Radiant Cheat Sheet

To determine	formula	Example
BTU's/hr/ft^2	Heat loss analysis	CDAM Chapter 7 page 61
Boiler size (output)	sq. ft of house x BTU's/hr/ft^2 (Snow melt and/or DHW must also be added + any auxiliary heat loads)	2,000 ft^2 house x 15 BTU's/hr/ft^2 = (approx.) 30,000 BTU/hr boiler output (Does not include downward loss or auxiliary heat loads)
Boiler size (input)	Boiler size output ÷ efficiency of boiler	30,000 ÷ .95 = 31,579 BTU input
Primary pump GPM	Boiler output ÷ 10,000 @20°Δ_T	30,000 BTU ÷ 10,000 = 3 GPM
Secondary pump GPM	Load ÷ 5,000 @10°Δ_T	30,000 BTU ÷ 5,000 = 6 GPM
Snow melt pump	Load ÷ 11,525 (factored with 40% Glycol)	30,000 ÷ 11,525 = 2.6 GPM
Floor Surface Temperature	BTU's/hr/ft^2 ÷ 2 + Setpoint of thermostat	15 ÷ 2 + 70 = 77.5
Ceiling Surface Temperature	BTU's/hr/ft^2 ÷ 1.6 + Setpoint of thermostat	15 ÷ 1.6 + 70 = 79.4
Wall Surface Temperature	BTU's/hr/ft^2 ÷ 1.4 + Setpoint of thermostat	15 ÷ 1.4 + 70 = 80.7
Supply Water Temp	Supply Water Temperature Charts	CDAM Appendix E pages 221-228
How many feet of tubing (not counting leader lengths)	12" o.c. = Room ft^2 x 1.0 10" o.c. = Room ft^2 x 1.2 9" o.c. = Room ft^2 x 1.33 8" o.c. = Room ft^2 x 1.5 7" o.c. = Room ft^2 x 1.7 6" o.c. = Room ft^2 x 2	A 400 ft^2 room is using Quik Trak which is 7" o.c. 400 x 1.7 = 680' of 5/16" tubing
How many Joist Trak™ Panels	Feet of tubing x 0.2125	Tubing is 8" o.c.
How many screws	# of Joist Trak's x 10	3/4" #8 screws
How many Quik Trak™ Panels	Room ft^2 x 0.386 (panels) Room ft^2 x 0.043 (returns)	Tubing is 7" o.c.
How many screws	# of panels x 10 # of returns x 10	1-1/4" #8 screws or 1" staples
How many tubes of caulk	1 tube/300' of tubing	1/8" bead. Do not fill the track
How many rows of Quik Trak	Distance from the outside wall to the manifold wall ÷ 0.583	
How many PEX clips	Loop length ÷ 3	280' ÷ 3 = 93.3 or 94 clips
How many Fast Trak 0.5 panels	Room ft^2 ÷ 8.3	1,000 FT^2 ÷ 8.3 = 120.5 OR 121 panels
How many Fast Trak 1.3i panels	Room ft^2 ÷ 12.1	1,000 ft^2 ÷ 12.1 = 82.6 or 83 panels
How many rolls of Fast Trak Edge Strip	(Room length x 2) + (Room width x 2) ÷ 65	(2) x 20' L + (2) x 25' W = 90' ÷ 65 = 1.38 rolls or 2 rolls

Version 2.3 May 2019

Max Loop Lengths	
Tubing Size	Max Loop Length
5/16″	250′
3/8″	225′
1/2″	300′
5/8″	450′
3/4"	575′
Quik Trak	250′ including leaders
Snow Melt	200′

Delta T's	
Primary Loop	20^0 ΔT
Secondary Loop Residential Commercial	 10^0 ΔT 20^0 ΔT
Quik Trak	20^0 ΔT
Indirect DHW Heater	20^0 ΔT
Fan Coil Units	20^0 ΔT
Baseboard	20^0 ΔT
Radiators	20^0 ΔT
Snow Melt	25^0 ΔT

Contents of Pipe at 60°	
Size	Gal/ft
5/16	0.0035
1/4	0.0024
3/8	0.0050
1/2	0.0092
5/8	0.0134
3/4	0.0184
1	0.0303
1-1/4	0.0454
1-1/2	0.0633
2	0.1085
2-1/2	0.1653
3	0.2351
4	0.4105

Max Supply Water Temp		
Material	Max SWT	Typical
Concrete	150^0	$110\text{-}135^0$
Asphalt	150^0	
Pavers	150^0	
Gypcrete	140^0	
Joist Trak	165^0	
Joist Clips	165^0	
Staple Up	165^0	
Joist Hangers	165^0	
Joist Heating No Plates	165^0	
Quik Trak	165^0	
Behind Drywall	120^0	
Baseboard	200^0	180^0
Fan Coil	180^0	160^0
Radiators*	200^0	160^0
Indirect DHW Heaters	180^0	180^0

* Some local codes restrict SWT of radiators not to exceed 165^0

Maximum Floor Surface Temperatures	
Hardwood floors	80^0F
All other floors	87.5^0F
Maximum Ceiling Surface Temperatures	
8′ ceilings	100^0F
9-12′ ceilings	110^0F

Water density values for D_{cold} and D_{hot} at water temperature shown

Generally use 60^0 F and 240^0 F for D_{cold} and D_{hot} providing for about 5% expansion

60^0F 62.34	100^0F 62	110^0F 61.84	120^0F 61.73	130^0F 61.54	140^0F 61.39	150^0F 61.20
160^0F 61.01	170^0F 60.79	180^0F 60.57	190^0F 60.39	200^0F 60.13	220^0F 59.63	240^0F 59.10

Primary Loop Pipe Sizing 20^0 ΔT		
BTU/hr	GPM	Pipe Size (in.)
20K – 40K	2 - 4	3/4"
40K – 90K	4 - 9	1″
60K – 160K	6 – 16	1-1/4″
100K – 210K	10 – 21	1-1/2″
200K – 450K	20 – 45	2″
400K – 780K	40 – 78	2-1/2″
650K – 1,120K	65 – 112	3″

Multiplier of Propylene Glycol for Universal Hydronic Formula	
Glycol %	Multiplier
0%	500
30%	480
40%	461
50%	442
Determined by: specific heat x specific gravity x 500	

Calculating Pipe Size

$$D_{in} = \sqrt{\left(\frac{0.4085}{V}\right) x\,(GPM)}$$

D_{in} = Diameter in Inches

V=Velocity in ft/sec

PEX Pipe ID			
Pipe Size	Pipe ID	Pipe Size	Pipe ID
1/4″	0.241	1-1/4″	1.054
3/8″	0.35	1-1/2″	1.244
1/2″	0.475	2″	1.629
3/4″	0.671	2-1/2″	2.011
1″	0.862	3″	2.4

Universal Hydronic Formula

BTU/Hr = GPM x 500 x $\triangle_T$

GPM = BTU/h ÷ ($\triangle_T$ x 500)

$\triangle_T$ = BTU/hr ÷ (GPM x 500)

Fahrenheit/Celsius

To convert Fahrenheit temperatures into Celsius:

- Subtract 32 from the Fahrenheit number.
- Divide the answer by 9
- Multiply that answer by 5

To convert Celsius temperatures into Fahrenheit:

- Multiply the Celsius temperature by 9
- Divide the answer by 5
- Add 32

Using CV (Based on 100% water at 60°F (15.6°C))

$$\Delta_p = \left(\frac{\mathrm{Q}}{\mathrm{Cv}}\right)^2 \qquad Cv = \frac{Q\sqrt{G}}{\sqrt{\Delta \mathrm{p}}} \qquad Q = Cv\sqrt{\Delta \mathrm{p}}$$

Where:

Q = Flow rate in GPM

C_v = Coefficient of flow of a valve

Δ_P = Pressure drop across valve in PSI

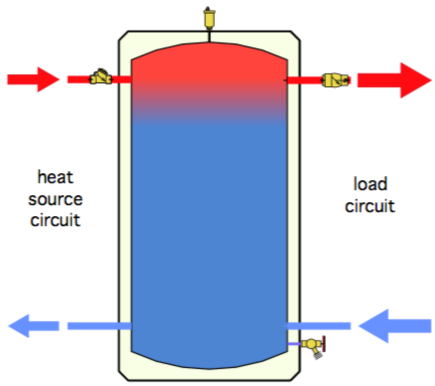
G = Specific gravity of fluid (*pure water has a specific gravity of 1*)

Specific Gravity

Specific gravity is a measure of relative density. The specific gravity is the density of a substance divided by the density of water. Density is measured in the units lbs/ft^3 (kg/m^3). The density of water at 60°F is 62.4 lbs/ft^3 (4.0°C is 1000 kg/m^3). So, the specific gravity is a unitless number.

$$Specific\ Gravity = \frac{Density\ of\ the\ substance}{Density\ of\ water\ at\ 60°F}$$

Buffer Tank Sizing



This formula can be used to determine the required volume of a buffer tank

$$V = \frac{t(Q_{heatsource} - q_{load})}{500(\Delta T)}$$

Where:

V = required volume of the buffer tank (gallons)

t = desired duration of the heat source's "on" cycle (minutes) (*Typically 15 Minutes*)

$Q_{heatsource}$ = heat output rate of the heat source (Btu/hr)

q_{load} = rate of heat extraction from the tank (Btu/hr) (*Smallest load*)

$\triangle_T$ = Temperature rise of the tank from when the heat source is turned on to when it is turned off (^{0}F) (*Typically 30°F*)

Example: A home with a 65,000 Btu boiler needs to be able to supply a 5,000 Btu/hr bedroom without short-cycling the boiler. They would like to run the boiler for a minimum of 15 minutes. The boiler turns on when the buffer tanks drops below 90^0 and turns off when the buffer tank reaches 120^0.

$$V = \frac{t(Q_{heatsource} - q_{load})}{500(\Delta T)}$$

$$V = \frac{(\qquad\qquad)}{500(\quad)}$$

$$V = \frac{15(65{,}000-5{,}000)}{500(30)} = \frac{15(60{,}000)}{15{,}000} = \frac{900{,}000}{15{,}000} = 60 \text{ Gallons}$$

This formula can be used when you know the tank size and you want to determine the duration of the on cycle in minutes

$$t = \frac{V\,x\,(500\Delta_T)}{Q_{heatsource} - q_{load}}$$

Expansion Tank Sizing

$$V = V_{system}\ x\ \left(\frac{D_{cold}}{D_{hot}} - 1\right)\ x\ \left(\frac{P_{reliefvalve} + 9.7}{P_{reliefvalve} - P_{charge} - 5}\right)$$

Where:

- V = Minimum size diaphragm tank in gallons
- V_{system} = Total volume of system in gallons
- D_{cold} = Density of the system water at fill temperature in lbs/ft^3
- D_{hot} = Density of the system water at operating temperature in lbs.ft^3
- $P_{reliefvalve}$ = Boiler relief valve pressure setting in PSIG
- P_{charge} = Pressure in diaphragm tank in PSIG

Expansion Tank Fill Pressure

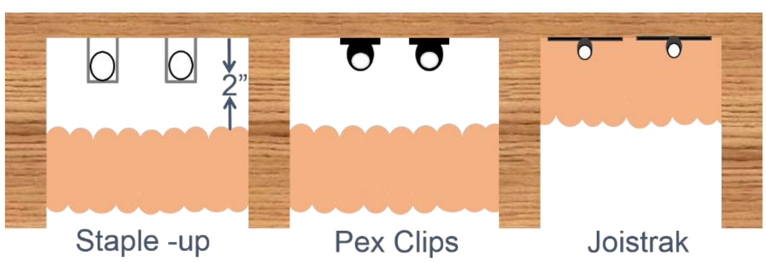
$$P_{charge} = 5 + \left\{(H_{system} - H_{tank})\ x\ \left(\frac{D_{cold}}{144}\right)\right\}$$

Where:

- P_{charge} = Diaphragm charge air pressure in PSIG
- H_{system} = Height from the boiler room floor to the highest system component in feet
- H_{tank} = Height from the boiler room floor to the expansion tank water connection
- D_{cold} = Density of the system water at fill temperature in lbs/ft^3

Insulation

Batt	
Type	R-value/in
Fiberglass	3.0-4.0/in
Blown	
Wool Fiber	4.0-5.0/in
Cellulous	3.2–3.8/in
Spray Foam	
Open-cell polyurethane	3.5-3.6/in
Closed-cell Polyurethane	5.5-6.6/in

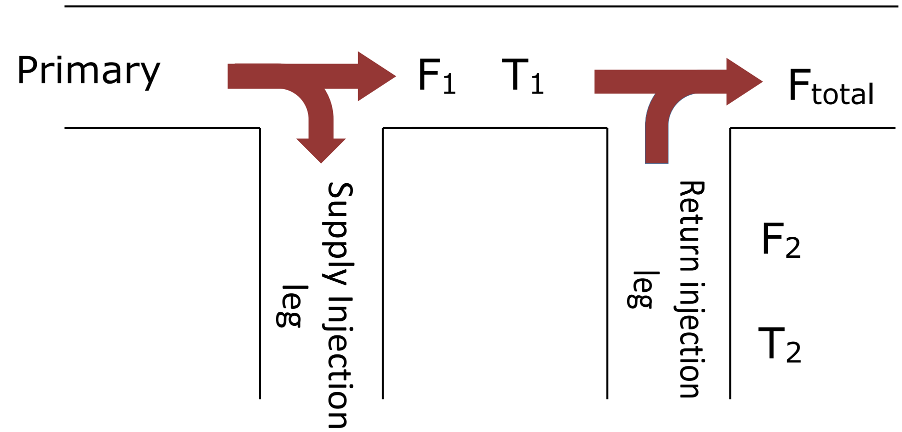


Minimum Insulation R-value

Area below:

- Conditioned space = R-11
- Unconditioned space = R-19
- Exposed crawl space = R-38

To determine water temperature in primary/secondary loops:



F_1 = Primary flow rate after injection leg (gpm)

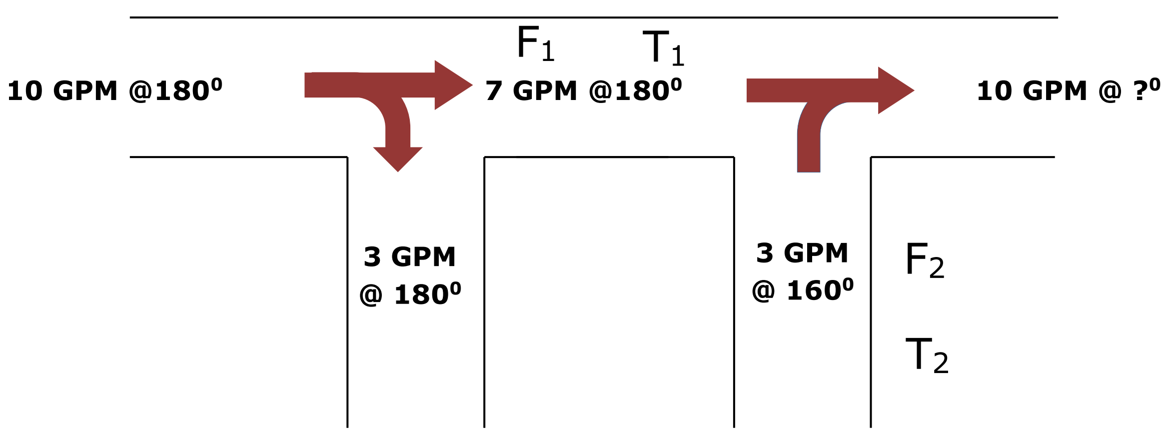
F_2 = Flow rate from return injection leg (gpm)

F_{total} = Primary flow rate after return injection leg (gpm)

T_1 = Primary temperature after injection leg

T_2 = Return temperature of return injection leg

Example: A secondary load requires 3 gpm at 180^0 with a 20^0 $\triangle_T$. The primary loop has 10 gpm @ 180^0. After the injection loop has removed it's Btu load, what will the new water temperature be?



$$\frac{(F_1 \times T_1) + (F_2 \times T_2)}{F_{total}} \qquad \frac{(7 \times 180) + (3 \times 160)}{10} = 174°F$$

To determine Btu’s needed for domestic hot water:

- 1 BTU = Amount of energy needed to raise one pound of water one degree F.
- One gallon of water weighs 8.33 pounds
- Capacity of tank in gallons X 8.33 = weight of water in tank
- Weight of water in tank X required temperature rise = BTU’s needed

Example: a 40 gallon water heater has an incoming temperature of 40^0 and an outgoing temperature of 130^0. How many Btu’s will be required to heat up this tank?

40 x 8.33 = 333.2 x 90 = 29,988 Btu’s

To determine injection flow rate:

Where:

F_I = Required injection flow rate (GPM)

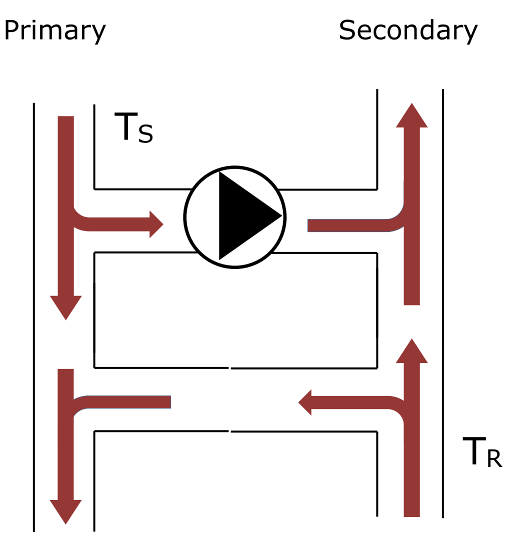
Q = Rate of heat transfer into system (BTU's)

K = Value of fluid used (100% water-500; 30% glycol*-480 40% glycol - 461; 50% glycol-438) *Typical propylene glycol (check with manufacturer)

T_S = Temperature of fluid being injected

T_R = Temperature of the fluid returning from the distribution system

Example: A Basement radiant system requires 30,000 Btu’s. The supply water temp from the boiler is 172^0. The supply water temperature to the secondary zone is 110^0 with a 10^0 $\triangle_T$.



$$F_I = \frac{Q}{K \times (T_S - T_R)}$$

$$F_I = \frac{30{,}000}{490 \times (172 - 100)}$$

$$F_I = .85 \text{ gpm}$$

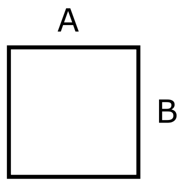
Other Formulas:

Rectangle:

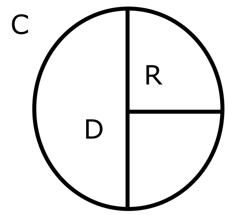
A x B

Square:

A^2



Circle:



Area = πR^2

= .7854 x D^2

= .07958 x C2

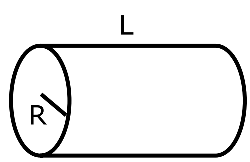
Circumference = πD

= 6.283185 x R

Diameter = C x .31831

Radius = C x .159155

Cylinder:



Volume = πR^2 x L

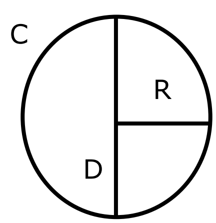
= .7854 x D x L

Area of the outer surface = (6.283 x R2) x 2

Capacity in Gallons = cu. in. / 231

= 7.48 x cu. ft.

Sphere



Surface Area = C x D

= πD^2

= C^2 x .3183

Volume = .5236 x D^2

= 4.1888 x R^3

= .016887 x C^3

Conversions

Area

1 sq. ft = 144 sq. in.

1 acre = 43,560 sq. ft.

Volume

1,728 cu in = 1 cu ft

27 cu ft = 1 cu yd

1 cu ft = 7.48 gallons

231 cu in = 1 gal

Power

1 horsepower = 745.7 watts

1 BTU = 0.293 watt hours

100,000 BTU = 1 therm

3,413 BTU = 1 KWH

Metric Conversion	
km to miles	1 km = 0.62 mi
miles to km	1 mi = 1.62 km
kilograms to lbs	1 kg = 2.2 lb
lbs to kilograms	1 lb = 0.45 kg
meters to feet	1 m = 3.28 ft
feet to meters	1 ft = .30 meters
centimeters to in	1 cm = .39 in
inches to centimeters	1 in = 2.54 cm
millimeter to inches	1 mm = .04 in
inches to millimeter	1 in = 25.4 mm

Feet of Head Conversions

Converting pump head to PSI

- 1 ft/hd **=** .433 PSI

Converting PSI to pump head

- 1 PSI = 2.31 ft/hd

Inches of water column 27.71” w.c. = 1 PSI

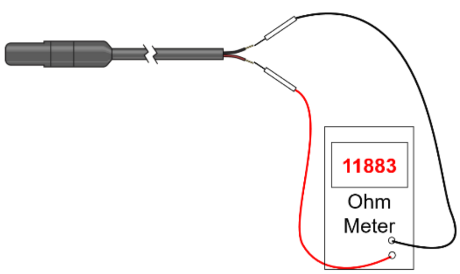
Heating Value of Fuels

Type of Fuel	Heating value in BTU’s	Approximate cost (2017)
Natural Gas	1,000 BTU’s / Ft^3 (1 therm)	$.40 per therm
#2 Fuel Oil	140,000 BTU’s per gallon	$2.10 per gallon
1 KWH	3,413 BTU’s	$.012 per KWH
Propane	2,500 Btu/ Ft^3 or 92,500 Btu/gal	$2.41 per gallon
Methanol	57,000 Btu/gal	
Ethanol	76,000 Btu/gal	

Testing a slab sensor

10K J curve sensor
Max 250’ with 18 AWG wire

At 70°F (21°C) room temperature, the ohmmeter should read ≈ 11,900 ohms (11.9K Ω) +/- .1%



Temperature		Resistance	Temperature		Resistance
°F	°C	Ω	°F	°C	Ω
-50	-46	490,813	90	32	7,334
-45	-43	405,710	95	35	6,532
-40	-40	336,606	100	38	5,828
-35	-37	280,279	105	41	5,210
-30	-34	234,196	110	43	4,665
-25	-32	196,358	115	46	4,184
-20	-29	165,180	120	49	3,760
-15	-26	139,402	125	52	3,383
-10	-23	118,018	130	54	3,050
-5	-21	100,221	135	57	2,754
0	-18	85,362	140	60	2,490
5	-15	72,918	145	63	2,255
10	-12	62,465	150	66	2,045
15	-9	53,658	155	68	1,857
20	-7	46,218	160	71	1,689
25	-4	39,913	165	74	1,538
30	-1	34,558	170	77	1,403
35	2	29,996	175	79	1,281
40	4	26,099	180	82	1,172
45	7	22,763	185	85	1,073
50	10	19,900	190	88	983
55	13	17,436	195	91	903
60	16	15,311	200	93	829
65	18	13,474	205	96	763
70	21	11,883	210	99	703
75	24	10,501	215	102	648
80	27	9,299	220	104	598
85	29	8,250	225	107	553

Placement of slab sensor