

## **Calculator Instructions**

Often times you have to do a project yourself to obtain the best value and achieve 100% personal satisfaction. We are do-it-yourselfers (DIY) and we support like-minded people. To this end, these calculators were created. ***Please use these calculators and the results they provide at your own discretion and your own risk...we are NOT responsible for any damage or harm that you may inflict on yourself or on others...please read and comply with our Terms of Use located at the bottom of our Web pages!***

These **Hydronic Radiant Floor Heating**, **Passive Solar Heating** and **Water Work Project** calculators were developed using JavaScript which is software that will run using your browser application. The calculator titles on this calculator instructions Adobe Portable Document File (PDF) contain hyperlinks to our Borst Engineering & Construction LLC calculator website. So you may want to first download the calculator instructions PDF from our website, spend some time studying the instructions, and then use the PDF hyperlinks to navigate back to our calculator website when you ready to use the actual calculators. The matching calculator titles on our calculator website contain hyperlinks to the actual calculators. Click the calculator link on our website to use the specific calculator that you desire. After you have obtained the calculator solution by following the specific calculator instructions, you may then save your results by right clicking the calculator form and selecting "Save Page As." If interested, you may also view the actual JavaScript code by right clicking the calculator form and selecting "View Page Source."

We hope you find these calculators to be useful for your non-commercial DIY projects. We welcome your feedback and suggestions. Please consider making a donation to help support our continued DIY calculator development and website maintenance efforts. Our mailing address may be found on the "Contact Us" section of our website.

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## Heat Loss Analysis Calculator

The first thing you need to do before designing a **Passive Solar Heating** or a **Hydronic Radiant Floor Heating** system is to know how much heat gain your building will require to keep the occupants comfortable. How much heat gain you will require is exactly the same amount as the heat you will lose from heat transfer through your walls, ceilings, doors, windows, and floors, as well as the heat you will lose from air infiltration (or controlled ventilation). This heat loss is proportional to surface area exposed to the outside, the temperature difference between inside and outside, and the heat transfer coefficient (U-factor) of your walls, ceilings, doors, windows, and floors. In order to use this calculator, you first need to use the known thermal resistance (R-value) of the materials used in your building construction to determine the total R-value of your walls, ceilings and floors. You also need to know the manufacturer specified total R-value of your external doors and windows. These total R-values are entered into the calculator and converted to U-factors which are used to determine the heat loss as previously described.

The following is a list of R-values for typical material used in the building construction industry:

### **AIR FILMS:**

Inside surface	0.64
Outside surface (15 MPH wind)	0.17

### **CONCRETE AND MASONRY:**

Common brick	0.2-0.4 per inch
Concrete	0.10 per inch
8" concrete block	1.11 for 8"
W/ vermiculite in cores	2.10 for 8"
10" concrete block	1.20 for 10"
W/ vermiculite in cores	2.90 for 10"
12" concrete block	1.28 for 12"
W/ vermiculite in cores	3.70 for 12"

### **FLOORING:**

Carpet ( 1/4" nylon level loop)	1.36 for 1/4"
Carpet (1/2" polyester plush)	1.92 for 1/2"
Ceramic tile	0.6 per inch
Polyurethane foam padding (8 PCF)	4.4 per inch
Vinyl tile or sheet flooring (1/8")	0.21 for 1/2"

### **INSULATION:**

Blown cellulose fiber	3.1-3.7 per inch
Blown fiberglass	2.45 per inch
Expanded polystyrene panels	3.85 per inch
Extruded polystyrene panels	5.4 per inch
Fiberglass batt (standard density)	3.17 per inch
Fiberglass batt (high density)	3.5 per inch
Foam in place urethane	5.6-6.3 per inch
Phenolic foam panels	8.3 per inch
Polyisocyanurate panels	7.2 per inch

Vermiculite	2.1 per inch
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**WOOD AND WOOD PANELS:**

Hardwoods	0.8-0.94 per inch
Plywood	1.24 per inch
Softwoods	0.9-1.1 per inch
Wafer board or oriented strand board	1.59 per inch

**MISCELLANEOUS:**

Building felt (15 lb / 100 sq ft)	0.06 per inch
Drywall	0.9 per inch
Fiberboard sheathing	2.18 per inch
Polyolefin house wrap	0 per inch
Poly vapor barriers	0 per inch
Vinyl clapboard siding	0.61 per inch

***The total R-value for a specific thickness of a material may be obtained by multiplying the R-value per inch by the thickness in inches. The R-values for each layer of material should be added together to determine the total R-value of your wall, ceiling, and framed floor assemblies. Please note, if you have a fully insulated slab-on-grade floor, you only need to know the R-value of this insulation and you need to enter exposed perimeter instead of exposed area!***

For example, for a 2x4 wall assembly we might have 0.64 (inside air film) plus 0.45 (0.9 times 0.5 inch drywall) plus 11.0 (3.17 times 3.5 inches of fiberglass batt) plus 0.62 (1.24 times 0.5 inch plywood sheathing) plus 0.31 (0.61 times 0.5 inch vinyl clapboard siding) plus 0.17 (outside air film) for total R-value of 13.19. If we had this same initial wall assembly except that the core was 2x6, we would have 17.44 (3.17 times 5.5 inches of fiberglass batt) instead of 11.0 for a total R-value of 20.34. If we had this same initial wall assembly except that the core was 11 inch Insulated Concrete Form (ICF) construction, we would have 0.6 (0.1 times 6 inches concrete) plus 19.25 (3.85 times 5 inches expanded polystyrene panel) instead of 11.0 for a total R-value of 22.75.

To use this calculator, enter the following input parameters:

- 1) **Design Outdoor Temp (Degrees Fahrenheit)** - This is typically specified by your local building code.
- 2) **Design Indoor Temp (Degrees Fahrenheit)** - This is typically 65 to 75 degrees F.
- 4) **Exposed Wall Area (SF)** - This is the total wall area of the building or room that is exposed to the outside temperature. If a wall is an interior wall and therefore not exposed to the outside temperature, do include this wall area. Please note that the calculator will subtract the area of any doors or windows that are associated with this wall area, so you do not need to accomplish this math.
- 5) **Wall R-value (SF-[ ])TJWall**

- 7) **Ceiling R-value (SF-Degrees F-Hour/BTU)** - This is the total R-value of the materials used for the ceiling construction.
- 8) **Exposed Door Area (SF)** - This is the total area of the building or room exterior doors.
- 9) **Door R-value (SF-Degrees F-Hour/BTU)** - This is the door R-value as stated by the door manufacturer.
- 10) **Exposed Window Area (SF)** - This is the total area of the building or room exterior windows.
- 11) **Window R-value (SF-Degrees F-Hour/BTU)** - This is the window R-value as stated by the window manufacturer.
- 12) **Floor Type** - This is a logic parameter that tells the calculator the type of building or room floor. Entering a 0 tells the calculator that there are no floors exposed to the outside temperature. Entering a 1 tells the calculator that the floor is framed with an unheated crawl space below. Entering a 2 tells the calculator that the building or room floor is fully insulated slab-on-grade and to use ASHRAE F-Factor recommendations for soil conductivity typical in the Pacific Northwest. Entering a 3 tells the calculator that the building or room floor is fully insulated slab-on-grade and to use Siegenthaler "Modern Hydronic Heating" generic recommendations.
- 13) **Framed Floor Area or Slab-on Grade Perimeter (SF or Feet)** - If you entered 1 for Floor Type, this is total floor area of your building or room. If you entered 2 or 3 for Floor Type, this is the total perimeter of the walls in your building or room that is exposed to the outside temperature. If a wall is an interior wall and therefore not exposed to the outside temperature, do include this perimeter.
- 14) **Framed Floor or Slab-on Grade Insulation R-value (SF-Degrees F-Hour/BTU)** - If you entered 1 for Floor Type, this is the total R-value of the materials used for the framed floor construction. If you entered 2 or 3 for Floor Type, this is the total R-value for the insulation used for the slab-on-grade.
- 15) **Building or room Volume (CF)** - This is the total inside volume of the building or room and includes the volume of ALL the rooms, even if they are not exposed to the outside temperature.
- 16) **Air Changes per Hour** - This is the number times that the building or room air is replaced by fresh outside air every hour. 0.35 ACH is the minimum allowed for health reasons. 0.5 ACH is typical for new construction and 1.0 ACH is typical for older construction.

Click to obtain the following output parameters:

- 1) **Exposed Wall Heat Loss (BTU/Hour)** - This is the exposed wall heat loss.
- 2) **Exposed Ceiling Heat Loss (BTU/Hour)** - This is the exposed ceiling heat loss.
- 3) **Exposed Door Heat Loss (BTU/Hour)** - This is the exterior door heat loss.
- 4) **Exposed Window Heat Loss (BTU/Hour)** - This the exterior window heat loss.
- 5) **Exposed Floor Heat Loss (BTU/Hour)** - This is the exposed floor heat loss. Use this value in the **Hydronic Radiant Floor Heating** Design calculator.
- 6) **Infiltration Heat Loss (BTU/Hour)** - This is the heat loss due to air infiltration or forced ventilation.
- 7) **Total Heat Loss (BTU/Hour)** - This is the total heat loss of the building or room. Use this value in the **Hydronic Radiant Floor Heating** Design calculator.

## Hydronic Radiant Floor Heating Design Calculator

Please be warned, this calculator can be intimidating at first sight! This calculator can be used to design a one to five room (with one to four circuits per room) **hydronic radiant floor heating** system supplied by a single pump, using a common boiler supply temp for all the circuits, and using manifolds with balancing valves to adjust the circuit hydraulic resistance and resulting flow rate. This calculator assumes the floor is fully insulated (i.e., a downward heat loss of 10% or less of the upward heat gain), four inch concrete slab-on-grade and that the hydronic fluid is water.

You may need more than one circuit per room because there is a maximum circuit length that can be achieved before the friction in the circuit becomes excessive and the pump becomes overly challenged to supply the necessary head to overcome this excessive friction at the necessary flow rate to provide the required heat gain. For nominal 0.5 inch diameter PEX tube, this maximum length is typically 300 feet. Once you exceed five rooms or about twelve circuits, you will likely need more than one pump and simply using a common boiler supply temp for all the circuits becomes problematic. There are ways to address this challenge (e.g., using injection mixing), but this is beyond the scope of a DIY project and this simple calculator.

To use this calculator, enter the following input parameters:

- 1) **Design Outdoor Temp (Degrees Fahrenheit)** - This is typically specified by your local building code.
- 2) **Design Indoor Temp (Degrees Fahrenheit)** - This is typically 65 to 75 degrees F.
- 3) **Allowed Temp Drop of Circuit (Degrees Fahrenheit)** - This is the allowed temperature change of the hydronic fluid after it passes through the PEX tube circuit. The fluid temperature drops from its initial below Required Average Fluid Supply Temperature by this amount. 15 degrees F or less is recommended for barefoot friendly residential floors.
- 4) **Heated Area (Square Feet)** - This is the room area minus the area that is NOT heated such as below kitchen counters, etc.
- 5) **Unblocked Heated Area (Square Feet)** - This is the heated area minus the area blocked by furniture, etc.
- 6) **Total Heat Loss (BTUs/Hour)** - This is the total heat loss of this room. This may be obtained by performing a building heat loss analysis using the previous Heat Loss calculator.
- 7) **Exposed Floor Heat Loss (BTUs/Hour)** - This is the room downward heat loss from the slab-on-grade floor, one component of your total heat loss. This may be obtained by performing a building heat loss analysis using the previous Heat Loss calculator.
- 8) **Required Leader Length to Manifold Station (Feet)** - This is the additional length of PEX tube required to reach the room circuit(s) depending on where you locate your manifold station.
- 9) **Tube Nominal Diameter (Inches)** - This is the standard nominal diameter of the PEX tube in inches. If you input a standard pipe size (such as 0.5 or 0.75 inches), the calculator will use the actual inside diameter of PEX tube.
- 10) **Selected Tube Spacing (Inches)** - This is the actual tube spacing between the tube runs in the concrete slab that you will use after considering Recommended Maximum Tube Spacing output. 12 inches or less is recommended for barefoot friendly residential floors.
- 11) **Supplemental Heat Gain (BTUs/Day)** - This is to account for any additional heat sources you may elect to use such as a **masonry heater** or **passive solar heating**.
- 12) **Balance Valve Setting** - Please see below detailed directions.
- 13) **Pump Performance Curve (Gallons per Minute versus Feet)** - This is the pump performance curve published by the manufacturer of your selected pump. This curve must be defined via 7 "points" of Pump Flow Rate (in Gallons per Minute) versus Pump Head (in Feet). Example Pump

Performance Curve "points" are shown for a Taco 006 pump. Please see below detailed directions.

Click

to obtain the following output parameters for each room:

- 1) **Required Heat Gain (BTUs/Hour & BTUs/Day)** - This is the heat gain that the floor must provide in order to meet your heating requirements for this room.
- 2) **Downward Heat Loss (Percent of Upward Heat Gain)** - This is the heat loss going into the ground below your floor slab as a percentage of the upward heat gain provided by heating the floor. A downward heat loss of 10% or less is recommended.
- 3) **Required Floor Temp (Degree Fahrenheit)** - 85 degrees F or less is recommended for barefoot friendly residential floors. You may need to adjust your design input parameters to achieve this.
- 4) **Recommended Maximum Tube Spacing (Inches)** - This is the recommended tube spacing to economically meet the required heat gain requirements. However, 12 inches or less is recommended for barefoot friendly residential floors.
- 5) **Required Number of Circuits** - This is number of room circuits required to keep PEX tube friction within acceptable pumping limits.
- 6) **Total Required Tube Length (Feet)** - This is the total length of PEX tube required for each room, including the additional length required to reach the manifold station.
- 7) **Reynold's Number** - This is an important performance design parameter. Greater than 2300 is recommended to ensure high thermal efficiency turbulent flow rate. You may need to adjust your design input parameters to achieve this.
- 8) **Velocity (Feet per Second)** - A design that results with between 2 and 4 FPS is recommended to ensure air bubble entrainment (important when initially filling the system and for long-term operational reliability) while also ensuring there will not be any perceptible flowing water floor noise.
- 9) **Required Flow Rate (Gallons per Minute)** - This is flow rate that the pump must provide in order to meet your heating requirements for this room.
- 10) **Flow Rate at Balance Valve Setting** - This is the manifold balance valve setting that is required to achieve the above required flow rate for this room given that the pump is supplying multiple rooms.
- 11) **Flow Rate provided by Pump at Balance Valve Setting at Hydraulic Equilibrium (Gallons per Minute)** - This is the actual flow rate provide to the room given the pump selected and given the above balance valve setting.
- 12) **Required Fluid Supply Temp (Degrees Fahrenheit)** - This is the temperature that the boiler must provide in order to meet your heating requirements for this room.
- 13) **Actual Heat Gain (BTUs/Hour & BTUs/Day)** - This is the actual heat gain that results from using the pump you selected, the above Balance Valve Setting you selected, and the below Required Average Fluid Supply Temp (please see below totalized output parameters).

This calculator will also provide the following totalized output parameters:

- 14) **Total Required Flow Rate (Gallons per Minute)** - This is the total flow rate that the selected pump must be capable of supplying given the below total system head loss. This parameter is used to select your pump (please see below detailed directions).
- 15) **Total System Head Loss at Balance Valve Setting (Feet)** - This is the head loss resulting from all the friction in the PEX tubes and from the balance valve settings. This parameter is used to select your pump (please see below detailed directions).

- 16) **Total Head provided by Pump (Feet)** - This is the actual head being supplied by the pump given where it is being operated on its pump performance curve.
- 17) **Pump Differential Pressure (Pound per Square Inch)** - This is the pressure that would be measured between the pump inlet and pump outlet.
- 18) **Required Average Fluid Supply Temp (Degree Fahrenheit)** - This is the single temperature that the boiler should be set to supply all the room circuits.
- 19) **Total Actual Heat Gain (BTUs/Hour & BTUs/Day)** - This is the total heat gain that all the circuits and rooms provide the building.

First enter design inputs 1) to 11) for your actual number of rooms, enter zeros for all the remaining inputs and then click  . Then adjust each room's **Balance Valve Setting** such that the **Flow Rate at Balance Valve Setting** is equal to the **Required Flow Rate** clicking  multiple times until you achieve this. Then select a pump based on **Total Required Flow Rate** and **Total System Head Loss at Balance Valve Setting**. For maximum pump efficiency and lowest energy use and operating cost, **Total Required Flow Rate** and **Total System Head Loss at Balance Valve Setting** should fall close to the center of the **Pump Performance Curve** (the data that pump manufactures publish for this purpose) for the actual pump that you select. Enter the **Pump Performance Curve** for the pump you selected into the calculator (example data points for a Taco 006 pump are shown) and click  . If you did a good job selecting your pump, **Flow Rate provided by Pump at Balance Valve Setting at Hydraulic Equilibrium** should be fairly close to **Required Flow Rate** for each room. **Actual Heat Gain** should also be fairly close to **Required Heat Gain** for each room.

*There is a significant time lag (i.e., many hours) for a hydronic heated floor to heat up and cool down. Therefore, it is important and well worth the effort to use a sophisticated control system that uses actual slab temps, actual indoor air room temps, both actual and forecast outdoor air temps, and additional feedback sensors to compensate for when other supplemental heat sources will be providing heat gain, and when they will NOT be providing heat gain.*

### **Masonry Heater Performance Calculator**

Energy efficient homes may only require 3,000 to 8,000 British Thermal Units (BTUs) of heat gain per hour. For most conventional woodstoves, this is well below their critical burn rate or where they start to smolder. Therefore, woodburning and energy efficient homes are not normally compatible unless you have some way to store the heat so your stove can operate cleanly all the time. **Masonry heaters** are the most efficient way to heat a home with wood. Unlike fireplaces or stoves, there is very little heat loss because the exhaust gases are circulated through the **masonry heater** several times before going to the chimney. There is very little pollution because **masonry heaters** burn the wood very quickly and operate at about 1700 degrees and fully burn what even certified stoves can't burn. However, **masonry heater** surfaces never get extremely hot like stoves and overheat your home. **Masonry heaters** store and slowly release stored radiant heat in a similar manner and compatible with **hydronic radiant floor heating** and **passive solar heating**. As a side benefit, you can also have a nice masonry oven that is available for energy free baking duties perhaps 10 hours per day.

To use this calculator, enter the following input parameters:

- 1) **Amount of Wood Burned per Day (Pounds)** - 10 to 20 lbs per day is typical for an energy efficient home and the wood can be burned by either one large firing per day or two small firings per day.
- 2) **BTU Value of Wood (BTUs per Pound)** - Dry Douglas Fir is 9250 BTUs/Lb.
- 3) **Heater Efficiency (Percent)** - This is a measure of how well the **masonry heater** converts the chemical energy of the wood (BTUs) into heat energy (BTUs) during the combustion process. This is typically 92 to 95%.

Click [here](#) to determine the **Heat Gain (BTUs/Hour & BTUs/Day)** your **masonry heater** will provide your home.



### Passive Solar Altitude Angle Calculator

This calculator can be used to determine the sun's altitude angle (as measured from the horizon to the sun) during various times of the day and the year. Exercising this calculator at noontime during the middle of each month of the year will provide you with solar altitude data to enable you to begin designing a passive solar heated building. You will see that the **Solar Altitude Angle** varies significantly during the course of the year. The highest solar altitudes occur during the summer months and lowest solar altitudes occur during the winter months.

To use this calculator, enter the following input parameters:

- 1) **Latitude (Degrees)** - This is a geographic coordinate that specifies the north-south position of a point on the Earth's surface. Latitude is an angle which ranges from 0 degrees at the Equator to 90 degrees northward and to -90 degrees southward. For example, the latitude of Rogue River, Oregon is 42.44 degrees.
- 2) **Longitude (Degrees)** - This is a geographic coordinate that specifies the east-west position of a point on the Earth's surface. Longitude is an angle which ranges from 0 degrees at the Prime Meridian to 180 degrees eastward and to -180 degrees westward. For example, the longitude of Rogue River, Oregon is -123.17 degrees.
- 3) **Hour** - This is the actual hour of the day and ranges from 0 to 24, where 12 would be noon and 24 would be midnight. You can also enter decimal value such as 12.5 for 12:30 PM (30 minutes after noon) or 0.15 for 12:15 PM (15 minutes after midnight).
- 4) **UTC Offset (Degrees)**

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- 2) **Solar Azimuth Angle (Degrees)** - The solar azimuth angle is the azimuth angle of the sun. It is most often defined as the angle from due north in a clockwise direction. As such, true east is a solar azimuth angle of 90 degrees, true south is 180 degrees and true west is 270 degrees. If you are using a compass to establish the true south orientation of your south wall, be sure to consider your local and current magnetic declination. For Rogue River, Oregon, the local magnetic declination was 15.3 degrees east of true in 2012.
- 3) **Solar Altitude Angle (Degrees)** - The solar altitude angle is the elevation angle of the sun. That is, the angle between the direction of the geometric center of the sun's apparent disk and the horizon. Depending on your latitude, the solar altitude angle can range from 0 to 90 degrees during the daylight hours.

Select a time of the year and the corresponding solar altitude angle above which you would like to have full shading of your south facing windows during the summer months. Your latitude plus 18.5 degrees is often cited as being a good "rule of thumb". However, you should consider deviating from this given your actual climate (e.g., if you have a very hot Summer and Fall, perhaps select a solar altitude angle that provides more shade through the summer and fall months). Select a time of the year and the corresponding solar altitude angle below which you would like to have full sun through your south facing windows during the winter months. Your latitude minus 18.5 degrees is often cited as being a good "rule of thumb". Again, you should consider deviating from this given your actual climate (e.g., if you have a very cold Winter and Spring, perhaps select a solar altitude angle that provides more sun through the winter and spring months). Next, use these solar altitude angle selections in the following Passive Solar Roof Overhang Calculator to see how they will affect your roof design and construction.

### Passive Solar Roof Overhang Calculator

This calculator can be used to determine the height that your roof overhang must be from the top of your south facing windows and the depth that your roof overhang must be from your south facing windows in order to achieve the passive solar design objectives that you previously selected by exercising the Passive Solar Altitude Calculator.

To use this calculator, enter the following input parameters:

- 1) **Height of Window Glass (Feet)** - This is the dimension between the upper most dimension and lower most dimension of the glass surface in your south facing windows, excluding the dimensions of the window frame.
- 2) **Desired Solar Altitude Angle for Full Shade (Degrees)** - This is the solar altitude angle you selected after exercising the previous Passive Solar Altitude Angle Calculator.
- 3) **Desired Solar Altitude Angle for Full Sun (Degrees)** - This is the solar altitude angle you selected after exercising the previous Passive Solar Altitude Angle Calculator.

Click to obtain the following output parameters:

- 1) **Required Height of Roof Overhang from Top of Glass (Feet)** - This is the dimension that the lower most dimension of your roof overhang must be from the upper most dimension of the glass surface in your south facing windows.
- 2) **Required Depth of Roof Overhang from Glass (Feet)** – This is the dimension that the furthest dimension of your roof overhang must be from the outside glass surface in your south facing windows, including the width dimension of any roof gutter being used.

You may need to iterate between this calculator and the previous Passive Solar Altitude Angle calculator to obtain both a roof design and **passive solar heating** design that you find to be acceptable.

## Passive Solar Window Exposure Calculator

This calculator essentially integrates and validates your passive solar design that you developed by using the previous passive solar calculators. Given your location, your roof overhang design, and your actual building orientation relative to due South, this calculator determines the amount of solar radiation that reaches your south facing wall windows during the various times of the day and the year, and how far into the building this solar radiation strikes the floor. By exercising this calculator, you will gain good insight on how **passive solar heating** is accomplished and determine the design parameters required to successfully accomplish **passive solar heating** for a building at your location.

An often cited "rule of thumb" is that buildings with passive solar heating should have a total south facing window/door area that is between 7% and 12% of the total building floor area. Another often cited "rule of thumb" is that for every square foot of southern exposure window/door area in excess of 7%, a passive solar building should have 5.5 square feet of 4 inch thick masonry thermal mass to absorb and slowly release the stored solar heat. These **passive solar heating** design recommendations may be reasonable if you do not have a **hydronic radiant floor heating** system. However, please note that these recommendations do NOT apply if you do have an integrated **passive solar heating** and **hydronic radiant floor heating** system!

To use this calculator, enter the following input parameters:

- 1) **Latitude (Degrees)** - This is a geographic coordinate that specifies the north-south position of a point on the Earth's surface. Latitude is an angle which ranges from 0 degrees at the Equator to 90 degrees northward and to -90 degrees southward. For example, the latitude of Rogue River, Oregon is 42.44 degrees.
- 2) **Longitude (Degrees)** - This is a geographic coordinate that specifies the east-west position of a point on the Earth's surface. Longitude is an angle which ranges from 0 degrees at the Prime Meridian to 180 degrees eastward and to -180 degrees westward. For example, the longitude of Rogue River, Oregon is -123.17 degrees.
- 3) **Hour** - This is the actual hour of the day and ranges from 0 to 24, where 12 would be noon and 24 would be midnight. You can also enter decimal value such as 12.5 for 12:30 PM (30 minutes after noon) or 0.15 for 12:15 PM (15 minutes after midnight).
- 4) **UTC Offset (Hours)** - This is the difference in hours from Coordinated Universal Time (UTC) for a particular time zone. Please be sure to account for Daylight Saving Time (DST) if this is used in your time zone. For example, for Rogue River, Oregon, DST begins at 2 AM on the second Sunday of March and ends at 2 AM on the first Sunday of November. The UTC offset for Rogue River, Oregon from the second Sunday of March until the first Sunday of November (while DST is in effect) is 7. The UTC offset for Rogue River, Oregon from the first Sunday of November until the second Sunday of March (while DST not in effect) is 8.
- 5) **Day** - This is the actual day of the month and ranges from 1 to 31, where 1 is the first day of the month. You can only enter an integer value within this range.
- 6) **Month** - This is the actual month of the year and ranges from 1 to 12, where 1 is January. You can only enter an integer value within this range.
- 7) **Year** - This is the actual year and entered in four digits, for example, 2012.
- 8) **South Wall Deviation from True South (Degrees)** - This is the direction angle that your south wall deviates from true south, which ideally should be zero. Your south wall deviation should be less than 20 degrees to ensure good **passive solar heating** performance. It is better to deviate toward the east than toward the west.

- 9) **Height of Window Glass (Feet)** - This is the dimension between the upper most dimension and lower most dimension of the glass surface in your south facing windows, excluding the dimensions of the window frame.
- 10) **Height of Bottom of Glass above Floor (Feet)** - This is the dimension that the lower most dimension of the glass surface in your south facing windows is from the upper most surface of the floor inside of your building.
- 11) **Height of Roof Overhang from Top of Glass (Feet)** - This is the design parameter you obtained after exercising the previous Passive Solar Roof Overhang Calculator. This is the dimension that the lower most dimension of your roof overhang is from the upper most dimension of the glass surface in your south facing windows.
- 12) **Depth of Roof Overhang from Glass (Feet)** - This is the design parameter you obtained after exercising the previous Passive Solar Roof Overhang Calculator. This is the dimension that the furthest dimension of your roof overhang is from the outside glass surface your south facing windows, including the width dimension of any roof gutter being used.

Click to obtain the following output parameters:

- 1) **Solar Declination Angle (Degrees)** - The solar declination angle varies seasonally due to the tilt of the Earth on its axis of rotation and the rotation of the Earth around the sun. If the Earth were not tilted on its axis of rotation, the solar declination angle would always be 0 degrees. However, the Earth is tilted by 23.45 degrees and the solar declination angle varies plus or minus this amount. Only during the spring and fall equinoxes is the solar declination angle exactly equal to 0 degrees. Therefore, in the northern hemisphere, the solar declination angle ranges from 0 degrees at the Spring Equinox (March 20th) and Fall Equinox (September 22nd) to 23.45 degrees at Summer Solstice (June 20th) to -23.45 at Winter Solstice (December 21st). It is this seasonal solar declination angle variation affect on the solar altitude angle that makes **passive solar heating** possible.
- 2) **Solar Azimuth Angle (Degrees)** - The solar azimuth angle is the true direction angle of the sun. That is, the angle between the direction of the geometric center of the sun's apparent disk and true north in a clockwise direction. As such

- 6) **Distance from Glass Solar Radiation Strikes Floor (Feet)** – This is the dimension from the inside glass surface of your south facing windows to the furthest and upper most surface of floor inside of your building that the sunlight will reach at the time of the day, day of the month, month of the year, and the year that you selected.

A proper passive solar design uses the above data in conjunction with:

- 1) Your specific degree heating/cooling day data for your specific location/climate
- 2) Your specific solar radiation data for your specific location/climate
- 3) Your specific building construction properties to determine the exact building heat gain/loss,
- 4) Your specific building construction properties to determine the exact passive solar thermal absorption/release requirements

This data is used to determine your actual daily heating needs and to determine how best to successfully meet these needs with an integrated solution (e.g., **hydronic radiant floor heating**, **masonry heater**, **passive solar heating**, and any additional supplemental heating/cooling). ***Borst Engineering & Construction LLC has successfully integrated passive solar heating and hydronic radiant floor heating systems to enable conveying heat from passive solar heated southern exposure floor areas (and from a masonry heater) to other floor areas to very efficiently heat a building and to maintain a comfortable inside environment even with a highly variable outside environment.***

## Cross Flow Turbine Design Calculator

The Banki cross flow turbine consists of a nozzle and runner. The runner consists of two parallel circular disks attached at the rim by a series of curved blades. The nozzle has a rectangular cross-sectional area and discharges a jet of water the full width of the runner. The jet typically enters the runner at a 16 degree angle tangent to the outer rim of the runner. The water initially strikes the blades at the rim of the runner, flows over the blade, passes thru the empty space in the center of the runner, enters another blade on the inner rim, flows over this blade, and finally exits the runner at the outer rim. While not as efficient as a Kaplan, a Francis or a Pelton turbine, the cross flow turbine has the following benefits:

- 1) Works well for low head streams
- 2) Has a flat efficiency curve under variable flow rates
- 3) Is self-cleaning and highly reliable
- 4) Is relatively easy to self-construct
- 5) Is relatively easy to self-maintain

To use this calculator you must first get an education about cross flow turbine design/build parameters. One good reference to get started with is "The Banki Water Turbine", Bulletin Series no. 25, C.A. Mockmore & Fred Merryfield, Oregon State College, February 1949. This calculator allows you to design and build a cross flow turbine optimized to your specific hydroelectric site.

To use this calculator, enter the following input parameters:

- 1) **Design Flow Rate (Cubic Feet per Second)** - This is the flow rate you would like to feed turbine given what is available at your site.
- 2) **Design Head (Feet)** - This is the elevation difference between your penstock inlet and turbine inlet.
- 3) **Design Turbine Speed (Rotations per Minute)** - This is the desired wheel rotation speed you would like to operate the turbine. You should perhaps consider your generator requirements and your pulley drive system before selecting this value.
- 4) **Expected Turbine Efficiency (Percent)** - This is a measure of how well the turbine converts the energy of the stream (head and flow rate) into mechanical energy (torque and RPM). This is typically 60 to 80%.
- 5) **Expected Generator Efficiency (Percent)** - This is a measure of how well the generator converts mechanical energy (torque and RPM) into electrical energy (volts and amps). This is typically 90% for a Permanent Magnet Generator (PMG).
- 6) **Number of Blades** - This is the number of blades you would like to have on your turbine. 18 blades is typical.
- 7) **Blade Thickness (Inches)** - This is the thickness of the blades and is normally obtained by performing a load/stress analysis.
- 8) **Shaft Diameter (Inches)** - This is the diameter of the runner shaft and is normally determined by performing a load/stress analysis. Please see our Shaft Stress Analysis calculator.
- 9) **Water Jet Angle of Attack (Degrees)** - This is the angle that the nozzle directs the jet of water into the runner. Ideally, for maximum mechanical efficiency, we would like this angle to be as close to 0 degrees as possible. 16 degrees can be typically achieved without too much difficulty.
- 10) **Turbine Inlet Water Velocity (Feet per Second)** - This is the velocity that the water enters the nozzle and is normally determined from a penstock analysis. Please see our Pipe Capacity calculators.

- 11) **Turbine Nozzle Velocity Coefficient** - This is used to determine the friction and head loss caused by the nozzle and is typically between 0.95 and 1.0.

Click to obtain the following output parameters:

- 1) **Theoretical Power (Kilowatts)** - This is the maximum theoretical power that could be generated given the design flow rate and head assuming that the turbine and generator are 100% efficient. You will never actually be able to generate this much power in actual operation.
- 2) **Expected Power (Kilowatts)** - This is the actual power that you should expect to generate accounting for the actual realistic efficiencies of the turbine and generator.
- 3) **Specific Speed** - This is a parameter used by engineers to categorize different styles of turbines. Cross flow turbines tBT1 0 0 1 388.y fl wi58(t)-4(hi)6ne the r(n)14(g)-8( )TJETBT1 0 0 1 32.574 597.82 T



- 21) **Blade Curvature Radius (Inches)** - This is the optimum radius of the runner blades given the design parameters.
- 22) **Blade Pipe Outside Diameter (Inches)** - This is the diameter of pipe that can be used to fabricate the runner blades.
- 23) **Blade Pipe Section Angle (Degrees)** - This is angle section of pipe that would be cut to fabricate the runner blades. This parameter is used to determine the total quantity of pipe required to fabricate the runner blades.
- 24) **Blade Width (Inches)** - This is the width of the runner blades.
- 25) **Weight of Runner** - This is the fully fabricated weight of the runner including the blades, shaft and side plates.
- 26) **Blade Pipe Section Length (Inches)** - This is the length section of pipe that would be cut to fabricate the runner blades. This parameter is used to determine the total quantity of pipe required to fabricate the runner blades.
- 27) **Number of Blades per Pipe Section** - This is the number of blades that can be fabricated from each section of pipe considering that the material lost for each cut is the same dimension as the pipe thickness. This parameter is used to determine the total quantity of pipe required to fabricate the runner blades.
- 28) **Number of Blade Pipe Sections** - This is the number of pipe sections required to fabricate the design number of blades. This parameter is used to determine the total quantity of pipe required to fabricate the runner blades.
- 29) **Required Total Length of Blade Pipe (Inches)** - This is the total length of pipe required to fabricate the runner blades.
- 30) **Blade Pitch Circle Diameter (Inches)** - This is a fabrication parameter used to scribe the slots on the runner end plates for the runner blades.
- 31) **Pitch of Blades on Pitch Circle (Inches)** - This is another fabrication parameter used to scribe the slots on the runner end plates for the runner blades.
- 32) **Outer Rim Blade Spacing (Inches)** - This is the spacing between the runner blades as measured at the outer rim.
- 33) **Inner Rim Blade Spacing (Inches)** - This is the spacing between the runner blades as measured at the inner rim.

## Ditch Capacity Calculator

This calculator is based on the Manning Formula and is used by Oregon Certified Water Right Examiners (CWREs) to determine the water flow rate capacity of a ditch. This calculator provides identical results to the Excel spreadsheet version available at the Oregon Water Resources Department:

### OWRD

To use this calculator, enter the following input parameters:

- 1) **Top Width (Feet)** - This is the width of the top of the ditch.
- 2) **Bottom Width (Feet)** - This is the width of the bottom of the ditch.
- 3) **Depth (Feet)** - This is the depth of the water flowing in the ditch.
- 4) **Fall (Feet)** - This is the elevation difference between the beginning and the end of ditch.
- 5) **Length (Feet)** - This is the length of the ditch from the beginning to the end.
- 6) **Manning Roughness Coefficient** - This is used to determine the friction in the ditch and the associated head loss resulting from the ditch lining material being used. This is typically 0.0015 for a concrete lined ditch.

Click to obtain the following output parameters:

- 1) **Gradient (Percent)** - This is the ratio of the fall divided by the length of the ditch.
- 2) **Area of Cross-Section (Square Feet)** - This is the effective cross sectional area of the ditch through which the water is flowing.
- 3) **Wetted Perimeter (Feet)** - This is the perimeter of the ditch walls that the flowing water is in contact.
- 4) **Hydraulic Radius (Feet)** - This is the effective radius of the ditch and is obtained by dividing the area of cross-section by the wetted perimeter.
- 5) **Maximum Velocity (Feet per Second)** - This is the maximum velocity that can be obtained.
- 6) **Ditch Capacity (Cubic Feet per Second)** - This is the maximum flow rate that can be obtained.

### [Electric Pump Capacity Calculator](#)

This calculator is based on an Oregon Water Resources Department developed formula and is used by

## Hydroelectric Capacity Calculator

The amount of hydroelectricity you can generate at your site is dependent on two parameters, flow rate and head. Flow rate is the amount of water as measured in cubic feet per minute (or perhaps gallons per minute) that your stream can feed your turbine. Head is the elevation drop feet between the intake of your penstock (i.e., the pipe or ditch used to feed your turbine) and the intake of your turbine. Before investing in hydroelectric equipment, it is always worthwhile to determine if your site can provide the hydroelectric capacity (Horse Power and Kilowatts) that you believe you require. And before you form a belief about your electrical requirements, you should do everything possible to reduce your electric footprint in general.

To use this calculator, enter the following input parameters:

- 1) **Flow Rate (Gallons per Minute)** - This is the maximum flow rate that you believe is available at your site.
- 2) **Head (Feet)** - This is the maximum elevation difference you believe you can create between your penstock inlet and your turbine inlet.
- 3) **Expected Turbine Efficiency (Percent)** - This is a measure of how well the turbine converts the energy of the stream (head and flow rate) into mechanical energy (torque and RPM). This is typically 60 to 80% for a cross flow turbine.
- 4) **Expected Generator Efficiency (Percent)** - This is a measure of how well the generator converts mechanical energy (torque and RPM) into electrical energy (volts and amps). 90% is typical for a Permanent Magnet Generator (PMG).

Click to obtain the following output parameters:

- 1) **Maximum Theoretical Power (Kilowatts)** - This is the maximum theoretical power that could be generated given the design flow rate and head assuming that the turbine and the generator are 100% efficient. You will never actually be able to generate this much power in actual operation.
- 2) **Expected Power (Kilowatts)** - This is the actual power that you should expect to generate accounting for the actual realistic efficiencies of the turbine and the generator.

## [Hydraulic Ram Pump Performance Calculator](#)

A hydraulic ram pump (often called a "hydram") is a cyclic water pump powered by hydropower. It functions as a hydraulic transformer that uses water at a low head pressure and high flow rate to deliver water at a higher head pressure and lower flow rate. A hydram uses a water hammer effect to develop a pressure wave that allows a portion of the input water that powers the pump to be lifted to a point higher than where the water was originally obtained. A hydram does not require any additional source of power and only uses the kinetic energy obtained from the source of water feeding it. As such, a hydram may be used in remote areas where there is both a source of low-head hydropower and a need to deliver water to a destination higher in elevation than the source.

There is some terminology associated with a hydram that you should become familiar with. The pipe feeding water to your hydram is called the "Drive Line". The pipe delivering water to your storage tank is called the "Delivery Line". "Fall" is the total elevation that the water feeding your hydram falls before reaching your hydram. "Lift" is the elevation that your hydram lifts the water to your storage tank. You can enter the desired elevation you would like to pump your water and the calculator will determine the delivery flow rate for that pumping elevation as well as determine your maximum pumping elevation given your fall and drive/delivery line parameters (diameters and lengths). The water that is used to generate the hydram pumping energy, but that does not get delivered to your storage tank, is called "waste" and flows out of the "clack valve" (often called the "waste valve") of your hydram. Your hydram can be set to a frequency of your choosing (typically between 30 and 90 cycles per minute) to govern how much water is used to generate the pumping energy and the associated delivery flow rate.

There are only two moving parts in a hydram, the waste valve and the delivery line check valve. The waste valve is used to create the water hammer effect and associated pressure wave that generates the pumping energy. The waste valve essentially senses the velocity of the water flowing through the drive line and, at the Installation Optimum Peak Drive Flow Rate Setting (which is normally set by tuning the hydram to the Installation Optimum Frequency Setting), quickly closes to suddenly stop this flow and create the water hammer effect. The delivery line check valve only allows water to flow up your delivery line and not out your waste valve. While the function of the delivery line check valve may sound simple enough, it also has to efficiently handle flow rates that can be several hundred times larger than the actual delivery line flow rate and which only have a fraction of a second to occur while also being able to handle large delivery line pressure when the lift is large. The hydram design that we have been experimenting with and have been refining has been designed to achieve zero maintenance by an affiliate who sells them on eBay:

### [The Landis Hydram](#)

Our interests with this enterprise are from an engineering, research, and scientific perspective to significantly improve the design of what we consider to be a very fascinating machine. We developed this calculator to better understand the physics that govern the workings of this machine and to also enable us to accurately forecast how various design element refinements will affect actual pumping performance.

There are many plastic hydram designs commercially available that are affordable, but these hydrams do not survive very long in this harsh water hammer environment and often perform very poorly besides. There are also many steel or cast iron hydram designs commercially available, but these hydrams are not very affordable and sometimes don't even perform well because actual site conditions are not properly considered and addressed. The Landis hydram design is all steel, is affordable, and this calculator allows you to accurately forecast the performance you can expect for your actual site conditions. The Landis hydram design also uses

a 2" diameter glass ball that seals against a 1" thick rubber gasket for the clack waste valve. It takes a very long time to wear out a rotating glass ball in this application. Every other hydram design that we are aware of uses a metal clack valve and the valve and guide eventually wear out.

Borst Engineering & Construction LLC has also been working on a highly efficient delivery line check valve design that we hope will prove to be equally robust as this waste valve design and significantly outperform commercially available hydrams in terms of both delivery flow rate performance and low maintenance. With this new check valve, we went from 514 to 1340 GPD with our 6.1 feet of fall, 28 feet of lift, 1.5 inch diameter times 63 feet long galvanized steel drive line, and 0.75 inch diameter times 280 feet long poly tube delivery line. ***Please note that this calculator forecasts performance based on this new Borst Engineering & Construction LLC delivery check valve design that is currently undergoing field testing. As such, this calculator forecasts delivery flow rate performance that is typically 2-3 times more than what can be currently achieved with the standard delivery check valve currently provided with the Landis hydram.*** It should also be noted that the flexibility and capability of the Landis hydram to use different delivery check valve options is a very worthwhile benefit that other commercial hydrams do not currently offer.

This may well be the most sophisticated and accurate hydram calculator available today. Borst Engineering & Construction LLC is very happy to make it available for your personal, non-commercial use. In summary, this calculator determines the kinetic energy that can be generated by accelerating water through the drive line given the potential energy of the fall after accounting for the friction characteristics of the drive line and pump. This calculator determines the percentage of this kinetic energy that can then be used for delivery pumping energy after accounting for the efficiency of the delivery check valve and also accounting for the quantized energy effect caused by the waste valve closure induced water hammer shock waves based on the innovative research and excellent work done by O'Brien 1933, Rennie 1980 and Thomas 1997. This calculator "site installation design version" provides several useful output parameters that may be used to properly design and construct a reliable and high performance hydram installation. We have developed a "hydram design calculator version" that may be used to properly design actual hydrams. We have developed "customized calculator versions" that have been customized to a specific manufacturer's hydram design parameters and may be used by their customers to accurately forecast hydram performance for their unique sites and installations. ***We have developed a customized calculator version specific to the Landis hydram and it is available to their customers on the above Landis hydram website. Please contact us if you are interested in having us develop and license a customized hydram calculator for your specific hydram design to provide your customers this high level of service too.***

To use this calculator, enter the following input parameters:

- 1) **Maximum Available Water Source Flow Rate (Gallons per Minute)** - This is the maximum available steady flow from your stream or dam. You can estimate this flow with a bucket and a stopwatch. If you initially input 1000 into the calculator and click [here](#), the **Drive Flow Rate** output parameter is the maximum the ram pump can use. So, if your source can supply more than this amount, you do not have to worry about the source being inadequate and limiting, and you can just leave 1000 as the **Maximum Available Water Source Flow Rate** input parameter.
- 2) **Fall 1 - Water Elevation Above Drive Line Inlet (Feet)** - This is the height of the water surface above the drive line inlet. This allows addressing the situation of feeding your hydram from below the base of a dam.
- 3) **Fall 2 - Drive Line Inlet Elevation Above Pump (Feet)** - This is the elevation difference between the drive line inlet and the pump. This allows addressing the situation of feeding your hydram

from just below the surface of a stream. Your site will likely be a combination of Fall 1 and Fall 2 and you will to input values for both.

- 4) **Lift - Desired Pumping Elevation Above Pump (Feet)** - This is the elevation of the storage tank above the pump.
- 5) **Drive Line Nominal Diameter (Inches)** - This is the standard nominal diameter of the drive line pipe. If you input a standard pipe size (such as 1.5 or 2 inches), the calculator will use the actual inside diameter of standard steel pipe. If you have nonstandard pipe, input the actual inside diameter.
- 6) **Drive Line Length (Feet)** - This is the length of the drive line. Standard steel pipe generally comes in lengths of 21 ft. If you adjust this number, the output of the pump will vary. So, in some cases, it is effective to put a standpipe somewhere in the drive line to shorten the drive line length. If this is done, the pipe upstream of the standpipe can be made of plastic to save some money. The standpipe should be at least 6 times the diameter of the drive pipe.
- 7) **Delivery Line Nominal Diameter (Inches)** - This is the standard nominal diameter of the delivery line pipe. If you input a standard pipe size (such as 0.75 or 1 inches), the calculator will use the actual inside diameter of polyethylene or PVC pipe. If you have nonstandard pipe, input the actual inside diameter.
- 8) **Delivery Line Length (Feet)** - This is the length of pipe from the ram pump to the storage tank.
- 9) **Drive Line Inlet Loss Coefficient** – This is used to determine the friction in the drive line and the associated head loss resulting from how the inlet is constructed. This is typically 0.3.
- 10) **Drive Line Darcy-Weisbach Absolute Roughness (Inches)** - This is used to determine the friction in the drive line and the associated head loss resulting from the pipe material being used. This is typically 0.006 inches for galvanized steel pipe and 0.0018 for plain steel pipe.
- 11) **Delivery Line Darcy-Weisbach Absolute Roughness (Inches)** - This is used to determine the friction in the delivery line and the associated head loss resulting from the pipe material being used. This is typically 0.00006 inches for polyethylene tube or PVC pipe.
- 12) **Effective Speed of Sound in Drive Line (Feet per Second)** - This is the speed of the water hammer shock waves travelling through the drive line after compensating for the elasticity of the drive line material. The actual speed of sound travelling through only water is 4800 feet per second. The effective speed of sound in a water filled steel pipe is approximately 4600 feet per second and the effective speed of sound in a water filled PVC pipe is approximately 1970 feet per second.
- 13) **Water Temp (Degrees Fahrenheit)** - This has an insignificant affect on performance for most situations and 50 degrees F is a typical value to use.

Click to obtain the following output parameters:

- 1) **Maximum Delivery Flow Rate (Gallons per Day & Gallons per Minute)**- This is the output from the pump into the storage tank.
- 2) **Drive Flow Rate (Gallons per Minute)** - This is the average flow of water from the source through the pump. It consists of delivery flow rate plus the waste flow rate.
- 3) **Waste Flow Rate (Gallons per Minute)** - This is the average flow of water out the waste valve.
- 4) **Delivery Pressure at Pump (Pounds per Square Inch)** - This is the water pressure as would be measured at the pump outlet.
- 5) **Installation Efficiency (Percent)** - This is a measure of how well the overall installation converts the energy of the water supply (head and flow rate) into delivery pumping energy (head and flow

rate). This can range from 0 to 97%. Maximum delivery flow rate does not occur at maximum efficiency.

- 6) **Optimum Pump Frequency Setting (Cycles per Minute)** - This the optimum frequency setting for the waste valve to close, which can be readily heard and timed with a stop watch. This frequency can be adjusted by raising or lowering the glass ball inside the pump body. This is done by loosening the lock nut on the stainless steel shaft under the pump and screwing the shaft up or down. Raising the ball will increase the frequency and lowering the ball will decrease the frequency. You may have to experiment a little to get the best results. Tighten the lock nut after the shaft is properly adjusted.
- 7) **Minimum Drive Line Length (Feet)** - This is the shortest length of drive line that can be successfully used as established by Calvert (1960).
- 8) **Maximum Drive Line Length (Feet)** - This is the longest length of drive line that can be successfully used as established by Calvert (1960).
- 9) **Drive Line Maximum Flow Rate (Gallons per Minute)** - This is the maximum flow rate in the drive line that would be measured if the pump was NOT installed at the drive line outlet.
- 10) **Installation (Drive Line + Pump) Mean Drive Flow Rate (Gallons per Minute)** - This is the average flow rate that would be measured in the drive line while the water is accelerating during the period the waste valve is open.
- 11) **Drive Line Head Loss at Installation Mean Drive Flow Rate (Percent of Total Fall)** - This is the head loss caused by friction in the drive line at the mean drive flow rate. This head loss makes the drive line appear to be shorter than it actually is.
- 12) **Installation Head Loss at Installation Mean Drive Flow Rate (Percent of Total Fall)** - This is the head loss caused by friction in the BOTH the drive line and the pump at the mean drive flow rate. This head loss makes the drive line appear to be shorter than it actually is.
- 13) **Delivery Line Head Loss at Delivery Flow Rate (Percent of Lift)** - This is the head loss caused by friction in the delivery line at the delivery flow rate. This head loss makes delivery line appear to be longer to the pump than it actually is and this causes the delivery line pressure to be higher than it would normally be.
- 14) **Installation Maximum Peak Drive Flow Rate (Gallons per Minute)** - This is the maximum flow rate in the drive line that would be measured if the waste valve were locked open.
- 15) **Installation Optimum Peak Drive Flow Rate Setting (Gallons per Minute)** - This is the flow rate in the drive line that would be measured at the exact moment the waste valve closed where the pump delivers the maximum flow rate.
- 16) **Efficiency of Acceleration Phase (Percent)** - This is a measure of how well the installation allows water to accelerate in the drive line. It is one of the four parameters used to determine the overall installation efficiency.
- 17) **Efficiency of Check Valve (Percent)** - This is a measure of how well the check valve allows water to flow into the delivery line with minimal friction and head loss. It is one of the four parameters used to determine the overall installation efficiency.
- 18) **Efficiency of Acceleration/Delivery Transition (Percent)** - This is a measure of how well the waste valve closes to generate the water hammer shock wave. It is one of the four parameters used to determine the overall installation efficiency.
- 19) **Fraction of Available Drive Kinetic Energy Used for Delivery Pumping (Percent)** - This is the percentage of available kinetic energy created by accelerating water down the drive line that is used by the pump to deliver water to the storage tank. It is one of the four parameters used to determine the overall installation efficiency.



- 20) **Normalized Water Hammer Flow Rate Ratio** - This is a useful ratio for forecasting the pump operational reliability based on the quantized energy effect caused by the waste valve closure induced water hammer shock waves. Operation will be 100% reliable when this ratio is an odd number (rounding down to the nearest integer) greater than 3. Operation will be 0% reliable when this ratio is less than 1.5.
- 21) **Likelihood of Reliable Waste Valve Operation at this Setting (Percent)** - This is the operation reliability forecast. The higher the percent, the higher the likelihood that the operation will be reliable and that the waste valve will NOT get stuck in the closed position.



- 12) **Selected Spring Rate of Left Isolation Mounts (Pounds/Inch)** - This input parameter is the spring rate of each left isolation mount as specified by the manufacturer of the selected isolation mount that will be used in the design. Please see below detailed directions.

Click to obtain the following output parameters:

- 1) **Load per Right Isolation Mount (Pounds)** - This is the static load resulting from the weight of the machines and the stand that each right isolation mount will experience and must be capable of handling. This parameter is used to select acceptable right isolation mounts from a manufacturer. Please see below detailed directions.
- 2) **Load per Left Isolation Mount (Pounds)** - This is the static load resulting from the weight of the machines and the stand that each left isolation mount will experience and must be capable of handling. This parameter is used to select acceptable left isolation mounts from a manufacturer. Please see below detailed directions.
- 3) **Recommended Spring Rate of Right Isolation Mounts (Pounds/Inch)** - This is the recommended spring rate of each right isolation mount required to achieve the Design Isolation Efficiency. This parameter is used to select acceptable right isolation mounts from a manufacturer. Please see below detailed directions.
- 4) **Recommended Spring Rate of Left Isolation Mounts (Pounds/Inch)** – This is the recommended spring rate of each left isolation mount required to achieve the Design Isolation Efficiency. This parameter is used to select acceptable left isolation mounts from a manufacturer. Please see below detailed directions.
- 5) **Actual Deflection of Right Isolation Mounts (Inches)** - This is the deflection each right isolation mount will actually experience resulting from the weight of the machines and the stand based on the Selected Spring Rate of Right Isolation Mounts input parameter. Please see below detailed directions.
- 6) **Actual Deflection of Left Isolation Mounts (Inches)** - This is the deflection each right isolation mount will actually experience resulting from the weight of the machines and the stand based on the Selected Spring Rate of Right Isolation Mounts input parameter. Please see below detailed directions.
- 7) **Actual Isolation Efficiency (Percent)** - This is the actual vibration isolation efficiency that the isolation stand will provide based on the Selected Spring Rate of Right/Left Isolation Mounts input parameters. This is the percentage of vibration energy that is absorbed by the isolation mounts (and converted into heat energy) and NOT transmitted to the floor.

Select mounts from a manufacturer that have a maximum compressive load rating equal or greater than the **Load per Right/Left Mount** and a spring rate equal or less than the **Recommended Spring Rate of Right/Left Isolation Mounts**. Please note that overloading isolation mounts is not recommended since this may lead to premature isolation mount failure. However, excessive under loading may not deflect the isolation mount enough to provide satisfactory vibration isolation. You may need to change **Number of Right/Left Isolation Mounts** that will be used in your design to achieve **Load per Right/Left Mount** and **Recommended Spring Rate of Right/Left Isolation Mounts** output parameter values that are actually available from a manufacturer. You may also want to change the ratio of **Number of Right/Left Isolation Mounts** such that the **Recommended Spring Rate of Right/Left Isolation Mounts** output parameter values are nearly the same spring rate so you can use the same isolation mount for both the right and left side of isolation stand. Once you have selected your isolation mounts, enter the manufacturer specified spring rate for **Selected**

**Spring Rate of Right/Left Isolation Mounts** and click to obtain **Actual Deflection of Right/Left Isolation Mounts** and **Actual Isolation**. Verify that **Actual Deflection of Right/Left Isolation Mounts** is less than the manufacturer maximum recommended compression deflection and that **Actual Isolation** achieves your isolation stand design objective. Please see [Lister Engine Gallery](#) for an example of how this approach was used to successfully design an isolation stand for a stationary engine back in 2004 when several "experts" claimed this was not possible.

## Pipe Capacity Calculator (Pressure Flow, Darcy-Weisbach)

This calculator is based on the Darcy-Weisbach Formula which is considered to be more accurate than the following Hazen-Williams Formula based calculator. This calculator uses a Haaland simplified Colebrook-White equation to obtain the Darcy-Weisbach pipe friction factors for either laminar or turbulent flow as appropriate (based on the estimated Reynolds number) using the entered absolute pipe roughness. This calculator may be used to determine the water flow rate capacity of a pressurized pipe. An example of this situation would be a pipe installed at the base of a dam used to divert water to a different location or as a penstock for a hydroelectric turbine.

To use this calculator, enter the following input parameters:

- 1) **Interior Diameter (Inches)** – This is the interior diameter of the pipe.
- 2) **Length (Feet)** - This is the length of the pipe.
- 3) **Darcy-Weisbach Absolute Roughness (Inches)** - This is used to determine the friction in the pipe and the associated head loss resulting from the pipe material being used. This is typically 0.0018 inches for plain steel pipe.
- 4) **Inlet Pressure (Pounds per Square Inch)** - This is the pressure that would be measured at the pipe inlet. If the pipe inlet is installed at the base of a dam, this pressure would be 0.433 times the depth of the water in feet that the inlet is located.
- 5) **Fall (Feet)** - This is the difference in elevation between the pipe inlet and the pipe outlet. It can be either a positive or a negative value. If the pipe outlet is below the pipe inlet, this value is positive. The total head is the sum of this parameter plus the inlet pressure (converted to head).
- 6) **Capacity or Specific Flow Rate Calculation? (1 or Gallons per Minute)** - This is a logic parameter. Enter 1 if you want the calculator to determine the maximum velocity and maximum flow rate capacity for this pipe given the total head. Enter a specific flow rate (normally less than this maximum flow rate capacity, but we have not made this calculator limiting) if you want the calculator to determine the head loss for this specific flow rate.

Click to obtain the following output parameters:

- 1) **Gradient (Percent)** - This is the ratio of the total head divided by the length of the pipe.
- 2) **Area of Cross-Section (Square Feet)** - This is the effective cross sectional area of the pipe through which the water is flowing.
- 3) **Reynolds Number** - This is an intermediate parameter used by engineers. The calculator transitions from laminar flow friction to turbulent flow friction at a Reynolds number of 4000.
- 4) **Darcy-Weisbach Friction Coefficient** – This is an intermediate parameter used by engineers.
- 5) **Darcy-Weisbach Friction Factor** - This is an intermediate parameter used by engineers.
- 6) **Velocity (Feet per Second)** - This is the resulting velocity in feet per second. If you entered 1 for the above input logic parameter 6), it is the maximum velocity capacity. If a specific flow rate is entered, it is this flow rate divided by the area of cross-section.
- 7) **Flow Rate (Gallons per Minute)** - This is the resulting flow rate in both cubic feet per second and gallons per minute. If you entered 1 for the above input logic parameter 6), it is the maximum flow rate capacity. If a specific flow rate was entered, it is this specific flow rate.
- 8) **Head Loss (Feet and Percent of Total Head)** - This is head loss resulting from the pipe friction created at the pipe flow rate in both feet and percent of total head. At maximum velocity and flow rate capacity, this head loss is equal to the total head and 100%.

### Pipe Capacity Calculator (Gravity Flow, Hazen-Williams)

This calculator is based on the Hazen-Williams Formula and is used by Oregon Certified Water Right Examiners (CWREs) to determine the water flow rate capacity of a gravity flow pipe. An example of this situation would be a pipe installed near the surface of a stream used to divert water to a lower location or as a penstock for a hydroelectric turbine. This calculator provides identical results to the Excel spreadsheet version available at the Oregon Water Resources Department:

### OWRD

To use this calculator, enter the following input parameters:

- 1) **Interior Diameter (Inches)** - This is the interior diameter of the pipe.
- 2) **Hazen-Williams Roughness Coefficient** - This is used to determine the friction in the pipe and the associated head loss resulting from the pipe material being used. This is typically 130 for plain steel pipe.
- 3) **Fall (feet)** - This is the elevation difference between the pipe inlet and the pipe outlet. It can only be a positive value (indicating that the pipe outlet is below the pipe inlet) since this is a gravity flow calculator.
- 4) **Length (Feet)** – This is the length of the pipe.

Click to obtain the following output parameters:

- 1) **Gradient (Percent)** - This is the ratio of the fall divided by the length of the pipe.
- 2) **Area of Cross-Section (Square Feet)** - This is the effective cross sectional area of the pipe through which the water is flowing.
- 3) **Wetted Perimeter (Feet)** - This is the perimeter of the ditch walls that the flowing water is in contact.
- 4) **Hydraulic Radius (Feet)** - This is the effective radius of the ditch and is obtained by dividing the area by the wetted perimeter.
- 5) **Maximum Velocity (Feet per Second)** - This is the maximum velocity that can be obtained.
- 6) **Pipe Capacity (Cubic Feet per Second)** - This is the maximum flow rate that can be obtained.

## Pulley Drive System Design Calculator

Flexible machine elements like pulley/belt drive systems are used for the transmission of power over comparatively long distance, where relative motion/vibration between the driver and driven element is a concern, and sometime just for economics and convenience. If power transmission is the sole objective, your pulley diameters are often the same. However, you may want to change the driven element RPM or torque from that of the driver element. This can be readily accomplished with a pulley drive system and the power transmitted remains the same.

This calculator is based on the Coulomb Friction Formula and allows you to design and build a pulley drive system. In order for the system to not experience belt slippage for a given power transmission level, the belt lap angle and associated friction developed must be adequate for the pulley diameters used in the design. This typically involves setting the static belt tension to a sufficiently high level. However, if you set the static belt tension too high, you can significantly shorten your bearing life. This calculator solves this problem and provides an accurate solution for both Flat and Vee pulley/belts. This calculator will provide a conservative solution for grooved and ribbed belts.

To use this calculator, enter the following input parameters:

- 1) **Horse Power** - This is the horse power applied to the input pulley shaft by the driving machine (e.g., an engine, cross flow turbine or water wheel).
- 2) **Input Pulley Speed (Rotations per Minute)** - This is the speed applied to the input pulley shaft by the driving machine (e.g., an engine, cross flow turbine or water wheel).
- 3) **Desired Output Pulley Speed (Rotations per Minute)** - This is the speed you want on the output pulley shaft for the driven machine (e.g., a generator).
- 4) **Input Pulley Pitch Diameter (Inches)** - This is the input pulley pitch diameter as indicated by the pulley manufacturer. The pitch diameter is typically slightly less than the actual measured outer diameter.
- 5) **Pulley Shaft Center-to-Center Distance (Inches)** - This is the dimension between the center of the input pulley and the center of the output pulley.
- 6) **Angle of Pulley Groove (Degrees)** - This is the belt capture angle of the pulleys. This is 90 degrees for a flat belt and 20 degrees for a Vee belt.
- 7) **Coefficient of Friction** - This is the effective coefficient of friction between the belt material and the pulley material. 0.32 is typical for a rubber belt and a steel pulley.

Click to obtain the following output parameters:

- 1) **Input Pulley Torque (Foot Pounds)** - This is the torque of the input pulley given the horse power and speed being applied by the machine attached to the input pulley shaft.
- 2) **Drive Ratio** - This is the ratio of the Desired Output Pulley Speed and the Input Pulley Speed.
- 3) **Output Pulley Pitch Diameter (Inches)** - This is the required output pulley pitch diameter as indicated by the pulley manufacturer. The pitch diameter is typically slightly less than the actual measured outer diameter.
- 4) **Input Pulley Belt Lap Angle (Degrees)** - This is the effective angle that the belt covers the input pulley given the pulley system geometry established by knowing the Input/Output Pulley Pitch Diameters and the Pulley Shaft Center-to-Center Distance. Larger belt lap angles are more effective at transmitting a given power without slipping.

- 5) **Output Pulley Belt Lap Angle (Degrees)** - This is the angle that the belt covers the output pulley given the pulley system geometry established by knowing the Input/Output Pulley Pitch Diameters and the Pulley Shaft Center-to-Center Distance.
- 6) **Belt Length (Inches)** - This is the required belt length given the pulley system geometry established by knowing the Input/Output Pulley Pitch Diameters and the Pulley Shaft Center-to-Center Distance.
- 7) **Belt Velocity (Feet per Second)** - This is the linear speed of the belt. Belts are rated for a maximum belt velocity and this limit should not be exceeded in your pulley system design.
- 8) **Belt Tension Ratio** - This is the ratio of the Maximum Dynamic Belt Tension divided by the Minimum Dynamic Belt Tension. It is calculated based on the Coulomb Friction Formula.
- 9) **Maximum Dynamic Belt Tension (Pounds)** - This is the tension on the taut side of pulley system during operation.
- 10) **Minimum Dynamic Belt Tension (Pounds)** - This is the tension on the slack side of pulley system during operation.
- 11) **Cyclic Tension Variation (Pounds)** - This is the difference between the Maximum Dynamic Belt Tension and the Minimum Dynamic Belt Tension.
- 12) **Required Static Belt Tension (Pounds)** - This is tension that the belt must be set in order to not have any slippage during operation.
- 13) **Static Bearing Load (Pounds)** - This is load that pulley system applies to pulley bearings when the pulley system is not operating. This load is two times the Required Static Belt Tension.
- 14) **Dynamic Bearing Load (Pounds)** - This is load that pulley system applies to pulley bearings when the pulley system is operating. This load is the sum of the Maximum Dynamic Belt Tension and the Minimum Dynamic Belt Tension.
- 15) **Output Pulley Torque (Foot Pounds)** - This is the torque of the output pulley given the horse power applied by the machine attached to the input pulley shaft and given the output pulley speed. The Output Pulley Torque can also be calculated by dividing the Cyclic Variation by the output pulley pitch radius, and this is how this parameter is calculated by this calculator. It should be noted that the horse power transmitted by output pulley is exactly the same as the horse power being applied by the machine attached to the input pulley shaft.



### Shaft Stress Analysis Calculator

This calculator is based on the Soderberg approach for determining the minimum safe shaft diameter of a shaft subjected to a combination of steady torque (e.g., perhaps induced by driving a generator) and alternating maximum bending moment (e.g., perhaps induced by the weight of a turbine runner), a common loading for water work project machines.

To use this calculator, enter the following input parameters:

- 1) **Steady Torque (Foot Pounds)** - This is the maximum steady torque resulting from either the driving machine or the driven machine.
- 2) **Maximum Bending Moment (Foot Pounds)** - This is the combination of acting force and moment arm that creates the maximum bending moment.
- 3) **Material Yield Strength (Pounds per Square Inch)** - This is the stress (i.e., force per area) at which the chosen shaft material begins to deform plastically (i.e., does not return to its original shape). This is typically 36000 PSI for A36 low carbon steel.
- 4) **Material Endurance Limit (Pounds per Square Inch)** - This is the cyclic stress that can be applied to the chosen shaft material without causing fatigue failure. This is typically 28000 PSI for A36 low carbon steel.
- 5) **Design Factor of Safety** - This is the ratio of the material yield strength to the design load. In this case, the design load result from the Steady Torque. This can range from 1.2 (where weight is an important design consideration such as in airplanes and where the material properties are well known and held to a high quality standard) to 5 or much more to ensure safety.

Click to obtain the following output parameter:

- 1) **Minimum Safe Shaft Diameter (Inches)** - This is the minimum recommended shaft diameter given the input parameters.

## [Sprinkler Capacity Calculator](#)

This calculator is based on the Orifice Formula and is used by Oregon Certified Water Right Examiners (CWREs) to determine the water flow rate capacity of a sprinkler system. This calculator provides identical results to the Excel spreadsheet version available at the Oregon Water Resources Department:

### [OWRD](#)

To use this calculator, enter the following input parameters:

- 1) **Nozzle Size (Inches)** - This is the diameter of the sprinkler orifice.
- 2) **Pressure (Pounds per Square Inch)** - This is the irrigation system operating pressure.
- 3) **Number of Heads** - This is the total number of sprinkler heads being used in the irrigation system.

Click to obtain the following output parameters:

- 1) **Sprinkler Capacity (Cubic Feet per Second)** - This is the maximum flow rate of the irrigation system.

## Undershot Water Wheel Design Calculator

While undershot water wheels are not the most efficient, they are very easy to build and one does not need a penstock to feed them water either. You do need to have a fast moving stream (i.e., average velocity greater than 4 FPS) in order to generate any significant amount of hydroelectricity because the effective head created by this fast moving water is proportional to the square of this velocity and the amount of hydroelectricity that can be generated is proportional to this effective head times the effective flow rate that the wheel is constructed to use. It should be noted that the British industrial revolution was initially started with these simple machines before steam engines came along.

This calculator allows you to design and build an undershot water wheel optimized to your specific hydroelectric site conditions.

To use this calculator, enter the following input parameters:

- 1) **Stream Velocity (Feet per Second)** - This is the velocity of the water moving in the stream.
- 2) **Design Diameter (Feet)** - This is the diameter of the wheel. Larger diameters will provide more torque, but will operate at a lower RPM. Smaller diameters will operate at a higher RPM, but will provide less torque. You may need to consider and determine the torque and RPM requirements of your generator before selecting the diameter of your wheel. You may need to consider using a pulley drive system to change the wheel torque and RPM values to meet the requirements of your generator.
- 3) **Design Width (Feet)** - This is the width of the wheel. Larger wheel widths will increase the Effective Flow Rate and increase the wheel Expected Power output.
- 4) **Expected Wheel Efficiency (Percent)** - This is a measure of how well the wheel converts the kinetic energy of the stream (head and flow rate) into mechanical energy (torque and RPM). This is typically 67% for an undershot water wheel.
- 5) **Expected Generator Efficiency (Percent)** - This is a measure of how well the generator converts mechanical energy (torque and RPM) into electrical energy (volts and amps). 90% is typical for a Permanent Magnet Generator (PMG).

Click to obtain the following output parameters:

- 1) **Effective Head (Feet)** - This is the effective head resulting from the stream velocity. Normally, head is the result of elevation change between the penstock inlet and the turbine inlet. This "normal" head is then converted to a water velocity that strikes the turbine blades. With an undershot water wheel, the stream velocity is striking the wheel blades without using a penstock.
- 2) **Minimum Optimal Diameter (Feet)** - This is the minimum recommended wheel diameter based on experimentation. This has been found to be approximately 3 times the Effective Head.
- 3) **Maximum Optimal Diameter (Feet)** - This is the maximum recommended wheel diameter based on experimentation. This has been found to be approximately 6 times the Effective Head.
- 4) **Working Diameter (Feet)** - This is the effective wheel diameter given that a portion of the wheel (typically the Effective Head dimension) is submersed below the stream surface
- 5) **Working Circumference (Feet)** - This is the effective wheel circumference based on the Working Diameter.
- 6) **Working Cross-Sectional Area (Square Feet)** - This is the effective wheel cross-sectional area given the Design Width and Effective Head.
- 7) **Blade Spacing (Feet)** - This is the recommended blade spacing based on experimentation and found to be approximately 0.95 times the Effective Head.

- 8) **Number of Blades** - This is the required spacing given the Working Circumference and the Blade Spacing.
- 9) **Optimal Rim Tangential Speed (Feet per Second)** - This is the optimal linear velocity at the rim Working Diameter given the Stream Velocity.
- 10) **Optimal Rotation Speed (Rotations per Minute)** - This is the optimal rotational velocity of the wheel given the Optimal Rim Tangential Speed and the Working Circumference.
- 11) **Effective Flow Rate (Gallons per Minute)** - This is the effective flow rate based on the Stream Velocity the Working Cross-Sectional Area.
- 12) **Maximum Theoretical Power (Kilowatts)** - This is the maximum theoretical power that could be generated given the design flow rate and head assuming that the undershot water wheel and the generator are 100% efficient. You will never actually be able to generate this much power in actual operation.
- 13) **Expected Power (Kilowatts)** - This is the actual power that you should expect to generate accounting for the actual realistic efficiencies of the undershot water wheel and the generator.
- 14) **Expected Wheel Shaft Torque (Foot Pounds)** - This is the expected torque that the undershot water wheel will produce given your design inputs.

## **Possible Future Calculator Developments**

**Integrated Heating System Monthly/Annual Performance Calculator**

**Passive Solar Heating Monthly/Annual Performance Calculator**

**Cross Flow Turbine Blade Stress Analysis Calculator**