blank. When multiple units are offered, enter only one steam flow and/or pressure. Boil-Bal will convert as needed. |
| Water | This sheet calculates the water consumption and costs. Enter the raw-water cost and treated-water costs in the appropriate units. Boil-Bal will convert as needed. If the cost for treated water includes the raw water cost leave the raw water cost blank. If the water is not treated, leave the treated-water cost blank. Most treatment processes have a waste stream. Estimate the percentage that goes to waster. With RO, it could be 30-50%. If treated water is purchased at a fixed cost, the percentage that goes to waster will likely be 0%. |
| Water Balance Flowsheet | This page gives a flowsheet with the water balance shown for the various streams. |
| Energy | This sheet calculates the energy consumption and costs. Enter either metric or non-metric units in the appropriate units, but not both. Boil-Bal will convert as needed. The various calculated values are shown in both units in the lower table. The steam table values are approximated from a curve fit. The fits is within ±1 C° or ±1% of the enthalpy for most of the range. |
| Energy Balance Flowsheet | This page gives a flowsheet with both the energy and the water balance shown for the various streams. |
| Treatment Worksheet | Due to the large variety of chemical-treatment programs available for different boilers designs and operating pressures, there is no generalized calculation that fits all. The table is offered only as a means to help the users estimate costs for their system. There is no implied intent that the end result is either complete or accurate. |

This is an Excel spreadsheet. Additional worksheets can be added and customized to the user's application. It is recommended that the existing structure be left intact and that individual values be accessed by the formula "=existing cell" rather than doing any cutting and pasting. It is also recommended that such customizing be done with a copy of the original.

## 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. **My load cycles from low to high output over the day. How does Boil-Bal handle that?**
   The chloride measurements that form the basis of the calculation are usually taken at a fixed time during the day. The calculations will be based upon the load at that time. To get the bigger picture, a program should be undertaken to do the testing under various load conditions and develop some form of average condition.

2. **Is there a way to do an accurate measurement of the blowdown rate?**
   The best way to do this is to run the blowdown through a cooler of some type and measure the liquid flowrate. Ideas to do this have utilized sending the blowdown through a copper tube. Bend the tube into a tight coiled and put it into a pail through which cold water is run continuously. Various jury-rigged systems can be established based upon the ideas and materials at hand.

3. **I found that more than 30% of my steam as lost. Is that real?**
   Very likely. Unless you can measure or calculate it, you don't know how much is lost.

4. **I use softened water. What would I gain by switching to demineralized water? Would adding a demineralizer be cost effective as opposed to adding a heat recovery system?**
   Try reducing the chloride values for the make-up and feedwater. This will allow you to simulate the changes. The blowdown rate will go way down.

5. **Would adding a demineralizer to replace the softener be cost effective as opposed to adding a heat recovery system?**
   Try simulating the conditions for adding the heat recovery and also for adding the demineralizer. It's now a decision with respect to the engineering costs associated with both.

6. **Would it be a good idea to recover some of that last condensate?**
   Definitely. The make-up requirements would be lower. Try reducing the chloride number on the feedwater. This will allow you to simulate the changes.

7. **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

# Boil-Bal

## BOILer - BALance calculations, version 2.0 for Excel, (C) 2006

*Developed by:* **MARVIN SILBERT and ASSOCIATES**

Boil-Bal uses a number of standard calculations readily available from the 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.

*This copy licensed to:* **Enter User's Name here**
**Enter User's Affiliation here**



## Instructions:

**General**
To ensure that data is entered into the correct locations, those cells into which data entries are made are identified by their yellow colour. The entries into those cells are identified with blue text. Protection in enabled, but no password is needed to disable it. If it is disabled, be careful not to make any entries into cells with formulae in them.

**Setup**
This tab sets up the units to be used for all the calculations. The appropriate values will display when the units are selected.

**Input**
Enter the plant and system identification and the water and product information. This information will be used for identifying the system in the subsequent worksheets.

The titles go into the cells marked in yellow. Their length is limited by the length of the boxes where the information is used.
If you do not want a title or note to appear, enter a blank
Enter only one steam flow and/or pressure. Boil-Bal will convert as needed.

**What if…?**

| To get a limited idea of what might change if: | Make these changes | |
|---|---|---|
| a. the make-up quality is improved | Reduce tracer in make-up. | Simple RO should reduce Cl to 0.1-0.5 ppm |
| go the other way if it deteriorates | | Full demineralization with polisher should be <0.01 ppm |
| | Reduce tracer in feedwater. | Drop until the calculated losses are the same. |
| | Adjust tracer in blowdown. | Reduce if you wish to carry less solids |
| b. More/less condensate can be recovered | Adjust tracer in feedwater. | Select value corresponding to the amount recovered |
| c. boiler quality is improved | Adjust tracer in blowdown. | |

Note that balance calculation is based upon providing a fixed steamflow and this limits the range that can be applied. When making changes, watch for systemflow limitation, e.g., being required to supply more make-up than the water-treatment plant can supply or exceeding the capacity of the blowdown line.

**Water**
This sheet calculates the water consumption and costs.

Enter the raw-water cost and treated-water costs in the appropriate units. Boil-Bal will convert as needed.
If the cost for treated water includes the raw water cost leave the raw water cost blank
If the water is not treated, leave the treated-water cost blank
Most treatment processes have a waste stream. Estimate the percentage that goes to waster. With RO, it could be 30-50%
If treated water is purchased at a fixed cost, the percentage that goes to waster will likely be 0%

**WaterBal-FS**
This page gives a flowsheet with the water balance shown for the various streams.

**Energy**
This sheet calculates the energy consumption and costs.

Enter either metric or non-metric units in the appropriate units, but not both. Boil-Bal will convert as needed.
The various calculated values are shown in both units in the lower table
The steam table values are approximated from a curve fit. The fits is within ±1 C° or ±1% of the enthalpy for most of the range.

**EnergyBal-FS**
This page gives a flowsheet with both the energy and the water balance shown for the various streams.

**Workspace**
Due to the large variety of chemical-treatment programs that are available for different boilers designs and operating pressures, there is no generalized calculation that fits all. The table is offered only as a means to help the users estimate costs for their system. There is no implied intent that the end result is either complete or accurate.

**Customized Worksheets**
This is an Excel spreadsheet. Additional worksheets can be added and set up in any manner the user desires. It is recommended that the existing structure be left intact and that individual values be accessed by the formula "=existing cell" rather than doing any cutting and pasting. It is also recommended that such customizing be done with a copy of the original.

*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**

# Boil-Bal Set-up Parameters

| | | | | | |
|---|---|---|---|---|---|
| **Flow units for plotting data on flowsheet** | | | | | |
| | | | | | |
| | 1 - IG/day | 1 - $/day | | | 1 - lb/hr |
| | 2 - USG/day | 2 - $/yr | | | 2 - lb/day |
| | 3 - m³ /day | | | | 3 - kg/hr |
| | 4 - IG/year | | | | 4 - kg/day |
| | 5 - USG/year | | | | 5 - kg/s |
| | 6 - m³ /year | | | | 6 - lb/yr |
| | | | | | 7 - kg/yr |
| Select >>> | 4 | 2 | | Select >>> | 3 |
| | | | | | |
| | IG/yr | $/yr | | | |
| **Make-up** | | | | **Water Balance** | |
| Raw Water | 12914365 | 20663 | | Flows | kg/hr |
| Treated Make-up | 11229883 | 11230 | | Steam | 27223 |
| Total Make-up Cost | | 31893 | | Feedwater | 29091 |
| **Losses** | | | | Cond Return | 21396 |
| Treatment Losses | 1684482 | 2695 | | Make-up | 5827 |
| Blowdown | 3368965 | 9568 | | Blowdown | 1748 |
| - Flashed Steam | 312550 | 888 | | Losses | 4079 |
| - Discharged to Sewer | 3056415 | 8680 | | | |
| Condensate Lost | 7860918 | 22325 | | | |

| | | | |
|---|---|---|---|
| **Energy units auto-selected by input** | | | |
| | | | |
| | | | |
| Boiler Pressure | | 100 | psia |
| Steam Temperature | | 327 | °F |
| Dearator Temperature: | | 239 | °F |
| Heat-Exchanger Outlet: | | 90 | °F |
| Make-up temperature | | 60 | °F |
| | | | |
| | | | |
| **Energy Losses** | | Million BTU/yr | |
| - With No Recovery | | 9143 | |
| - With Flash Tank | | 5588 | |
| - & Heat Exchanger | | 1007 | |
| **Energy Savings** | | | |
| - With Flash Tank | | 3555 | |
| - & Heat Exchanger | | 4581 | |
| | | 8136 | |

| | | |
|---|---|---|
| **Units for calculating chemical consumption** | | |
| | | |
| | 1 - kg | |
| | 2 - lb | |
| Select >>> | 1 | |
| | | |
| Unit Price | $/kg | |
| Daily Consumption | kg/day | |
| Annual Consumption | kg/yr | |

| A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|

# Boil-Bal Data Input Screen

**BOILER MASS-BALANCE CALCULATIONS**

| | |
|---|---|
| Plant: | XYZ Manufacturing |
| System: | #2 Utility boiler |
| Note 1: | Operating with softened water |
| Note 2: | Phosphate-based treatment |
| Note 3: | Standard operation |
| Note 4: | Operating 24/7 |

**STEAM PRODUCTION:**

| | | | | |
|---|---|---|---|---|
| | 60000 | lb/hr | 60000 | lb/hr |
| | | lb/day | 1440000 | lb/day |
| **Flow** | | kg/day | 653180 | kg/day |
| | | kg/hr | 27223 | kg/hr |
| | | kg/s | 7.56 | kg/s |
| | | | | |
| | | kPa | 689.0 | kPa |
| **Pressure** | | psig | 85.3 | psig |
| | 100 | psia | 100.0 | psia |
| | | | | |
| | | | | |
| **Temperature** | | | 164 | °C |
| | | | 327 | °F |
| | | | | |
| **Operation** | 365 | days/yr | | |

**SOLUBLE TRACER**

| | **ppm Cl** | **%** | **kg/hr** | **COC** |
|---|---|---|---|---|
| Make-up | 30 | 21.4 | 5827 | 3.3 |
| Feedwater | 6.5 | 106.9 | 29091 | 15.6 |
| Steam Flow | | 100.0 | 27223 | |
| Boiler Blowdown | 100 | 6.42 | 1748 | |
| Cond. Return | 0.1 | 78.6 | 21396 | |
| Losses | | 15.0 | 4079 | |

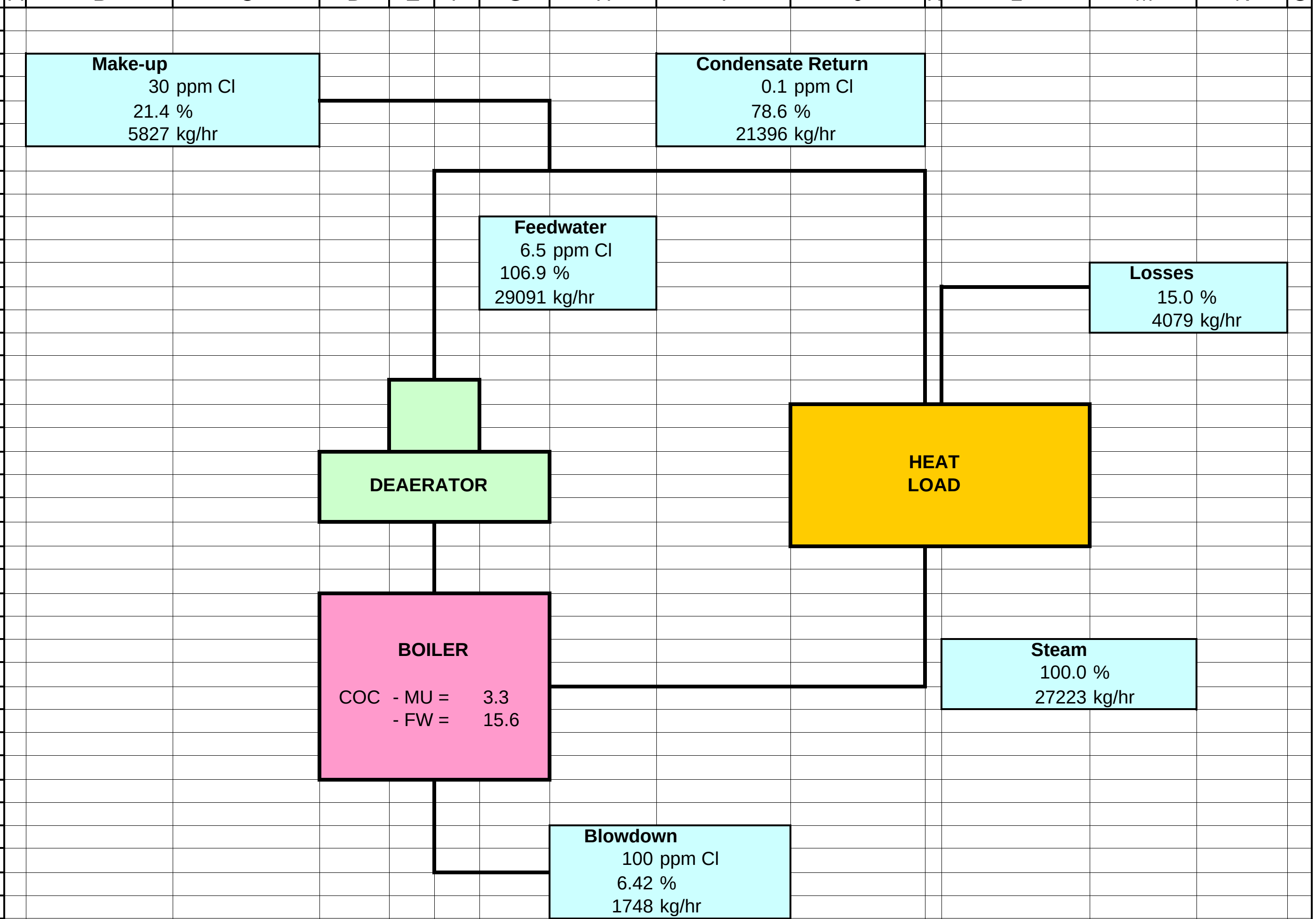
| | |
|---|---|
| Plant: | **XYZ Manufacturing** |
| System: | **#2 Utility boiler** |
| Note 1: | **Operating with softened water** |
| Note 2: | **Phosphate-based treatment** |
| Note 3: | **Standard operation** |
| Note 4: | **Operating 24/7** |

## CALCULATED WATER BALANCE

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Cycles of Concentration** | | 3.3 | Relative to Make-up | | | | | |
| | | 15.6 | Relative to Feedwater | | | | | |
| | | | | | | | | |
| **Flows** | **percent** | **lb/hour** | **lb/day** | **kg/hr** | **kg/day** | **kg/s** | **lb/yr** | **kg/yr** |
| **Steam** | 100.00 | 6.00E+04 | 1.44E+06 | 2.72E+04 | 6.53E+05 | 7.56 | 5.26E+08 | 2.38E+08 |
| **Feedwater** | 106.86 | 6.41E+04 | 1.54E+06 | 2.91E+04 | 6.98E+05 | 8.08 | 5.62E+08 | 2.55E+08 |
| **Condensate Returns** | 78.60 | 4.72E+04 | 1.13E+06 | 2.14E+04 | 5.14E+05 | 5.94 | 4.13E+08 | 1.87E+08 |
| **Make-up** | 21.40 | 1.28E+04 | 3.08E+05 | 5.83E+03 | 1.40E+05 | 1.62 | 1.13E+08 | 5.10E+07 |
| **Blowdown** | 6.42 | 3.85E+03 | 9.25E+04 | 1.75E+03 | 4.20E+04 | 0.49 | 3.38E+07 | 1.53E+07 |
| **Losses** | 14.98 | 8.99E+03 | 2.16E+05 | 4.08E+03 | 9.79E+04 | 1.13 | 7.88E+07 | 3.57E+07 |

## ESTIMATE OF WATER COST:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **Raw Water Cost** | | **+ Treatment Cost** | | | **Water Lost by** | |
| | | 1.60 | $/1000 IG | 1.00 | $/1000 IG | | **Treatment Process** | |
| | | | $/1000 usg | | $/1000 usg | | 15 | % |
| | | | $/m³ | | $/m³ | | | |
| | | | | | | | | |
| | **IG/day** | **USG/day** | **m³/day** | **$/day** | **IG/yr** | **usg/yr** | **m³/yr** | **$/yr** |
| **Make-up** | | | | | | | | |
| Raw Water | 35382 | 42458 | 161 | 57 | 1.29E+07 | 1.55E+07 | 58702 | 20663 |
| Treated Make-up | 30767 | 36920 | 140 | 31 | 1.12E+07 | 1.35E+07 | 51045 | 11230 |
| - Total Make-up Cost | | | | 87 | | | | 31893 |
| | | | | | | | | |
| **Losses** | | | | | | | | |
| Treatment Losses | 4615 | 5538 | 21 | 7 | 1.68E+06 | 2.02E+06 | 7657 | 2695 |
| Blowdown | 9230 | 11076 | 42 | 26 | 3.37E+06 | 4.04E+06 | 15313 | 9568 |
| - Flashed Steam | 856 | 1028 | 4 | 2 | 3.13E+05 | 3.75E+05 | 1421 | 888 |
| = Blowdown to Sewer | 8374 | 10048 | 38 | 24 | 3.06E+06 | 3.67E+06 | 13893 | 8680 |
| Condensate Lost | 21537 | 25844 | 98 | 61 | 7.86E+06 | 9.43E+06 | 35731 | 22325 |




**BOILER-WATER MASS BALANCE DIAGRAM**

| | |
|---|---|
| *Plant:* | **XYZ Manufacturing** |
| *System:* | **#2 Utility boiler** |
| *Note 1:* | **Operating with softened water** |
| *Note 2:* | **Phosphate-based treatment** |
| *Note 3:* | **Standard operation** |
| *Note 4:* | **Operating 24/7** |

| | |
|---|---|
| Plant: | **XYZ Manufacturing** |
| System: | **#2 Utility boiler** |
| Note 1: | **Operating with softened water** |
| Note 2: | **Phosphate-based treatment** |
| Note 3: | **Standard operation** |
| Note 4: | **Operating 24/7** |

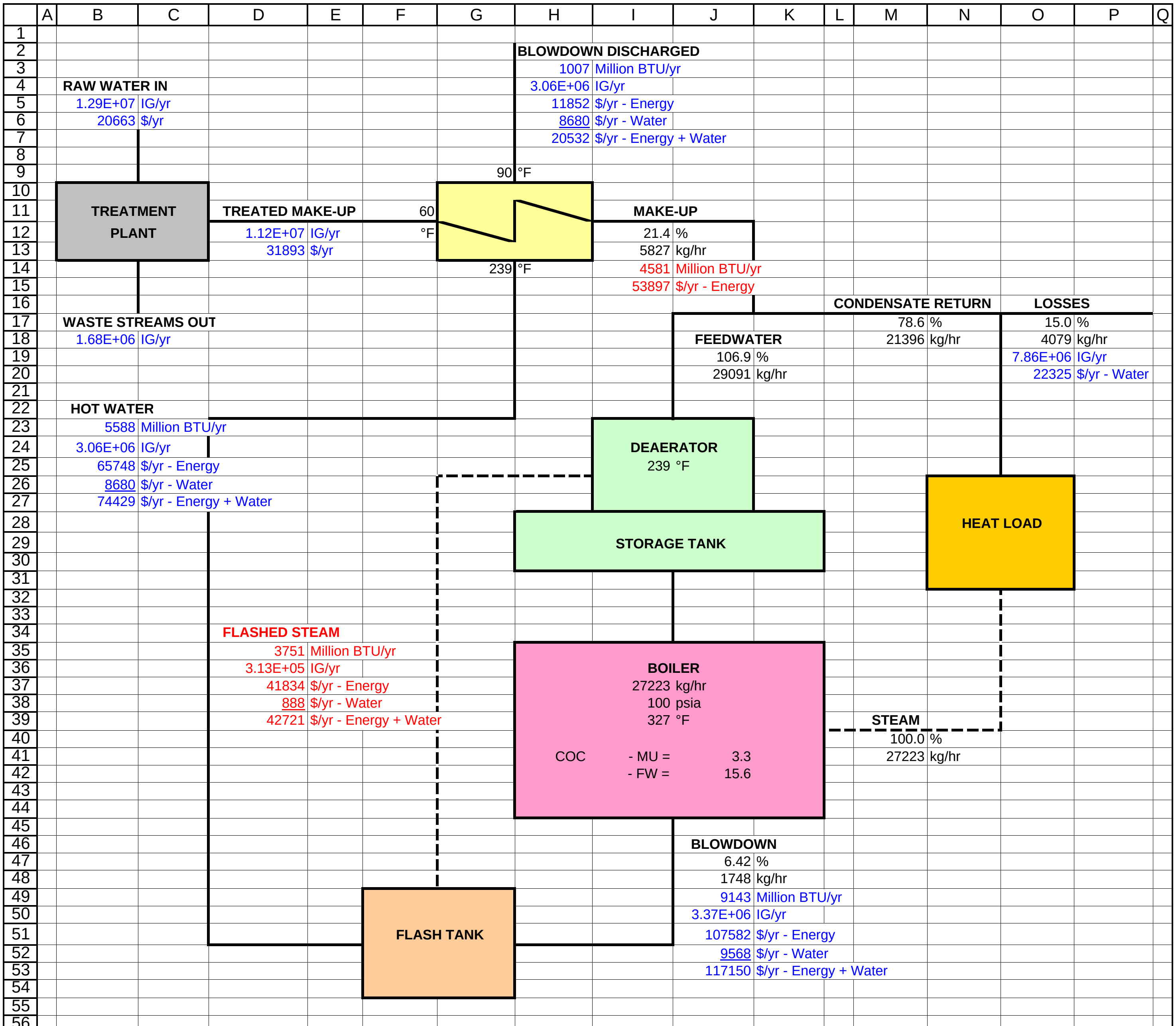
**BLOWDOWN ENERGY LOSS ESTIMATE:**

| | | | | | | |
|---|---|---|---|---|---|---|
| Fuel: | Natural Gas | Heat Value: | 7.4 | $/million BTU | | $/GJ |
| Boiler Efficiency: | | | 70 | % | | |
| Dearator Temperature: | | | | °C | 239 | °F |
| Heat-Exchanger Outlet: | | | | °C | 90 | °F |
| Make-up temperature | | | | °C | 60 | °F |
| Flashed Steam: | | | 9.3 | % | | |

| **Losses** | **Million BTU/day** | **Million BTU/yr** | **GJ/day** | **GJ/yr** | **$/day** | **$/yr** |
|---|---|---|---|---|---|---|
| **No Recovery** | 25.1 | 9143 | 26.4 | 9646 | 295 | 107,582 |
| **- With Flash Tank** | 15.3 | 5588 | 16.2 | 5895 | 180 | 65,748 |
| **- & Heat Exchanger** | 2.8 | 1007 | 2.9 | 1063 | 32 | 11,852 |
| **Savings** | | | | | | |
| **- With Flash Tank** | 9.7 | 3555 | 10.3 | 3751 | 115 | 41,834 |
| **- & Heat Exchanger** | 12.5 | 4581 | 13.2 | 4833 | 148 | 53,897 |
| | 22.3 | 8136 | 23.5 | 8583 | 262 | 95,730 |

**ENERGY LOSS CALC.**

| | | | | |
|---|---|---|---|---|
| **FUEL COST** | | | | |
| Natural Gas | 8.2 | $/million BTU | 7.807 | $/GJ |
| | | | | |
| **FLASH TO D/A** | | | | |
| Boiler pressure | 100 | psia | 689 | kPa |
| Enthalpy - at pressure | 296 | BTU/lb | 688 | kJ/kg |
| Temperature | 239 | °F | 115 | °C |
| Enthalpy - at D/A temperature | 208 | BTU/lb | 483 | kJ/kg |
| Latent heat of vaporization | 953 | BTU/lb | 2216 | kJ/kg |
| Make-up Temperature | 60 | °F | 16 | °C |
| Enthlapy of make-up | 28 | BTU/lb | 65 | kJ/kg |
| % flashed to steam | 9.3 | % | 9.3 | % |
| Enthalpy of flashed steam | 1160 | BTU/lb | 2699 | kJ/kg |
| Energy saved | 1132 | BTU/lb | 1195 | kJ/kg |
| | | | | |
| **HEAT EXCHANGER** | | | | |
| Enthalpy - HX out | 58 | BTU/lb | 135 | kJ/kg |
| Outlet Temperature | 90 | °F | 32 | °C |
| Energy saved | 150 | BTU/lb | 158 | kJ/kg |




## BOILER ENERGY AND WATER MASS BALANCE DIAGRAM

| | |
|---|---|
| *Plant:* | **XYZ Manufacturing** |
| *System:* | **#2 Utility boiler** |
| *Note 1:* | **Operating with softened water** |
| *Note 2:* | **Phosphate-based treatment** |
| *Note 3:* | **Standard operation** |
| *Note 4:* | **Operating 24/7** |

| | A | B | C | D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | |
| 2 | | | Plant: | **XYZ Manufacturing** | | | | | | | |
| 3 | | | System: | **#2 Utility boiler** | | | | | | | |
| 4 | | | Note 1: | **Operating with softened water** | | | | | | | |
| 5 | | | Note 2: | **Phosphate-based treatment** | | | | | | | |
| 6 | | | Note 3: | **Standard operation** | | | | | | | |
| 7 | | | Note 4: | **Operating 24/7** | | | | | | | |
| 8 | | | | | | | | | | | |
| 9 | | TREATMENT COSTS | | | | | | | | | |
| 10 | | | | | | | | | | | |
| 11 | | TREATMENT PRODUCTS: | | mg/L | $/kg | kg/day | $/day | kg/yr | $/yr | | |
| 12 | | ........ | to steam | 10 | 5.00 | 0.3 | 1.36 | 99 | 497 | | |
| 13 | | ........ | " | 10 | 5.00 | 0.3 | 1.36 | 99 | 497 | | |
| 14 | | ........ | to feedwater | 10 | 5.00 | 0.3 | 1.45 | 106 | 531 | | |
| 15 | | ........ | " | 10 | 5.00 | 0.3 | 1.45 | 106 | 531 | | |
| 16 | | ........ | to make-up | 10 | 5.00 | 0.1 | 0.29 | 21 | 106 | | |
| 17 | | ........ | " | 10 | 5.00 | 0.1 | 0.29 | 21 | 106 | | |
| 18 | | | | | | | 6.21 | | 2268 | | |
| 19 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |