

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 developed. ***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. Please note that this Adobe Portable Document File (PDF) contains thumbnails and bookmarks to help you navigate to the specific set of instructions for the calculator that you would like to use. The calculator titles on this 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 calculator title hyperlinks to navigate back to our calculator website when you ready to actually use the calculators. The calculator titles on our calculator website contain hyperlinks to the actual calculators. Click the specific calculator link on our website for the calculator that you would like to use. After you have obtained the calculator solution by following the instructions for the specific calculator, 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." Our design objective for these calculators was to use a simple user interface and minimal required calculator inputs to solve the engineering equations required to accurately and efficiently accomplish the intended function and purpose of each calculator. Multiple calculators are used in some cases (e.g., our passive solar suite of calculators) to break up the design process in logical phases.

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

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Heat Loss Analysis Calculator

The first step before designing your integrated Hydronic Radiant Floor, Passive Solar, and/or Masonry Heater heating system is to know exactly how much heat gain will be required for your building to keep the occupants comfortable. How much heat gain will be required is exactly the same amount as the heat loss your building will experience. Building heat loss occurs for two reasons: 1) heat transfer through the walls, ceilings, floors and external fenestration (i.e., external doors and windows) and 2) uncontrolled air infiltration or controlled ventilation causing the warm inside air to be exchanged with cold outside air. The heat transfer loss is proportional to surface area exposed to the outside, the temperature difference between the inside and outside, and the heat transfer coefficient (U-factor) of the materials used in your building construction. In order to use this calculator, you will first need to determine the thermal resistance (R-values) 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 fenestration. These total R-values are then entered into this calculator and converted by the calculator into U-factors which are then used to determine the heat transfer loss in a manner consistent with American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) recommendations.

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

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 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 a 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. Be sure to use this same value in our **Hydronic Radiant Floor Heating Design Calculator!**
- 2) **Design Indoor Temp (Degrees Fahrenheit)** - This is typically 65 to 75 degrees F. Be sure to use this same value in our **Hydronic Radiant Floor Heating Design Calculator!**
- 3) **Exposed Wall Area (Square Feet)** - 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 not 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 manually.

- 4) **Wall R-value (Square Feet -Degrees F-Hour/BTU)** - This is the total R-value of the materials used for the wall construction.
- 5) **Exposed Ceiling Area (Square Feet)** - This is the total ceiling area of the building or room that is exposed to the outside temperature. If the ceiling is below a heated upstairs living area and therefore not exposed to the outside temperature, do not include this ceiling area.
- 6) **Ceiling R-value (Square Feet -Degrees F-Hour/BTU)** - This is the total R-value of the materials used for the ceiling construction.
- 7) **Exposed Door Area (Square Feet)** - This is the total rough opening area of the building or room exterior doors.
- 8) **Door R-value (Square Feet -Degrees F-Hour/BTU)** - This is the door total R-value as stated by the door manufacturer.
- 9) **Exposed Window Area (Square Feet)** - This is the total rough opening area of the building or room exterior windows.
- 10) **Window R-value (Square Feet -Degrees F-Hour/BTU)** - This is the window total R-value as stated by the window manufacturer.
- 11) **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 American Society of Heating, Refrigerating and Air-Conditioning Engineers (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.
- 12) **Framed Floor Area or Slab-on Grade Perimeter (Square Feet 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 are exposed to the outside temperature. If a wall is an interior wall and therefore not exposed to the outside temperature, do not include this perimeter.
- 13) **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 assembly. If you entered 2 or 3 for Floor Type, this is the R-value of the actual insulation used for the slab-on-grade.
- 14) **Building or room Volume (Cubic Feet)** - 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.
- 15) **Air Changes per Hour** - This is the number of times per hour that the building or room air is replaced by fresh outside air every hour. This can occur as the result of having a leaky building, forced air ventilation, or some combination. 0.35 ACH is the minimum allowed for health reasons and often accomplished using forced air ventilation with a heat recovery system for airtight building construction. 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 is the exterior window heat loss.
- 5) **Exposed Floor Heat Loss (BTU/Hour)** - This is the exposed floor heat loss. Use this value in our **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 per hour. Use the heat loss for each room in our **Hydronic Radiant Floor Heating Design Calculator**.
- 8) **Total Heat Loss (BTU/Day)** - This is the total heat loss of the building or room per day. Use the appropriate value (room or building) when exercising our **Hydronic Radiant Floor Heating Design Calculator**, **Masonry Heater Performance Calculator**, and **Passive Solar Heat Gain Calculator** to assess how well the heat gain achieved by your integrated Hydronic Radiant Floor, Passive Solar, and/or Masonry Heater heating system meets your daily heating needs.
- 9) **Total Heat Loss (BTU/Hour-Degrees F)** - This important heat loss design parameter is the **Total Heat Loss** output parameter divided by the difference between the **Design Indoor Temp** and the **Design Outdoor Temp** input parameters. If you did a room-by-room heat loss analysis, you will need to add the calculated heat loss for each room to determine the total building heat loss. Use this total building heat loss, along with published Heating Degree Day data for the specific climate where the building is located, in our **Integrated Heating Performance Calculator** to assess how well the heat gain achieved by your integrated Hydronic Radiant Floor, Passive Solar, and/or Masonry Heater heating system meets your monthly and annual heating needs.

Hydronic Radiant Floor Heating Design Calculator

Please be warned, this calculator can be intimidating at first sight, but it will accurately get the job done! 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 as necessary to provide the required heat gain. This calculator assumes that the floor is fully insulated (with a downward heat loss of 10% or less of the required upward heat gain), four inch concrete slab-on-grade and that the hydronic fluid is water. The engineering used in this calculator is consistent with the methodology and recommendations published in John Siegenthaler's "Modern Hydronic Heating for Residential and Light Commercial Buildings", which is by far the best book on this subject.

The reason you may need more than one circuit per room is 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 about 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 probt tiy

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Spacing output parameter. 12 inches or less is recommended for barefoot friendly residential floors.

- 11) **Supplemental Heat Gain (BTU/Day)** - This is to account for any additional heat sources that you may elect to use such as a masonry heater or passive solar heating.
- 12) **Balance Valve Setting** - This is the manifold balance valve setting that is required to achieve the **Required Flow Rate** output parameter for this room. 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 is defined by 7 data points of pump flow rate (in Gallons per Minute) versus pump head (in Feet). Example Pump Performance Curve data 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 (BTU/Hour & BTU/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 maximum 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 the PEX tube friction within acceptable pumping limits.
- 6) **Circuit & Leader Tube Length (Feet)** - This is the total length of PEX tube required for each circuit, including the additional length required to reach the manifold station.
- 7) **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.
- 8) **Reynold's Number** - This is an important performance design parameter. Greater than 2300 is recommended to ensure a turbulent flow rate that produces a high thermal efficiency. You may need to adjust your design input parameters to achieve this.
- 9) **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) and to also ensure that there will not be any objectionable flowing water floor noise.
- 10) **Required Flow Rate (Gallons per Minute)** - This is flow rate that that must provided in order to meet your heating requirements for this room.
- 11) **Design Flow Rate at Balance Valve Setting (Gallons per Minute)** - This is design flow rate that will be provided given the associated room **Balance Valve Setting** input parameter. The design objective is to have this flow rate be equal to the **Required Flow Rate** output parameter by adjusting the **Balance Valve Setting** input parameter.
- 12) **Actual Flow Rate provided by Pump (Gallons per Minute)** - This is the actual flow rate provided by the selected pump given the associated room **Balance Valve Setting** input parameter and given where the pump it is being operated on its pump performance curve at system hydraulic equilibrium.

- 13) **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.
- 14) **Actual Heat Gain (BTU/Hour & BTU/Day)** - This is the actual heat gain that results from using the pump that you selected, the **Balance Valve Setting** input parameter that you selected, and the **Required Average Fluid Supply Temp** output parameter (please see below totalized output parameters).

This calculator will also provide the following totalized output parameters:

- 15) **Design Total Flow Rate (Gallons per Minute)** - This is the total flow rate that the selected pump must be capable of supplying to provide the required design flow rates of all the circuits/rooms. The selected pump will need to supply this flow rate while also providing head equal to the **Design Total Head Loss** output parameter. ***This parameter is used to select your pump (please see below detailed directions)!***
- 16) **Design Total Head Loss (Feet)** - This is the total head loss resulting from all the friction in the PEX tube and balance valve settings while operating at the required design flow rates for all the circuits/rooms. The selected pump will need to supply this head while also supplying the **Design Total Flow Rate** output parameter. ***This parameter is used to select your pump (please see below detailed directions)!***
- 17) **Actual Total Flow Rate provided by Pump (Gallons per Minute)** - This is the actual total flow rate supplied by the selected pump given where it is being operated on its pump performance curve at system hydraulic equilibrium. If you did a good job selecting your pump, this flow rate should be fairly close to **Design Total Flow Rate** output parameter.
- 18) **Actual Total Head provided by Pump (Feet)** - This is the actual total head supplied by the selected pump given where it is being operated on its pump performance curve at system hydraulic equilibrium. If you did a good job selecting your pump, this head should be fairly close to **Design Total Head Loss** output parameter.
- 19) **Pump Differential Pressure (Pound per Square Inch)** - This is the pressure difference that would be measured between the pump inlet and pump outlet.
- 20) **Required Average Fluid Supply Temp (Degree Fahrenheit)** - This is the single temperature that the boiler should be set to supply all the room circuits.
- 21) **Total Actual Heat Gain (BTU/Hour & BTU/Day)** - This is the total actual 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 [Calculate](#). Then adjust each room's **Balance Valve Setting** input parameter such that the **Design Flow Rate at Balance Valve Setting** output parameter is equal to the **Required Flow Rate** output parameter clicking [Calculate](#) multiple times as necessary until you achieve this. Then select a pump based on the **Design Total Flow Rate** and **Design Total Head Loss** output parameters. For maximum pump efficiency and minimum operating cost, the **Design Total Flow Rate** and **Design Total Head Loss** should be 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. Then enter the actual **Pump Performance Curve** for the pump that you have selected into the calculator (example data points for a Taco 006 pump are shown) and click [Calculate](#). If you did a good job selecting your pump, the **Actual Flow Rate provided by Pump** should be fairly close to the **Required Flow Rate** for each room. The **Actual Heat Gain** should also be fairly close to the **Required Heat Gain** for each room. Any minor discrepancies can normally be adequately addressed by making minor

adjustments to the actual balance valve settings and the actual boiler supply temperature after the system has been constructed.

Please be aware that there can be 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 additional effort and expense 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 and schedule data to compensate for when other supplemental heat sources will be providing heat gain, and when they will NOT be providing heat gain.

Integrated Heating System Performance Calculator

Before using this calculator, you should first exercise our **Heat Loss Analysis Calculator** and our suite of passive solar calculators: **Passive Solar Altitude Calculator**, **Passive Solar Roof Overhang Design Calculator**, **Passive Solar Fenestration Exposure Calculator**, and **Passive Solar Heat Gain Calculator**. This calculator is used to assess how well the heat gain achieved by your passive solar heating design meets your actual monthly and annual heating needs and to determine the amount of any supplemental heat that may also be required. The amount of electrical power, fuel oil, natural gas, propane, and/or wood that would be required to supply this supplemental heat is also calculated.

To use this calculator, enter the following input parameters:

- 1) **Total Heat Loss (BTU/Hour-Degrees F)** - This is the total heat loss of the building and is an output parameter of our **Heat Loss Analysis Calculator**.
- 2) **Heating Degree Days** - This is a design parameter designed to reflect the demand for energy needed to heat a building during January through December. The heating requirements for a given structure at a specific location are considered to be directly proportional to the number of heating degree days at that location. Heating degree day data is published by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and by the National Renewable Energy Laboratory (NREL):

NREL Solar Radiation Manual for Buildings

- 3) **Average Monthly Climatic Solar Heat Gain (BTU/Day)** - This is the best estimate, in BTU/Day, of how much passive solar heat gain will actually be produced during January through December and is an output parameter of our **Passive Solar Heat Gain Calculator**.

Click to obtain the following output parameters for each room:

- 1) **Monthly Heat Loss (BTU/1 Million)** - This is the monthly heat loss, in BTU divided by 1 million, during January through December based on the **Total Heat Loss** and **Heating Degree Days** input parameters.
- 2) **Monthly Climatic Solar Heat Gain (BTU/1 Million)** - This is the best estimate, in BTU divided by 1 million, of how much passive solar heat gain that will actually be produced during January through December based on the **Average Monthly Climatic Solar Heat Gain** input parameter.
- 3) **Monthly Climatic Solar Heat Gain (Percent of Monthly Heat Loss)** - This is the best estimate, in percent of monthly heat loss, of how much passive solar heat gain will actually be produced during January through December based on the **Average Monthly Climatic Solar Heat Gain** input parameter.
- 4) **Monthly Required Supplemental Heat Gain (BTU/1 Million)** - This is difference between the **Monthly Heat Loss** and **Monthly Climatic Solar Heat Gain** output parameters, in BTU divided by 1 million, and represents that amount of additional heat that must be supplied during January through December to address the building heat loss.

This calculator will also provide the following totalized output parameters:

- 5) **Annual Required Supplemental Heat Gain (BTU/1 Million)** - This is annual amount of additional heat, in BTU divided by 1 million, which must be supplied to address the building heat loss.

- 6) **Annual Required Supplemental Electrical Power (Kilowatt Hours)** - This is annual equivalent of electrical power required to supply the **Annual Required Supplemental Heat Gain** assuming 3,414 BTU/KWH.
- 7) **Annual Required Supplemental Fuel Oil (Gallons)** - This is the annual equivalent of fuel oil required to supply the **Annual Required Supplemental Heat Gain** assuming 138,690 BTU/Gallon.
- 8) **Annual Required Supplemental Natural Gas (Cubic Feet)** - This is the annual equivalent of natural gas required to supply the **Annual Required Supplemental Heat Gain** assuming 1,020 BTU/Cubic Feet.
- 9) **Annual Required Supplemental Propane (Gallons)** - This is the annual equivalent of propane required to supply the **Annual Required Supplemental Heat Gain** assuming 91,500 BTU/Gallon.
- 10) **Annual Required Supplemental Wood (Cords)** - This is the annual equivalent of wood required to supply the **Annual Required Supplemental Heat Gain** assuming 9250 BTU/pound (Dry Douglas Fir) and 2770 pounds/cord.

Any required supplemental heat may be supplied using numerous heating system approaches. We highly recommend that you research and consider using hydronic radiant floor heating and masonry heaters. Please also see our **Hydronic Radiant Floor Heating Design Calculator** and our **Masonry Heater Performance Calculator**.

Borst Engineering & Construction LLC has successfully designed integrated passive solar heating and hydronic radiant floor heating systems to enable conveying heat from passive solar heated areas to other areas of the building where it is needed or to store this unneeded heat until it is needed.

Masonry Heater Performance Calculator

Energy efficient homes may only require 3,000 to 8,000 British Thermal Units (BTU) of heat gain per hour. For most conventional woodstoves, this is well below their critical burn rate for operating cleanly and they will start to smolder. If you operate most conventional woodstoves at or above their critical burn rate, you may easily overheat an energy efficient home. Therefore, woodburning and energy efficient homes are not normally compatible unless you have some way to burn the wood at or above the critical burn rate to operate cleanly and also store and then release excess heat as needed. Masonry heaters are the most efficient way to heat a home with wood. Unlike fireplaces or wood stoves, there is very little heat loss because the exhaust gases are circulated through the masonry heater several times before going up the chimney. There is very little pollution because masonry heaters burn the wood very quickly and operate at about 1700 degrees so as to fully burn what even certified woodstoves can't burn. Masonry heaters store and slowly release radiant heat over a 24 hour period accomplished by either one or two firings per day. Therefore, masonry heater surfaces never get extremely hot like stoves and do not overheat your home. Masonry heaters are similar 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 and you can have heated benches for you or your pets to enjoy all 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 this amount of wood can be burned in either one or two firings per day.
- 2) **BTU Value of Wood (BTU per Pound)** - Dry Douglas Fir is 9250 BTU/Lb.
- 3) **Heater Efficiency (Percent)** - This is a measure of how well the masonry heater converts the chemical energy of the wood (BTU) into heat energy (BTU) during the combustion process. This is typically 92 to 95%.

Click [here](#) to determine the **Heat Gain (BTU/Hour & BTU/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 solar noon near 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** output parameter varies significantly over the course of the year. The highest solar altitude angles occur during the summer months and lowest solar altitude angles 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. If your Latitude is south, enter a negative value. You may also need to convert latitude that is in degrees, minutes and seconds into decimal degrees. The latitude of Rogue River, Oregon is North 42° 26' 24", so the correct entry is 42.44.
- 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. If your longitude is west, enter a negative value. You may also need to convert longitude that is in degrees, minutes and seconds into decimal degrees. The longitude of Rogue River, Oregon is West 123° 10' 12", so the correct entry is -123.17.
- 3) **Time Zone (Hours)** - This is the difference in hours from Greenwich Mean Time (GMT) or Coordinated Universal Time (UTC) for a particular time zone. If west of GMT/UTC, enter a negative value. The time zone of Rogue River, Oregon is -8.
- 4) **Solar or Local Time** - This is a logic parameter to tell the calculator whether the **Hour** input parameter will be in solar time or Local Standard Time (LST).
- 5) **Hour** - This is either the solar time or the Local Standard Time (LST) of the day depending on the value of the input logic parameter 4) and ranges from 1 to 24. If input logic parameter 4) is 0, a value of 12 corresponds to solar noon which is the time when the **Solar Altitude Angle** output parameter will be the maximum value for the day and when the **Solar Azimuth Angle** output parameter will be exactly 180 degrees (true south). If input logic parameter 4) is 1, a value of 12 is local noon. If input logic parameter 4) is 1, a value of 15 is 3 PM LST. You can also enter decimal values such as 15.5 for 3:30 PM or 15.75 for 3:45 PM. Please be sure to also account for Daylight Saving Time (DST) if this is used in your area. You normally need to subtract 1 hour from your LST when DST is in effect. For example, for Rogue River, Oregon, DST is in effect from 2 AM on the second Sunday of March until 2 AM on the first Sunday of November. Therefore, the correct value to enter into the calculator during this DST period is the LST minus 1 hour. So if it is 3:45 PM LST, the correct entry is 14.75.
- 6) **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 should only enter an integer value within this range.
- 7) **Month** - This is the actual month of the year and ranges from 1 to 12, where 1 is January and 12 is December. You should only enter an integer value within this range.
- 8) **Year** - This is the actual year and entered in four digits, for example, 2012. You can select any year you want for this exercise as this will not affect the passive solar heating design.

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 (March 20th) and fall (September 22nd) equinoxes 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 most often defined as the clockwise angle from true north to the direction of the sun similar to a standard compass dial. As such, a solar azimuth angle of 90 degrees is true east, 180 degrees is true south and 270 degrees is true west. If you are using a compass to establish the true south orientation of your south wall, be sure to consider your local magnetic declination (also known as magnetic variation) which changes over time. For Rogue River, Oregon, the local magnetic declination was 15.3 degrees east of true in 2012. Therefore, true south in Rogue River, Oregon was equivalent to a magnetic compass reading of 195.3 degrees at this time.
- 3) **Solar Altitude Angle (Degrees)** - The solar altitude angle is the angle between the direction of the geometric center of the sun's apparent disk and the horizon. Depending on your latitude and the solar declination angle, 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). The next step is use these **Solar Altitude Angle** selections in our **Passive Solar Roof Overhang Design Calculator** to design your roof overhang.

Passive Solar Roof Overhang Design Calculator

The objective is to design a roof overhang that will allow sunshine to enter your windows during the cold winter months when the **Solar Altitude Angle** is low, but not allow sunshine to enter your windows during the hot winter months when the **Solar Altitude Angle** is high. 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 our [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. Be sure to use this same value in our [Passive Solar Fenestration Exposure Calculator](#) and [Passive Solar Heat Gain Calculator](#)!
- 2) **Desired Solar Altitude Angle for Full Shade (Degrees)** - This is the solar altitude angle you selected after exercising our [Passive Solar Altitude Angle Calculator](#). This is typically your latitude plus 18.5 degrees.
- 3) **Desired Solar Altitude Angle for Full Sun (Degrees)** - This is the solar altitude angle you selected after exercising our [Passive Solar Altitude Angle Calculator](#). This is typically your latitude minus 18.5 degrees.

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. This design value is used as an input parameter for our [Passive Solar Fenestration Exposure Calculator](#) and for our [Passive Solar Heat Gain Calculator](#).
- 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. This design value is used as an input parameter for our [Passive Solar Fenestration Exposure Calculator](#) and for our [Passive Solar Heat Gain Calculator](#).

You may need to iterate between this calculator and our [Passive Solar Altitude Angle Calculator](#) to obtain both a roof design and passive solar heating design that you find to be acceptable. The next step is to use this roof overhang design in our [Passive Solar Fenestration Exposure Calculator](#) to assess whether you are getting the appropriate amount of sun or shading for your climate and time of the year.

Passive Solar Fenestration Exposure Calculator

This calculator integrates and enables you to validate the passive solar design that you developed by exercising our [Passive Solar Altitude Angle Calculator](#) and our [Passive Solar Roof Overhang Design Calculator](#). 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, vertically oriented, fenestration (i.e., windows and doors) during the various times of the day and the year. The calculator also determines how far into the building this solar radiation strikes the floor so you may plan your furniture floor plan. By exercising this calculator, you will gain good insight on how passive solar heating is accomplished using a roof overhang design that controls the amount solar radiation that reaches your south facing windows and doors during the various times of the day and the year.

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. If your Latitude is south, enter a negative value. You may also need to convert latitude that is in degrees, minutes and seconds into decimal degrees. The latitude of Rogue River, Oregon is North 42° 26' 24", so the correct entry is 42.44. Be sure to use the same value that you used in our [Passive Solar Altitude Angle Calculator](#) !
- 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. If your longitude is west, enter a negative value. You may also need to convert longitude that is in degrees, minutes and seconds into decimal degrees. The longitude of Rogue River, Oregon is West 123° 10' 12", so the correct entry is -123.17. Be sure to use the same value that you used in our [Passive Solar Altitude Angle Calculator](#) !
- 3) **Time Zone (Hours)** - This is the difference in hours from Greenwich Mean Time (GMT) or Coordinated Universal Time (UTC) for a particular time zone. If west of GMT/UTC, enter a negative value. The time zone of Rogue River, Oregon is -8. Be sure to use the same value that you used in our [Passive Solar Altitude Angle Calculator](#) !
- 4) **Solar or Local Time** - This is a logic parameter to tell the calculator whether the **Hour** input parameter will be in solar time or Local Standard Time (LST).
- 5) **Hour** - This is either the solar time or the Local Standard Time (LST) of the day depending on the value of the input logic parameter 4) and ranges from 1 to 24. If input logic parameter 4) is 0, a value of 12 corresponds to solar noon which is the time when the **Solar Altitude Angle** output parameter will be the maximum value for the day and when the **Solar Azimuth Angle** output parameter will be exactly 180 degrees (true south). If input logic parameter 4) is 1, a value of 12 is local noon. If input logic parameter 4) is 1, a value of 15 is 3 PM LST. You can also enter decimal values such as 15.5 for 3:30 PM or 15.75 for 3:45 PM. Please be sure to also account for Daylight Saving Time (DST) if this is used in your area. You normally need to subtract 1 hour from your LST when DST is in effect. For example, for Rogue River, Oregon, DST is in effect from 2 AM on the second Sunday of March until 2 AM on the first Sunday of November. Therefore, the correct value to enter into the calculator during this DST period is the LST minus 1 hour. So if it is 3:45 PM LST, the correct entry is 14.75.
- 6) **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 should only enter an integer value within this range.

- 7) **Month** - This is the actual month of the year and ranges from 1 to 12, where 1 is January and 12 is December. You should only enter an integer value within this range.
- 8) **Year** - This is the actual year and entered in four digits, for example, 2012. You can select any year you want for this exercise as this will not affect the passive solar heating design.
- 9) **South Wall Deviation from True South (Degrees)** – This is the direction angle that your south wall deviates from facing true south, which ideally should be zero. Your south wall deviation from true south should be less than 20 degrees to ensure good passive solar heating performance. It is normally better to deviate toward the east than toward the west to avoid the potential for afternoon overheating during the summer months.
- 10) **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. Be sure to use the same value that you used in our [Passive Solar Roof Overhang Design Calculator](#)!
- 11) **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.
- 12) **Height of Roof Overhang from Top of Glass (Feet)** - 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. This is the design parameter you obtained after exercising our [Passive Solar Roof Overhang Design Calculator](#).
- 13) **Depth of Roof Overhang from Glass (Feet)** - 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. This is the design parameter you obtained after exercising our [Passive Solar Roof Overhang Design Calculator](#).

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 most often defined as the clockwise angle from true north to the direction of the sun similar to a standard compass dial. As such, a solar azimuth angle of 90 degrees is true east, 180 degrees is true south and 270 degrees is true west. If you are using a compass to establish the true south orientation of your south wall, be sure to consider your local magnetic declination (also known as magnetic variation) which changes over time. For Rogue River, Oregon, the local magnetic declination was 15.3 degrees east of true in 2012. Therefore, true south in Rogue River, Oregon was equivalent to a magnetic compass reading of 195.3 degrees at this time.
- 3) **Solar Altitude Angle (Degrees)** - The solar altitude angle is the angle between the direction of the geometric center of the sun's apparent disk and the horizon. Depending on your latitude and

the solar declination angle, the solar altitude angle can range from 0 to 90 degrees during the daylight hours.

- 4) **Does solar radiation reach south wall at this time?** – This answers the question whether your south facing windows are being exposed to the sun at the time of the day, day of the month, month of the year, and the year that you selected. It is a good confirmation that you correctly entered the inputs correctly!
- 5) **Solar Radiation Allowed by Roof Overhang (Percent of Glass Area)** – This is the percentage of the glass surface area of your south facing windows being exposed to the sun that will pass sunlight through to the inside of your building at the time of the day, day of the month, month of the year, and the year that you selected.
- 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.

If you are happy with your passive solar design, the next step is to use this data in our **Passive Solar Heat Gain Calculator** to determine how much passive solar heat gain you can produce.

Passive Solar Heat Gain Calculator

This calculator determines the passive solar heat gain that will be produced during each month of the year for the passive solar design th

- 3) **South Wall Deviation from True South (Degrees)** – This is the direction angle that your south wall deviates from facing true south, which ideally should be zero. Your south wall deviation from true south should be less than 20 degrees to ensure good passive solar heating performance. It is normally better to deviate toward the east than toward the west to avoid the potential for afternoon overheating during the summer months. Be sure to use the same value that you used in our [Passive Solar Altitude Angle Calculator](#) and [Passive Solar Fenestration Exposure Calculator](#)!
- 4) **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. Be sure to use the same value that you used in our [Passive Solar Roof Overhang Design Calculator](#)!
- 5) **Height of Roof Overhang from Top of Glass (Feet)** - 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. This is the design parameter you obtained after exercising our [Passive Solar Roof Overhang Design Calculator](#).
- 6) **Depth of Roof Overhang from Glass (Feet)** - 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. This is the design parameter you obtained after exercising our [Passive Solar Roof Overhang Design Calculator](#).
- 7) **Window SHGC** - This is the fraction of solar energy that the window transmits and is the “whole window” Solar Heat Gain Coefficient as normally provided by window manufacturers. A window with a SHGC value of 1.0 will transmit 100% of the solar energy that it receives. A window with a SHGC value of 0 won't transmit any of the solar energy that it receives. There is also another term called Shading Coefficient (SC) that is often used to describe window energy transmission. Multiply SC by 0.87 to convert it to SHGC for use in this calculator.
- 8) **Window Area (Square Feet)** - This is the rough opening area of the south facing windows and doors being used for passive solar heating. By varying this window area input parameter to assess the heat gain that will be produced and by already knowing the window height from previously accomplishing the roof overhang design, the window width and the number of windows required can be determined.
- 9) **Clear Sky Optical Depth for Beam Irradiance** - This is a measure of the atmosphere optical transparency quality (i.e., the amount of solar radiation that is not scattered or absorbed by the atmosphere) for a beam of sunshine directly striking the ground. For Rogue River, OR in January, the **Clear Sky Optical Depth for Beam Irradiance** input value is 0.297. Values for each month of the year for specific locations are published by ASHRAE and other sources.
- 10) **Clear Sky Optical Depth for Diffuse Irradiance** - This is a measure of the atmosphere optical transparency quality (i.e., the amount of solar radiation that is not scattered or absorbed by the atmosphere) for diffuse sunshine (i.e., sunshine that has been scattered by the affect of the atmosphere) indirectly reaching the ground. For Rogue River, OR in January, the clear sky optical depth for Diffuse Irradiance input value is 2.693. Values for each month of the year for specific locations are published by ASHRAE and other sources.
- 11) **Ground Reflectance Coefficient** - This is the fraction of solar energy that the window receives from the reflectivity of the ground outside the window. A ground reflectance coefficient of 1.0 is representative of a completely reflective ground surface. A ground reflectance coefficient of 0 is representative of a completely non-reflective surface. Solar ground reflectance can be significant and must be included in the heat gain calculation. A snow covered rural site has a value between 0.5 and 0.7. Desert sand has a value of 0.4. Dry grassland has a value between 0.2 and 0.3.

Dry bare ground has a value of 0.2. A coniferous forest has a value of 0.07. 0.2 is often a typical and reasonable value to use for most locations unless you have one of the aforementioned ground surfaces.

- 12) **Climatic Sunshine (Percent)** - This is the forecast average percentage of possible sunshine that reaches the ground during the month in a specific location accounting for the affect of cloud cover and other climatic conditions that block solar radiation. 42% is the forecast climatic sunshine for Rogue River, OR in January. This value of 42% indicates that the average percentage of possible sunshine that will likely reach the ground during January is only 42% of the amount that would reach the ground if perfect "clear sky" conditions occur during the entire month. The climatic sunshine value determines the **Monthly Climatic Solar Heat Gain** output value. The **Monthly Maximum Clear Day Solar Heat Gain** output value is the heat gain that will occur if perfect "clear sky" conditions occur during the entire month. Setting the climatic sunshine value to 100% will result in the **Monthly Climatic Solar Heat Gain** output value being identically the same as the **Monthly Maximum Clear Day Solar Heat Gain** output value. Climatic Sunshine values are published for many places for each month of the year at this NOAA website:

[Climatic Sunshine Data](#)

- 13) **Terrain Obstruction Point** - Entering these terrain obstacle azimuth angle and terrain obstacle altitude angle data points allows the calculator to determine the adverse affect that any local terrain obstacles may have on limiting the amount of solar radiation that reaches your south facing windows. Terrain obstacles are objects such as hills, mountains, or trees that may block sunshine from reaching your south facing windows. If you do not have any terrain obstacles (i.e., you can see an unobstructed southern horizon from true east to true south to true west), enter 0 for all these terrain obstruction data points. If you do have terrain obstacles, you should consider using a Solar Pathfinder (please see the Affiliates tab of our website) to acquire this data or hire someone to do this for you. Enter the associated terrain obstacle altitude angle in degrees for the indicated terrain azimuth angle.

Click to obtain the following output parameters:

- 1) **Hourly Maximum Instantaneous Clear Sky Solar Heat Gain (BTU/Hour)** - This is the maximum hourly heat gain found to occur during the month for perfect "clear sky" conditions.
- 2) **Monthly Maximum Clear Sky Solar Heat Gain (BTU/Day)** - This is the maximum heat gain that will occur if perfect "clear sky" conditions occur during the entire month. This heat gain value should be compared against the associated building or room **Total Heat Loss (BTU/Day)** value obtained by exercising our **Heat Loss Analysis Calculator** to assess the likelihood of overheating the room or building.
- 3) **Monthly Climatic Solar Heat Gain (BTU/Day)** - This is the forecast heat gain that will occur based on the **Climatic Sunshine** input parameter value used. This is the best estimate of how much passive solar heat gain will actually be produced during the month. This heat gain value should be compared against the associated building or room **Total Heat Loss (BTU/Day)** value obtained by exercising our **Heat Loss Analysis Calculator** to assess the need for any additional supplemental heating requirements (e.g., hydronic radiant floor heating and/or masonry heater). This heat gain value is used by our **Integrated Heating System Performance Calculator**.

This calculator should be exercised to obtain the **Monthly Climatic Solar Heat Gain** for January through December. The next step is to use this data in our **Integrated Heating System Performance Calculator** to assess how well the heat gain achieved by your passive solar heating design meets your actual monthly and annual heating needs.

Blade Stress Analysis Calculator

This calculator is based on the Euler-Bernoulli simple beam formula for determining EITHER the minimum recommended thickness of a blade (for a known blade length) OR the maximum recommended blade length (for a known blade thickness). The engineering equations are for a blade (or for a bucket) subjected to an alternating maximum bending moment (e.g., induced by water forces acting on a rotating blade). This is a common blade loading for water work project machines.

To use this calculator, enter the following input parameters:

- 1) **Blade Thickness (Inches or Enter 0 for Blade Thickness Calculation)** - This is a logic parameter that tells the calculator what type of stress analysis to perform. If you are using a given and fixed material thickness for the blades (e.g., a section of steel pipe or stock plate), you should enter this thickness value to have the calculator determine the **Maximum Recommended Blade Length between Supports** output parameter. If you can specify and obtain the optimal material thickness for the blades, enter 0 to have the calculator determine the **Minimum Recommended Blade Thickness** output parameter.
- 2) **Maximum Blade Bending Moment or Maximum Blade Force (Inch-Pounds or Pounds)** - If you entered the blade thickness for input parameter 1), enter the maximum blade bending moment in inch-pounds. If you entered 0 for input parameter 1), enter the maximum blade force in pounds. The maximum blade bending moment and maximum blade force can be obtained by exercising our [Cross Flow Turbine Design Calculator](#), [Overshot Water Wheel Design Calculator](#), or [Undershot Water Wheel Design Calculator](#).
- 3) **Blade Width (Inches)** - This is the width of the associated cross flow turbine or undershot water wheel blade (or the width of the associated overshot water wheel bucket using an appropriately reduced **Design Factor of Safety** to account for the overshot bucket box structure being stronger than a blade). The blade (or bucket) width can be obtained by exercising our [Cross Flow Turbine Design Calculator](#), [Overshot Water Wheel Design Calculator](#), or [Undershot Water Wheel Design Calculator](#).
- 4) **Material Endurance Limit (Pounds per Square Inch)** - This is the cyclic stress (e.g., induced by water forces acting on a rotating blade) 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 results from the **Maximum Blade Bending Moment**. The design factor of safety can range from 1.1 (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. 1.25 might be a reasonable value to use for cross flow turbine and undershot water wheel blades. 0.5 might be a reasonable value to use for overshot water wheel buckets.

Click to obtain the following output parameter:

- 1) **Minimum Recommended Blade Thickness (Inches)** - This is the minimum recommended blade thickness given the input parameters.
- 2) **Maximum Recommended Blade Length between Supports (Inches)** - This is the maximum recommended blade (or bucket) length between the end plates of your cross flow turbine or water wheel given the input parameters. If your design blade (or bucket) length exceeds this recommendation, you may need additional support plates to stay within this recommendation.

Cross Flow Turbine Design Calculator

A cross flow turbine is a machine for converting the energy of moving water into power. A cross flow turbine consists of a nozzle and runner. Most commonly, the cross flow turbine is mounted vertically on a horizontal shaft. 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. Cross flow turbines are normally fed by water directly from a stream or indirectly from a pond, which is formed when a stream is dammed. A penstock (i.e., a pipe) is used to bring the water from the stream or pond to the cross flow turbine nozzle inlet.

A cross flow turbine can often operate at a much higher RPM than a water wheel can given the same head and flow rate, and may therefore not require a drive system between the turbine and the generator. As such, a cross flow turbine may be more reliable and suitable for hydroelectric projects. While not as efficient as a Kaplan, a Francis or a Pelton turbine, the cross flow turbine has the following benefits worth considering:

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 fully understand and use this calculator, you must first gain an understanding 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. Another good reference is "The Cross-Flow Turbine", Vol. 12, No.1, L.A. Haimerl, Munich-Pasing, January 1960. If your written technical German is good, the ultimate reference is, "Neue Wasserturbine Zeitschriu8 0 0 1.4r3(8 0 0,)-4()JTJb TJETBT1 0 0 1 3

- 5) **Blade Thickness (Inches)** - This is the thickness of the blade material and is normally obtained by performing a load/stress analysis. Please see our [Blade Stress Analysis Calculator](#).
- 6) **Shaft Diameter (Inches)** - This is the diameter of the shaft material and is normally determined by performing a load/stress analysis. Please see our [Shaft Stress Analysis Calculator](#).
- 7) **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.
- 8) **Turbine Nozzle 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](#).
- 9) **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.
- 10) **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%.
- 11) **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).

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 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) **Maximum Steady Shaft Torque (Foot-Pounds)** - This is the maximum steady shaft torque that the turbine will produce given your design inputs. If you require more torque, decrease the **Design Turbine Speed** input parameter. Use this value in our [Shaft Stress Analysis Calculator](#).
- 4) **Specific Speed** - This is a parameter used by engineers to categorize different styles of turbines. Cross flow turbines typically fall within the range of 36 to 146. You should consider using a different style of turbine (i.e., Kaplan, Francis or Pelton) or using a water wheel (overshot or undershot) if your design input parameters (flow rate, head and turbine speed) cause you to not be within this range.
- 5) **Blade Angle (Degrees)** - This is the optimal angle to orient the blade inlet given the Water Jet Angle of Attack. It is typically about 30 degrees when the Water Jet Angle of Attack is 16 degrees.
- 6) **Runner Diameter (Inches)** - This is the diameter of the runner.
- 7) **Rim Entrance Channel Thickness (Inches)** - This is the thickness of the rim channel through which the nozzle water jet will enter the runner.
- 8) **Runner Length (Inches)** - This is the length of the runner.
- 9) **Runner Aspect Ratio** - This is the ratio of the **Runner Length** divided by the **Runner Diameter**.
- 10) **Turbine Runaway Speed (Rotations per Minute)** - This is the speed the turbine would reach at the design flow rate and head without any shaft load. The turbine must be designed to survive the mechanical forces induced at this speed.

- 11) **Speed Ratio** - This is the ratio of the **Design Turbine Speed** divided by the **Turbine Runaway Speed**. The range is typically 0.42 to 0.50.
- 12) **Rim Diameter Ratio** - This is the ratio of the **Rim Inside Diameter** divided by the **Runner Diameter**. The ratio is actually a very complicated trigonometric calculation based on the **Blade Inlet Angle** and is used to determine the proper **Rim Inside Diameter**.
- 13) **Rim Inside Diameter (Inches)** - This is the inside diameter of the runner rim.
- 14) **Rim Width (Inches)** - This is the width of the runner rim.
- 15) **Water Jet Thickness at Runner Entrance (Inches)** - This is the thickness of the jet of water when it initially enters the runner.
- 16) **Banki Experimental Coefficient** - This is the ratio of the **Water Jet Thickness at Runner Entrance** divided by the **Runner Diameter**. This is an important performance parameter for a cross flow turbine. The optimal range as determined by Banki experimentation is 0.075 to 0.1.
- 17) **Water Jet Central Angle (Degrees)** - This is an engineering intermediate parameter used to determine the water jet thickness.
- 18) **Water Jet Thickness Inside Runner (Inches)** - This is the thickness of the jet of water when it passes through the inside of the runner.
- 19) **Water Jet Clearance from Shaft (Inches)** - This is the clearance between the jet of water and the runner shaft.
- 20) **Water Jet Clearance from Inner Rim (Inches)** - This is the clearance between the jet of water and the inner runner rim.
- 21) **Blade Curvature Radius (Inches)** - This is the optimum radius of the blades given the design parameters.
- 22) **Blade Pipe Outside Diameter (Inches)** - This is the diameter of pipe that can be used to fabricate the blades.
- 23) **Blade Pipe Section Angle (Degrees)** - This is angle section of pipe that would be cut to fabricate the blades. This parameter is used to determine the total quantity of pipe required to fabricate the blades.
- 24) **Blade Width (Inches)** - This is the width of the blades. Use this value in our [Blade Stress Analysis Calculator](#).
- 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 blades. This parameter is used to determine the total quantity of pipe required to fabricate the 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 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 blades.
- 29) **Required Total Length of Blade Pipe (Inches)** - This is the total length of pipe required to fabricate the blades.
- 30) **Blade Pitch Circle Diameter (Inches)** - This is a fabrication parameter used to scribe the slots on the side plates for the blades.
- 31) **Pitch of Blades on Pitch Circle (Inches)** - This is another fabrication parameter used to scribe the slots on the side plates for the blades.

- 32) **Outer Rim Blade Spacing (Inches)** - This is the spacing between the blades as measured at the outer rim.
- 33) **Inner Rim Blade Spacing (Inches)** - This is the spacing between the blades as measured at the inner rim.
- 34) **Maximum Blade Force (Pounds)** - This is the maximum force experienced by the blades based on the **Design Flow Rate** and the **Turbine Nozzle Inlet Water Velocity** input parameters. Use this value in our [Blade Stress Analysis Calculator](#).
- 35) **Maximum Shaft Force (Pounds)** - This is the maximum force experienced by the shaft. The engineering equations consider both the **Weight of Wheel** and **Maximum Blade Force** output parameters.
- 36) **Maximum Blade Bending Moment (Inch-Pounds)** - This is the maximum bending moment experienced by the blades resulting from the **Maximum Blade Force** output parameter acting at the blade mid-length. Use this value in our [Blade Stress Analysis Calculator](#).
- 37) **Maximum Shaft Bending Moment (Inch-Pounds)** - This is the maximum bending moment experienced by the shaft resulting from the **Maximum Shaft Force** output parameter acting at the shaft mid-length. Use this value in our [Shaft Stress Analysis Calculator](#).

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 the ditch.
- 5) **Length (Feet)** - This is the length of the ditch between the beginning and the end of the ditch.
- 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 interior perimeter of the ditch walls that the flowing water is actually in contact and this can vary depending on the actual depth of the water flowing in the ditch.
- 4) **Hydraulic Radius (Feet)** - This is the effective radius of the pipe and is obtained by dividing the **Area of Cross-Section** output parameter by the **Wetted Perimeter** output parameter.
- 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.

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 "hydam") 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 hydam 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 hydam 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 hydam 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 hydam that you should become familiar with. The pipe feeding water to your hydam 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 hydam falls before reaching your hydam. "Lift" is the elevation that your hydam 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 hydam 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 hydam. Your hydam 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 hydam, 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 hydam to the **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 hydam 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 Hydam

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 hydam 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 hydam 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 hydam 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 "hydram site installation design calculator version" provides several useful output parameters that may be used to properly design and construct a reliable and high performance hydram installation. We have also developed a "hydram design calculator version" that may be used to properly design very efficient hydrams. We have also developed "customized hydram 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 hydram. 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 may need to input values for both.
- 4) **Lift - Desired Pumping Elevation Above Pump (Feet)** - This is the elevation of the storage tank above the hydram.
- 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. ***Please note that there is both a minimum and maximum acceptable drive line length. The actual drive line length has a significant effect on delivery performance!*** 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 4 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 hydram 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 is used to accurately calculate the water density used by the engineering equations. It typically 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 hydram into the storage tank.
- 2) **Drive Flow Rate (Gallons per Minute)** - This is the average flow of water from the source through the hydram. 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 Frequency Setting (Cycles per Minute)** - This is the optimum frequency setting for the waste valve to close, which can be readily heard and timed with a stop watch. For the Landis Hydram, this frequency can be adjusted by raising or lowering the glass ball inside the hydram 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 hydram 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 reduces the effective fall which adversely affects delivery performance.
- 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 hydram at the mean drive flow rate. This head loss reduces the effective fall which adversely affects delivery performance.
- 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 increases the effective lift which adversely affects delivery performance and 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 optimum peak flow rate in the drive line that would be measured at the exact moment the waste valve closes when the hydram 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 hydram 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 installation operational reliability based on the quantized energy effect caused by the hydram waste valve closure induced water hammer shock waves. Operational reliability will be 100% when this ratio is an odd number (rounding down to the nearest integer) and greater than 1.5. Operational reliability will vary between 99% and 1% when this ratio is an even number with larger ratio values resulting in higher operational reliability. Operational reliability will be 0% when this ratio is less than 1.5.
- 21) **Likelihood of Reliable Waste Valve Operation at this Setting (Percent)** - This is the actual operational reliability forecast. The higher this percentage, the higher is the likelihood that the operation will be reliable and that the waste valve will NOT get stuck in the closed position.

Isolation Stand Design Calculator

Machines such as engines, electrical motors, pumps, and turbine runners can create both air-borne (sound) and structure-borne vibrations. Other equipment can be sensitive to vibration excitation. Vibration isolation (using rubber isolation mounts) can be used to achieve significant reductions of transmitted vibrations. This calculator may be used to design an isolation stand where either one or two machines may be fastened to the isolation stand and isolation mounts are fastened to the right and left side of the isolation stand between the isolation stand and the floor (or between one isolation level and another isolation level). To use this calculator, you need to know the weight of the machines that will be mounted to the isolation stand as well as the weight of the actual isolation stand. You also need to know the distance between each machine's center-of-gravity (CG) and the "isolation stand datum" (defined herein to be the location on the isolation stand where the right isolation mounts will be attached to the isolation stand).

To use this calculator, enter the following input parameters:

- 1) **Design Isolation Efficiency (Percent)** – This is the percentage of vibration that is absorbed by the isolation mounts (and converted into heat energy) and NOT transmitted to the floor. A design isolation efficiency of 80 to 90% is generally considered satisfactory and within the range of isolation mounts that can be readily obtained from manufacturers.
- 2) **Weight of Machine 1 (Pounds)** - This is the weight of machine 1 (plus fasteners) which is attached directly to the isolation stand and which is typically an engine, electrical motor, pump, or turbine runner.
- 3) **Weight of Machine 2 (Pounds)** - This is the weight of machine 2 (plus fasteners) which is attached directly to the isolation stand and which is typically a generator. If only one machine will be attached to the isolation stand, enter 0 for this input parameter.
- 4) **Weight of Isolation Stand (Pounds)** - This is the weight of the isolation stand that the machines will be attached and does NOT include the weight of the actual machines or the weight of the isolation mounts.
- 5) **Distance Between Right/Left Isolation Mounts (Inches)** - This is the dimension between the right and left isolation mount attachment locations on the isolation stand.
- 6) **Distance Between Machine 1 CG and Right Isolation Mounts (Inches)** - This is the dimension between the center-of-gravity of machine 1 and where the right isolation mounts will be attached on the isolation stand (i.e., the aforementioned isolation stand datum).
- 7) **Distance Between Machine 2 CG and Right Isolation Mounts (Inches)** - This is the dimension between the center-of-gravity of machine 2 and where the right isolation mounts will be attached on the isolation stand (i.e., the aforementioned isolation stand datum).
- 8) **Number of Right Isolation Mounts** - This is the total number of right isolation mounts that will be used for the design. You may want to use a different number of mounts for right/left side to achieve design objectives.
- 9) **Number of Left Isolation Mounts** - This is the total number of left isolation mounts that will be used for the design. You may want to use a different number of mounts for right/left side to achieve design objectives.
- 10) **Disturbing Frequency of Machine 1 (Rotations per Minute)** - This is the frequency of vibration caused by a source such as an engine expressed as the number of oscillations that occur per unit time. This is typically the operational RPM of the machine.
- 11) **Selected Spring Rate of Right Isolation Mounts (Pounds/Inch)** – The spring rate is a ratio of the imposed static load to the resulting deflection of a specific isolation mount expressed in pounds per inch. This input parameter is the spring rate of each right isolation mount as specified

by the manufacturer of the selected isolation mount that will be used in the design. Initially enter 0 for this input parameter. Please see below detailed directions.

- 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. Initially enter 0 for this input parameter. 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 weight of the isolation 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 weight of the isolation 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 weight of the isolation 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 left isolation mount will actually experience resulting from the weight of the machines and the weight of the isolation stand based on the **Selected Spring Rate of Left 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**. Select 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 the **Number of Right/Left Isolation Mounts** that will be used in your design to achieve the **Load per Right/Left Mount** and the **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 manufacturer part number for all the isolation mounts. Once you have selected your isolation mounts, enter the manufacturer specified spring rate for the **Selected Spring Rate of Right/Left Isolation Mounts** and click to obtain the **Actual Deflection of Right/Left Isolation Mounts** and the **Actual Isolation**. Verify that the **Actual Deflection of Right/Left Isolation Mounts** is less than the manufacturer maximum recommended compression deflection and that the **Actual Isolation** achieves your isolation stand design objective. You may also want to see the [Lister Engine Gallery](#) website for an example of how this approach was used to successfully design an isolation stand for a heavy, single piston, stationary diesel engine back in 2004 when several "experts" claimed this was not possible.

Overshot Water Wheel Design Calculator

An overshoot water wheel is a machine for converting the energy of falling water into power. An overshoot water wheel consists of a large metal wheel, with a number of buckets arranged on the outer rim forming the driving surface. Most commonly, the wheel is mounted vertically on a horizontal shaft. Water wheels are normally fed indirectly by water from a pond, which is formed when a stream is dammed. A penstock (i.e., a channel or ditch) is used to bring the water from the pond to a few feet above the wheel. This calculator allows you to design and build an overshoot water wheel optimized to your specific hydroelectric site conditions.

To use this calculator, enter the following input parameters:

- 1) **Penstock Flow Rate (Gallons per Minute)** - This is the flow rate you would like to feed the turbine given what is available at your site. Please see our [Ditch Capacity Calculator](#).
- 2) **Penstock Height above Wheel (Feet)** - This is the vertical dimension that the penstock outlet is located above the wheel.
- 3) **Design Diameter (Feet)** - This is the diameter of the wheel. Larger design diameters will increase the **Maximum Steady Shaft Torque** output parameter, but will reduce the **Optimal Rotation Speed** output parameter. Smaller design diameters will increase the **Maximum Steady Shaft Torque**, but will reduce the **Maximum Steady Shaft 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 **Maximum Steady Shaft Torque** and **Maximum Steady Shaft Torque** to meet the requirements of your generator. Please see our [Pulley Drive System Design Calculator](#).
- 4) **Bucket Thickness (Inches)** - This is the thickness of the bucket material and is normally obtained by performing a load/stress analysis. Please see our [Blade Stress Analysis Calculator](#).
- 5) **Shaft Diameter (Inches)** - This is the diameter of the shaft material and is normally determined by performing a load/stress analysis. Please see our [Shaft Stress Analysis Calculator](#).
- 6) **Expected Wheel Efficiency (Percent)** - This is a measure of how well the wheel converts the kinetic energy of the penstock water (head and flow rate) into mechanical energy (torque and RPM). This is typically 80%.
- 7) **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 undershot water wheel 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 undershot water wheel and the generator.
- 3) **Maximum Steady Shaft Torque (Foot-Pounds)** - This is the maximum steady shaft torque that the undershot water wheel will produce given your design inputs. If you require more torque, increase the **Design Diameter** input parameter.
- 4) **Operating Head (Feet)** - This is the head resulting from the sum of the wheel **Design Diameter** and the **Penstock Height above Wheel** input parameters. The site must have this amount of head PLUS the additional head required to achieve the **Penstock Flow Rate** input parameter!

- 5) **Working Circumference (Feet)** - This is the effective wheel circumference based on the wheel **Design Diameter** input parameter.
- 6) **Working Cross-Sectional Area (Square Feet)** - This is the effective wheel cross-sectional area given the **Design Width** input parameter and **Effective Head** output parameter.
- 7) **Optimal Rim Tangential Speed (Feet per Second)** - This is the optimal linear velocity at the rim **Working Diameter** given the **Stream Velocity** input parameter.
- 8) **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** output parameters. If you require more rotation speed, reduce the wheel **Design Diameter** input parameter.
- 9) **Wheel Width** - This is the width of the wheel and also the length of the buckets.
- 10) **Number of Radial Arms** - This is the recommended number of radial arms (based on the Redtenbacher formula) used to connect the wheel rim to the shaft if solid side plates are not used for the design.
- 11) **Number of Buckets** - This is the recommended number of total buckets. It is recommended that the **Design Diameter** input parameter be varied so as to have an even number of buckets to simplify construction. If radial arms will be used for the design in lieu of solid side plates, the number of buckets should be a multiple of the number of radial arms.
- 12) **Bucket Width (Inches)** - This is the width of the buckets and also the bucket spacing. Use this value in our [Blade Stress Analysis Calculator](#).
- 13) **Bucket Depth (Inches)** - This is the depth of the buckets and is 10% of the wheel **Design Diameter** input parameter.
- 14) **Bucket Volume (Gallons)** - This is the volume of a single bucket.
- 15) **Required Penstock Width (Inches)** - This is the required penstock width above the wheel that will enable the buckets to quickly fill with water by properly allowing for the air to escape.
- 16) **Minimum Penstock Width (Inches)** - This is the minimum penstock width associated with the **Required Penstock Width** output parameter required to achieve the **Penstock Flow Rate** input parameter.
- 17) **Weight of Wheel** - This is the fully fabricated weight of the wheel including the buckets, shaft and solid side plates. It is assumed that the entire wheel is constructed using the same thickness steel as the buckets. The weight of the wheel can be significantly reduced by using radial arms in lieu of solid side plates.
- 18) **Maximum Bucket Force (Pounds)** - This is the maximum force experienced by the buckets. The engineering equations consider both the water entry force into the buckets as well as the bucket being completely full of water. Use this value in our [Blade Stress Analysis Calculator](#).
- 19) **Maximum Shaft Force (Pounds)** - This is the maximum force experienced by the shaft. The engineering equations consider the **Weight of Wheel** output parameter and 50% of the buckets being completely full of water.
- 20) **Maximum Bucket Bending Moment (Inch-Pounds)** - This is the maximum bending moment experienced by the buckets resulting from the **Maximum Bucket Force** output parameter acting at the bucket mid-length. Use this value in our [Blade Stress Analysis Calculator](#).
- 21) **Maximum Shaft Bending Moment (Inch-Pounds)** - This is the maximum bending moment experienced by the shaft resulting from the **Maximum Shaft Force** output parameter acting at the shaft mid-length. Use this value in our [Shaft Stress Analysis Calculator](#).

Pipe Capacity Calculator (Darcy-Weisbach)

This calculator is based on the Darcy-Weisbach Formula which is considered to be more accurate than the Hazen-Williams Formula based calculator which is also provided on our website. 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 a well known intermediate parameter often used by engineers.
- 5) **Darcy-Weisbach Friction Factor** - This is a well known intermediate parameter often used by engineers.
- 6) **Velocity (Feet per Second)** - If 1 was entered for input logic parameter 6), this is the maximum velocity capacity. If a specific flow rate was entered for input logic parameter 6), this is the specific flow rate that was entered divided by the **Area of Cross-Section** output parameter.
- 7) **Flow Rate (Gallons per Minute)** - If 1 was entered for input logic parameter 6), this is the maximum flow rate capacity. If a specific flow rate was entered for input logic parameter 6), this is the specific flow rate that was entered.

- 8) **Head Loss (Feet and Percent of Total Head)** - This is the 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 (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 interior perimeter of the pipe that the flowing water is in contact and is 100% of the pipe perimeter.
- 4) **Hydraulic Radius (Feet)** - This is the effective radius of the pipe and is obtained by dividing the **Area of Cross-Section** output parameter by the **Wetted Perimeter** output parameter.
- 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 may be 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, the pulley diameters are often the same. However, you may want to change the driven element RPM or torque from that of the driver element and this can be readily accomplished with a pulley drive system. Please note that 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 of the pulley.
- 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

[Shaft Stress Analysis Calculator](#)

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

To use this calculator, enter the following input parameters:

- 1) **Maximum Steady Shaft Torque (Foot-Pounds)** - This is the maximum steady shaft torque resulting from either the driving machine or the driven machine. The maximum steady shaft torque can be obtained by exercising our [Cross Flow Turbine Design Calculator](#), [Overshot Water Wheel Design Calculator](#), or [Undershot Water Wheel Design Calculator](#).
- 2) **Maximum Shaft Bending Moment (Inch-Pounds)** - This is the combination of acting force and moment arm that results in the maximum bending moment applied to the shaft. We have taken a conservative approach with this. The maximum shaft bending moment can be obtained by exercising our [Cross Flow Turbine Design Calculator](#), [Overshot Water Wheel Design Calculator](#), or [Undershot Water Wheel Design Calculator](#).
- 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 (e.g., induced by the weight of a turbine runner and water forces acting on a rotating runner/shaft) 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 results from the combination **Maximum Steady Shaft Torque** and **Maximum Shaft Bending Moment**. The design factor of safety can range from 1.1 (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. 1.5 might be a reasonable value to use for cross flow turbines and water wheels.

Click to obtain the following output parameter:

- 1) **Minimum Recommended 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

Undershot Water Wheel Design Calculator

An undershoot water wheel is a machine for converting the energy of moving water into power. An undershot water wheel consists of a large metal wheel, with a number blades arranged on the outer rim which allows the wheel to be rotated by the water striking the blades. Most commonly, the wheel is mounted vertically on a horizontal shaft. A penstock (i.e., a channel, ditch or pipe) is NOT required.

While undershot water wheels may not be the most efficient machine for this job, they are relatively easy to construct. You first need to have a fast moving stream (i.e., average velocity greater than 4 FPS) in order to generate any significant amount of hydroelectricity. The amount of hydroelectricity that can be generated by this fast moving stream is proportional to the square of this velocity and proportional to 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 design diameters will increase the **Maximum Steady Shaft Torque** output parameter, but will reduce the **Optimal Rotation Speed** output parameter. Smaller design diameters will increase the **Maximum Steady Shaft Torque**, but will reduce the **Maximum Steady Shaft 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 **Maximum Steady Shaft Torque** and **Maximum Steady Shaft Torque** to meet the requirements of your generator. Please see our [Pulley Drive System Design Calculator](#).
- 3) **Design Width (Inches)** - This is the width of the wheel. Larger wheel widths will increase the **Effective Flow Rate** output parameter and increase the wheel **Expected Power** output parameter.
- 4) **Blade Thickness (Inches)** - This is the thickness of the blade material and is normally obtained by performing a load/stress analysis. Please see our [Blade Stress Analysis Calculator](#).
- 5) **Shaft Diameter (Inches)** - This is the diameter of the shaft material and is normally determined by performing a load/stress analysis. Please see our [Shaft Stress Analysis Calculator](#).
- 6) **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 25% for an undershot water wheel with "flat" blades and 65% with "curved" Jean V. Poncelet style blades.
- 7) **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 undershot water wheel 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 undershot water wheel and the generator.
- 3) **Maximum Steady Shaft Torque (Foot-Pounds)** - This is the maximum steady shaft torque that the undershot water wheel will produce given your design inputs. If you require more torque, increase the **Design Diameter** input parameter.
- 4) **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 directly striking the blades without using a penstock to convert the head into water velocity.
- 5) **Effective Flow Rate (Gallons per Minute)** - This is the effective flow rate based on the **Stream Velocity** input parameter and the **Working Cross-Sectional Area** output parameter.
- 6) **Minimum Optimal Diameter (Feet)** - This is the minimum recommended wheel diameter. This has been found by experimentation to be approximately 3 times the **Effective Head** output parameter.
- 7) **Maximum Optimal Diameter (Feet)** - This is the maximum recommended wheel diameter. This has been found by experimentation to be approximately 6 times the **Effective Head** output parameter.
- 8) **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.
- 9) **Working Circumference (Feet)** - This is the effective wheel circumference based on the **Working Diameter** input parameter.
- 10) **Working Cross-Sectional Area (Square Feet)** - This is the effective wheel cross-sectional area given the **Design Width** input parameter and **Effective Head** output parameter.
- 11) **Optimal Rim Tangential Speed (Feet per Second)** - This is the optimal linear velocity at the rim **Working Diameter** given the **Stream Velocity** input parameter.
- 12) **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** output parameters. If you require more rotation speed, reduce the **Design Diameter** input parameter.
- 13) **Number of Radial Arms** - This is the recommended number of radial arms (based on the Redtenbacher formula) used to connect the wheel rim to the shaft if solid side plates are not used for the design.
- 14) **Number of Blades** - This is the recommended number of total blades. It is recommended that the **Design Diameter** input parameter be varied so as to have an even number of blades to simplify construction. If radial arms will be used for the design in lieu of solid side plates, the number of blades should be a multiple of the number of radial arms.
- 15) **Blade Spacing (Inches)** - This is the recommended blade spacing based on experimentation and found to be approximately 0.95 times the **Effective Head** output parameter.
- 16) **Blade Width (Inches)** - This is the width of the blades. Use this value in our [Blade Stress Analysis Calculator](#).
- 17) **Weight of Wheel** - This is the fully fabricated weight of the wheel including the blades, shaft and solid side plates. It is assumed that the entire wheel is constructed using the same thickness steel as the blades. The weight of the wheel can be significantly reduced by using radial arms in lieu of solid side plates.
- 18) **Maximum Blade Force (Pounds)** - This is the maximum force experienced by the blades based on the **Stream Velocity** input parameter and the **Effective Flow Rate** output parameter. Use this value in our [Blade Stress Analysis Calculator](#).

- 19) **Maximum Shaft Force (Pounds)** - This is the maximum force experienced by the shaft. The engineering equations consider the **Weight of Wheel** output parameter.
- 20) **Maximum Blade Bending Moment (Inch-Pounds)** - This is the maximum bending moment experienced by the blades resulting from the **Maximum Blade Force** output parameter acting at the blade mid-length. Use this value in our [Blade Stress Analysis Calculator](#).
- 21) **Maximum Shaft Bending Moment (Inch-Pounds)** - This is the maximum bending moment experienced by the shaft resulting from the **Maximum Shaft Force** output parameter acting at the shaft mid-length. Use this value in our [Shaft Stress Analysis Calculator](#).