1. Problem Statement:

Calculate the heating requirements of the 190,000 gallon exterior pool shown below. Dimension X is unknown but the pool length and approximate depths are know. Determine if 45 swimmers exercising for two hours will produce sufficient heat to negate the requirement of a pool heater(s).

Assumptions

- the pool is uncovered from 5 AM until 7 PM daily
- the pool cover from 7 PM to 5 AM is a 3" fiber insulating board (k = 0.028)
- the pool walls/bottom are uninsulated 8" concrete
- the pool is steady at 81 deg F

2. Solution technique:

A) Calculate the pool width (dimension X)
B) Calculate the wall, bottom, and surface areas
C) Calculate the heat flow (loss) through the pool bottom and sides/hour
D) Calculate the heat flow (loss) through the surface/hour
E) Calculate the heat flow (loss) through the pool cover/hour
F) Compute the total heat flow (per 24 hour cycle)
G) Calculate the heat generated by 45 swimmers for 2 hours.

Then... Analyze the computations and draw a conclusion

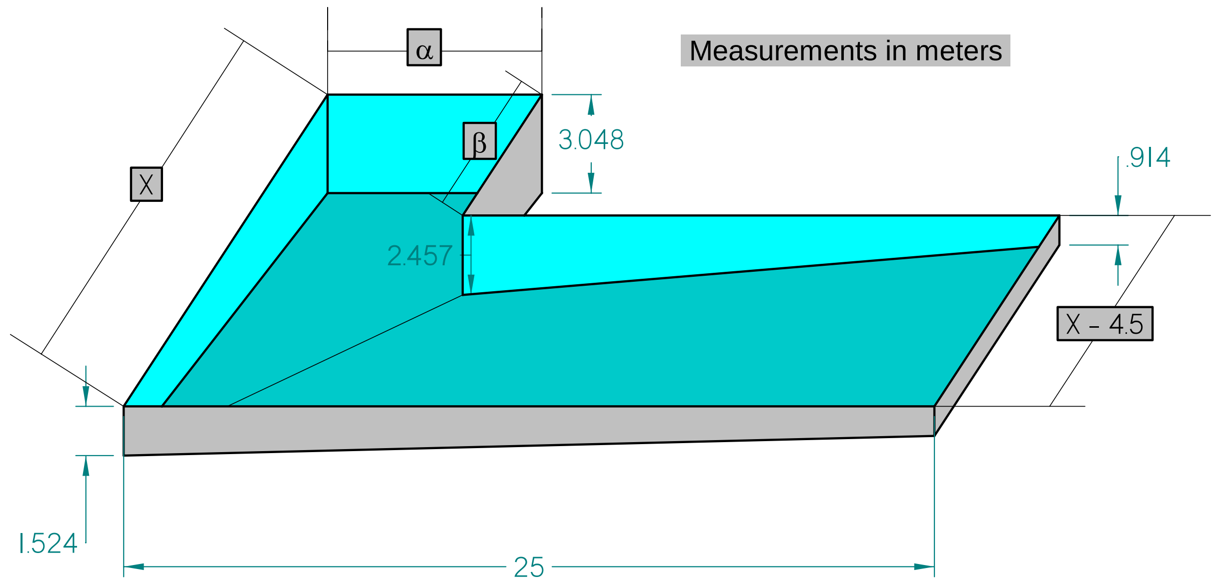
A) Calculate the pool width (dimension X) for the pool shown below assuming:

$\alpha := 6.6 \cdot m$ $\beta := 4.5 \cdot m$

$Vol := 190000 \cdot gal$

or

$Vol = 25399\ ft^3$



Calculate the width (X) using known and estimated dimensions:

$$Vol = x \cdot (\alpha) \cdot \left(\frac{3.048 \cdot m + 1.524 \cdot m}{2} \right) + \left(\frac{1.363 \cdot m + 2.457 \cdot m}{2} \right) \cdot (25 \cdot m - 6.6 \cdot m) \cdot (x - \beta)$$

solving for X: $x := 7.963 \cdot 10^{-5} \cdot \frac{250. \cdot Vol + 39537. \cdot m^3}{m^2}$ $x = 57.304\ ft$ or $x = 17.466\ m$

B) Calculate wall and wall / surface areas

Area walls $A_{walls} := 30.480 \cdot m^2 + x \cdot \left(\frac{10 \cdot ft + 5 \cdot ft}{2}\right) + (10 \cdot ft \cdot \alpha) + \beta \cdot \left(\frac{3.048 \cdot m + 2.457 \cdot m}{2}\right) + 30.742 \cdot m^2 + x \cdot 3 \cdot ft$ $A_{walls} = 1610.5\, ft^2$

Area top $A_{surface} := x \cdot \alpha + (x - \beta) \cdot (25 \cdot m - \alpha)$ $A_{surface} = 3808.9\, ft^2$

Area bottom (approximate) $A_{bottom} := A_{surface} \cdot 1.1$ $A_{bottom} = 4189.8\, ft^2$

Surface ground temperatures in Summer.

C) Calculate the heat flow (loss) through the pool bottom and sides

Assume water maintained at constant: $t_{water} = 81F$ $t_{water} = 27.22 \cdot C$

Assume exterior of 8" thick concrete walls / floor maintained at 55 deg F (below 4 ft, maintains a constant 50-55 deg F). *[http://www.alliantenergygeothermal.com/stellent2/groups/public/documents/pub/geo_how_001211.hcsp]*

Heat transfer (conduction) through walls & bottom using Fourier's Law for 1-D steady state system.

$q_w = -k \cdot A_w \cdot \left(\frac{\Delta T}{\Delta x}\right)$ $q_w = -.8 \cdot \left(\frac{BTU}{hr \cdot ft \cdot F}\right) \cdot (1610.5 + 4189.8) \cdot \left(ft^2\right) \cdot \frac{-26 \cdot F}{0.667 \cdot ft} = 180879 \cdot \frac{BTU}{hr}$

Heat loss (q_w) due to sides and bottom = 180879 BTU/hr

where: $k = .8 \cdot \left(\frac{BTU}{hr \cdot ft \cdot F}\right)$ $\frac{8}{12} = 0.667$ $\Delta T := 55 - 81$ $\Delta T = -26$

D) Calculate the heat flow (loss) through the pool surface ($h_{surface}$)

$h_{surface}$ = heat loss through surface - mainly evaporation of water from the surface (btu./hr.)

[http://www.engineeringtoolbox.com/swimming-pool-heating-38_878.html]

Using: $k_s := 5$

$\Delta T_{surface} := (81 - 72)$

$A := 3808.9$

The heat load necessary to cover up the surface loss can be expressed as

hsurface = $(k_s)*(dT_{aw})*(A)$ where

k_s = surface heat loss factor - for sheltered positions with average wind velocity 2 to 5 (mph), the surface heat loss factor is in the range 4 to 7 (btu/hr. sq.ft. oF)

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dT_{aw} = temperature difference between the air and surface water in the pool (oF)

A = surface area of the pool (sq.ft.)

$$h_{surface} = k_s \cdot \left(\frac{BTU}{hr \cdot ft^2 \cdot degF}\right) \cdot \Delta T_{surface} \cdot (degF) \cdot A \cdot \left(ft^2\right)$$

$$h_{surface} := k_s \cdot \Delta T_{surface} \cdot A$$

$$h_{surface} = 171401 \quad \frac{BTU}{hr}$$

E) compute the heat flow (loss) through the 3" fiberboard pool cover

$$q_b = -k \cdot A_w \cdot \left(\frac{\Delta T}{\Delta x}\right) \qquad q_b = -0.028 \cdot \left(\frac{BTU}{hr \cdot ft \cdot F}\right) \cdot (3809) \cdot \left(ft^2\right) \cdot \frac{-25 \cdot F}{0.25 \cdot ft} = 10665 \cdot \frac{BTU}{hr}$$

Heat loss (q_b) due to pool cover = 10665 BTU/hr

where: $k = 0.028 \cdot \left(\frac{BTU}{hr \cdot ft \cdot F}\right)$ $\quad \frac{3}{12} = 0.25$ $\quad \Delta T := 56 - 81$ $\quad \Delta T = -25$ $\quad A_{surface} = 3809\,ft^2$

F) Compute the total heat flow (per 24 hour cycle)

Heat loss through walls / floor over 24 hours: $h_1 := 180879 \cdot \frac{BTU}{hr} \cdot 24 \cdot hr$ $h_1 = 4341096\,BTU$

Heat loss through uncovered pool surface for 14 hours: $h_2 := 171401 \cdot \frac{BTU}{hr} \cdot 14 \cdot hr$ $h_2 = 2399614\,BTU$

Heat loss through pool cover for 10 hours: $h_3 := 10665 \cdot \frac{BTU}{hr} \cdot 10 \cdot hr$ $h_3 = 106650\,BTU$

Heat loss total: $h_t := h_1 + h_2 + h_3$ $h_t = 6847360\,BTU$ (about 7 million BTU / 24 hours)

$h_{avg} := \frac{h_t}{24 \cdot hr}$ $h_{avg} = 285307\,\frac{BTU}{hr}$

A suggested heater (see the manufacturer for exact sizing):

Teledyne Laars Jandy Mighty Therm Pool Heater
Model AP - energy efficient, compact pool heaters are designed for commercial, institutional and large residential pools where economical performance and rapid heat-up are needed.

Available in twenty-one sizes to precisely match any heating requirement, the Mighty Therm is sized from 500,000 to **5,000,000 BTU (per hour)** input indoor and outdoor models.

[*http://www.swimmingpoolsetc.com/mightytherm.htm]*

G) Calculate the heat generated by 45 swimmers for 2 hours (and assuming all energy to transferred to the pool water).

Assume 2000 kilo calories spent per swimmer during 2 hours $Swim_{energy} := 2000 \cdot dcal$ $Swim_{energy} = 7934\,BTU$

Using 45 swimmers (for 2 hours every 24 hours) $h_{gen} := 45 \cdot Swim_{energy}$ $h_{gen} = 357038\,BTU$

From http://www.umm.edu/ency/article/002457.htm
The energy stored in food is measured in terms of "calories".
Technically, one calorie is the amount of energy required to raise the temperature of 1 gram of water 1 degree Centigrade (from 14.5 to 15.5). The "calorie" measure used commonly to discuss the energy content of food is actually a kilocalorie or 1000 real calories; this is the amount of energy required to raise one kilogram of water (about 2.2 pounds) one degree Centigrade.

3. Analysis: The daily heat loss from the pool is over 7 million BTU (about 285,307 BTU/hr average). The heat generated by the swimmers and transferred to the pool water each 24 hour period is at most 357,000 BTU. **The swimmers will provide only about 6% of the energy lost daily by the pool.**

4. Conclusion: The swimmers cannot be used to adequately heat the pool.