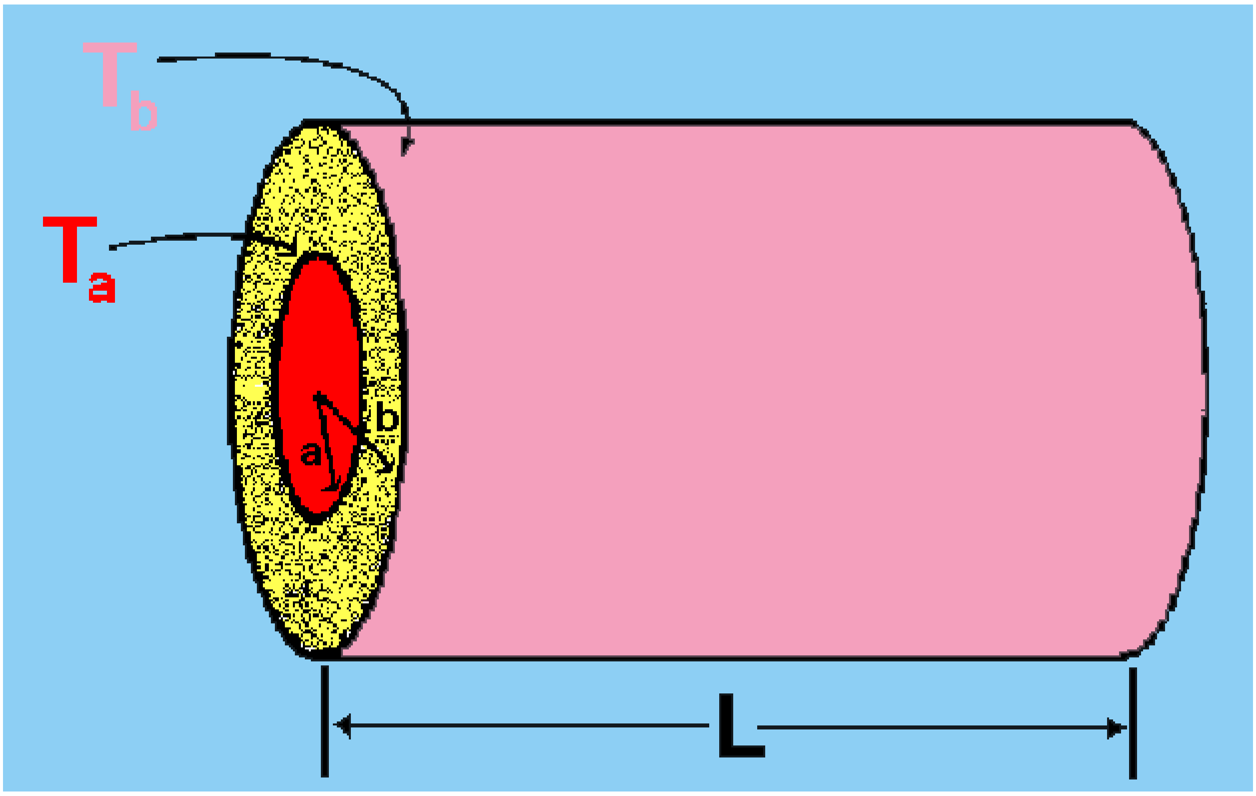
Cost-Efficient Steam Pipe Insulation



- a = Outer radius of steam pipe (m).
- b = Outer radius of pipe insulation (m).
- Ta = Temperature of pipe surface (C).
- Tb = Temperature outer surface of insulation (C).
- Tair = Air temperature (C).

When deciding on the amount of insulation to be installed on a long steam supply line, the amount of money to be saved from lower fuel bills must be compared with the initial insulation purchase and installation costs; that, is excessive insulation can be just as wasteful as too little. This problem will allow you to determine the thickness of the insulation that will give the greatest savings for the least cost.

The heat through the insulation is given by:

Q1 = 2pkL [(Ta - Tb)/(ln(b/a)] (watts) Equation 1

while the heat transfer from the insulation to the air is given approximately by

Q2 = 2pbF(Ta - Tair)L (watts) Equation 2

Where

- k = Thermal conductivity of the insulation = 0.1 watts/(m C)
- F = Convection coefficient for the air-insulation interface = 3.0 watts/(m2 C)

In a steady-state situation Q1 = Q2 , so that Tb can be eliminated from Equations 1 an 2, and by combining the two equation we obtain

Q = [(2pbkFL) / (k + bFln(b/a))](Ta - Tair) Equation 3

Now for the costs. The pipe insulation costs $325.00 per cubic meter (Cvol = 325.00) and the insulation costs amount to $1.50 per meter of pipe (CL = 1.50), independent of thickness. The cost of heat is 0.4 cents per kilowatt-hour or $1.11 * 10-9 per watt-sec (Cheat = 1.11 * 10-9). Assuming a pipe of length L, the volume of the insulation is p(b2 - a2)L and the total cost is

Cinsul = p(b2 - a2)LCvol + LCL Equation 4

To obtain the amount of fuel savings we need the difference between the heat loss with no insulation, i.e.,

Q3 = 2paF(Ta - Tair)L Equation 5

and the heat loss with insulation (Equation 3), i.e., dQ = Q3 - Q, or

dQ = Q3{1 - [b/a] / [1 + (bF/k)ln(b/a)]} Equation 6

The fuel savings over a 5-year period (1.578 * 108 sec) is then

C2 = dQ(1.578 * 108) Cheat Equation 7

The outer radius of the pipe is 5 cm (a = 0.05) and insulation is available in thicknesses t ranging from 1 to 10 cm in 1-cm steps (i.e., b = a + t, t =1, 2, . . . 10 cm). For air temperatures of Tair = -10 C and +10 C, determine the most cost-effective thickness of insulation.

Thickness of Insulation

- Start with the insulation thickness, T = 0.01 and calculate the total cost of insulation (Equation 4), and the dollar savings over five years (Equation 7). Print these quantities as one line in the table. (Be sure to convert CH to cost per watt-second.)
- Increment the thickness by 0.01 (T = T + 0.01), and if T <= to 0.10 go to step D and repeat the calculation.
- When T > 0.10 the above IF test fails and the program should then go to step B and read a second value for the air temperature (+10.00 C). The remaining parameters stay the same.
- Add a run counter (RUN) to the program that is incremented after each complete set of calculations.
- The program should STOP if RUN > 2.
- By inspecting the printout from the program, determine the most cost-effective insulation thickness for each of the two air temperatures. Indicate this optimum thickness in pencil on the output.

Reference:

http://www.personal.psu.edu/faculty/c/w/cwf/cs201/insul.htm