Thermal Systems Design – Design Project 2
ME5810/6810
Fall 2008
Due Tuesday November, 18 2008

Designing for the Optimum Economic Insulation Thickness using a Least Annual Cost Analysis

Consider the design of a small building that will be used to store frozen produce. A technical analysis of the problem indicates that there is no optimum insulation thickness in the ceiling, floors and walls of the building. Thicker insulation will generally result in less heat loss. The effect of adding additional insulation decreases as the total thickness increases, but in general more insulation is always better when only heat loss is considered (recall the exception for thin layers of insulation on pipes). When economic aspects are included, however there will be an optimum thickness which corresponds to minimum cost. Thicker insulation results in reduced heat loss and less costly refrigeration equipment and lower electrical cost; however, the insulation is more expensive to purchase and install. The optimum thickness will depend on economic factors as well as technical aspects.

Design Problem

A refrigerated warehouse is to be maintained at -18^{o}C, while the outside design temperature is 35 ^{o}C. Insulation board is available in the following thicknesses: 50 mm, 75 mm, 100 mm and 125 mm. More than one layer of insulation can be installed if thickness greater than 125 mm is desired. Properties of the insulation board include: k = 0.03 W/m-K, ρ = 70 kg/m^3, C_p = 1045 J/kg-K. The electric power required by the refrigeration equipment is 0.6 kW for each kW of heat removed from the cold space.

Cost of the insulation is \$0.10/m^2 per mm of thickness. Installing the insulation costs \$5.00/m^2 for the first layer and \$3.00/m^2 for each additional layer. Capital costs of the refrigeration machinery is estimated at \$1000/kW of refrigeration capacity. Expected life of the project is 15 years. Both the interest rate and electric rate may vary. An appropriate range for the interest rate is 6-12%, while for the electric rate it is \$0.05-0.12 per kW-h. Assume the cost of electricity is paid at the end of each operating year.

Develop a model for this problem using EES. Carry out the analysis and determine the optimum insulation thickness for the range of electric rates and interest rates. Report your results in a short technical memo. Include your EES code as well as any appropriate plots describing your results in an appendix. Be sure to provide a thorough discussion of the results as well as a description of your solution method and all assumptions.