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CHE 3326: Heat Transfer

Fall 2023 Final Project

PART A:

Output for part a:

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Fluid temperature = 1100 F | Pipe OD = 20 in | Insulation thickness 2 in | Jacket emissivity = 0.09 | Outer temperature = 285.85 F

Fluid temperature = 1100 F | Pipe OD = 20 in | Insulation thickness 2 in | Jacket emissivity = 0.9 | Outer temperature = 192.18 F
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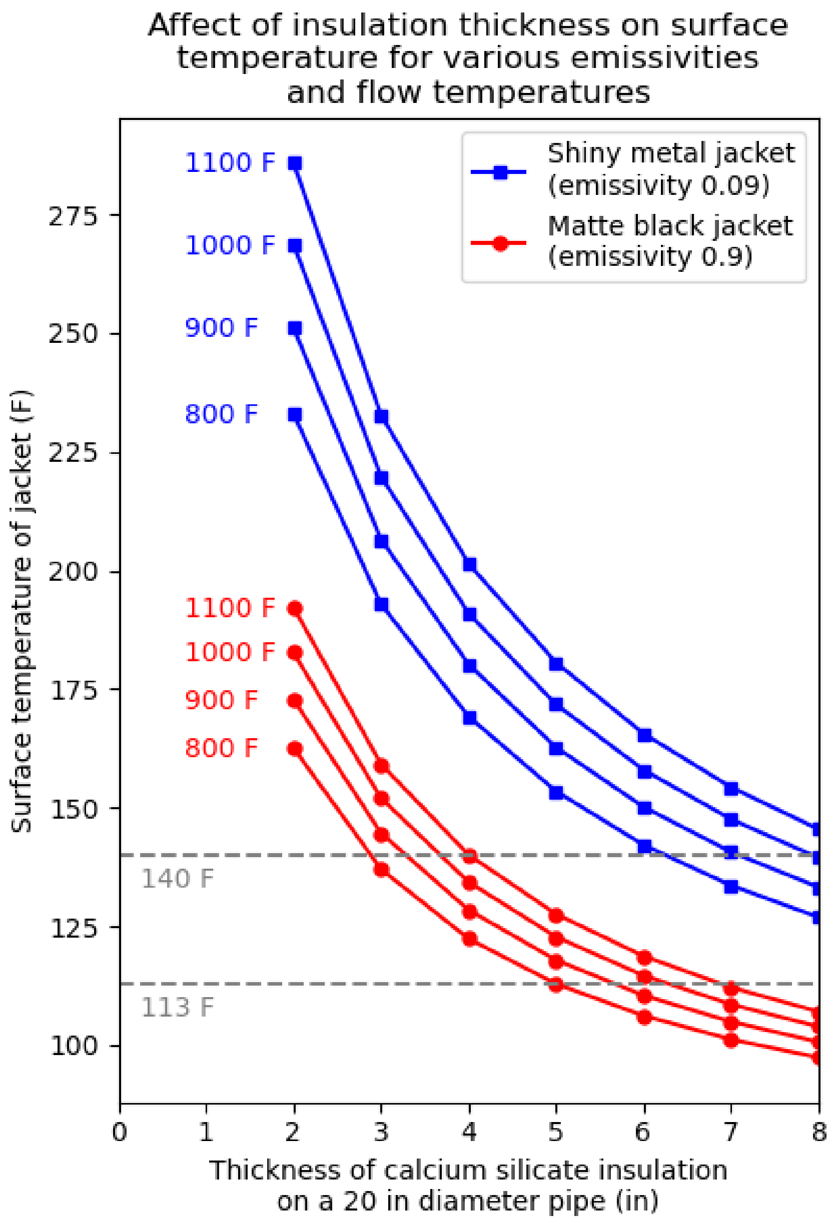
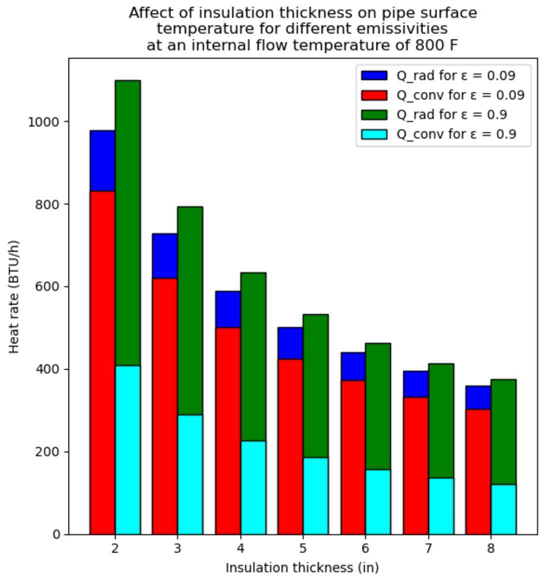
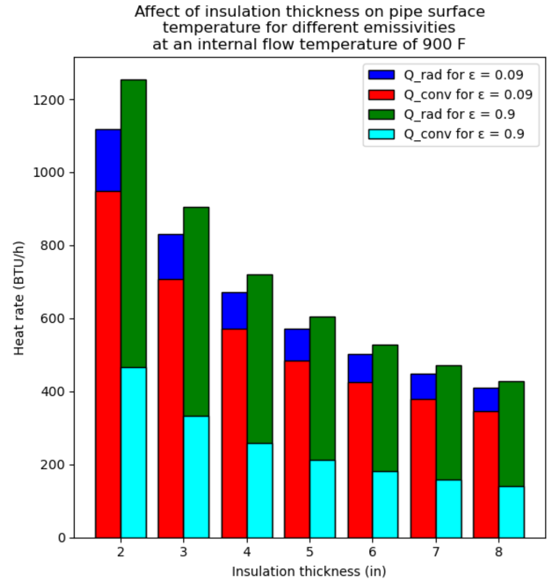
PART B:

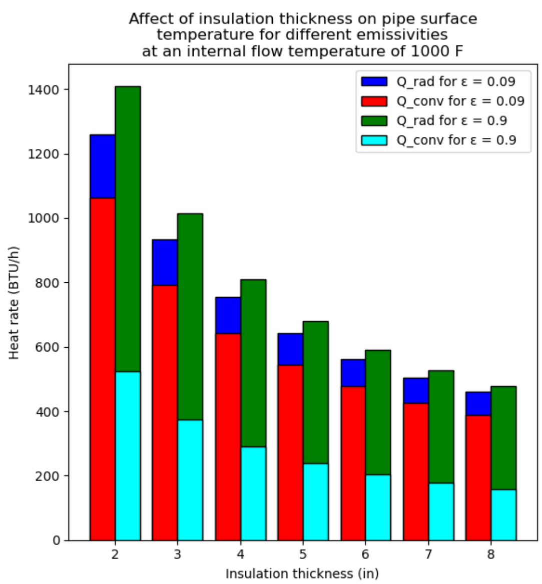


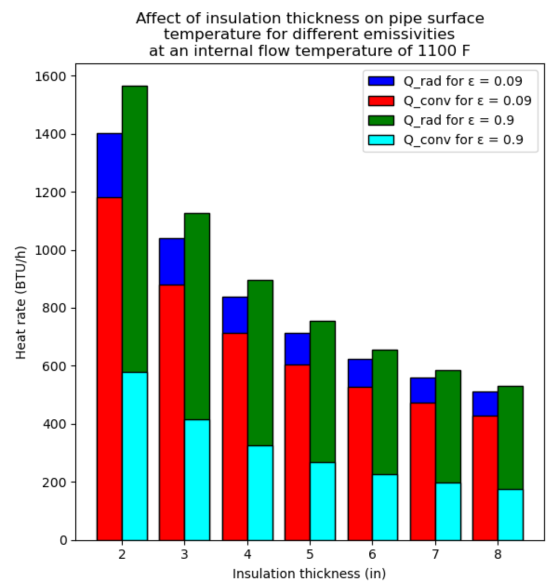
Affect of insulation thickness on surface temperature for various emissivities and flow temperatures
Shiny metal jacket (emissivity 0.09)
Matte black jacket (emissivity 0.9)
1100 F
1000 F
900 F
800 F
1100 F
1000 F
900 F
800 F
140 F
113 F
Surface temperature of jacket (F)
100
125
150
175
200
225
250
275
0
1
2
3
4
5
6
7
8
Thickness of calcium silicate insulation on a 20 in diameter pipe (in)

PART C:


Affect of insulation thickness on pipe surface temperature for different emissivities at an internal flow temperature of 800 F
Q_rad for ε = 0.09
Q_conv for ε = 0.09
Q_rad for ε = 0.9
Q_conv for ε = 0.9
Heat rate (BTU/h)
Insulation thickness (in)


Affect of insulation thickness on pipe surface temperature for different emissivities at an internal flow temperature of 900 F
Q_rad for ε = 0.09
Q_conv for ε = 0.09
Q_rad for ε = 0.9
Q_conv for ε = 0.9
Heat rate (BTU/h)
Insulation thickness (in)


Affect of insulation thickness on pipe surface temperature for different emissivities at an internal flow temperature of 1000 F
Q_rad for ε = 0.09
Q_conv for ε = 0.09
Q_rad for ε = 0.9
Q_conv for ε = 0.9
Heat rate (BTU/h)
Insulation thickness (in)


Affect of insulation thickness on pipe surface temperature for different emissivities at an internal flow temperature of 1100 F
Q_rad for ε = 0.09
Q_conv for ε = 0.09
Q_rad for ε = 0.9
Q_conv for ε = 0.9
Heat rate (BTU/h)
Insulation thickness (in)

PART D:

As the thickness of insulation increases, what happens to the surface temperature?

The surface temperature decreases as the thickness of insulation increases.

As the jacket emissivity increases from 0.09 to 0.9, what is the effect on surface temperature and total rate of heat loss? How does this effect tie into selection of appropriate jacket types for safety and proper balance of economics of running a plant?

As jacket emissivity increases, this causes increased heat flux due to radiation, causing increased heat flow to the surroundings and thus a lower surface temperature.

This effect can help with selection for appropriate jacket types, as it is important to ensure that pipe surfaces are safe in the event of incidental skin contact. It is important to choose a jacket with high emissivity to lower the surface temperature and ensure that the outer surface of the pipe is within the safe temperature range for that material. In terms of economics, providing increased insulation and selecting a proper jacket may cost a little more than simply allowing an unsafe pipe to exist, however, safety should be a priority, and preventing personal injury is always a reason to spend a little more on process safety. In addition, adding proper amounts of insulation decreases the heat loss due to conduction, meaning that the process fluid inside the pipe retains heat better, which may be important for a process further down the line, and, for some processes, possibly saving money.

As the jacket emissivity increases from 0.09 to 0.9, what change does it produce on the relative contribution of heat loss by radiation and convection towards the total heat loss? Make an argument to explain this observation.

As jacket emissivity increases, the share of heat loss by radiation is increased, and the share of heat loss by convection is decreased, and the overall heat loss is slightly increased as well.

As the process fluid within the pipe loses heat, it loses heat by conduction first. Mathematically, the amount of heat loss by conduction depends only on the thermal conductivity of the pipe and insulation (in this case, only the insulation), the inner and outer temperatures, and the inner and outer diameters. Overall, it is based on the amount of material the heat must be conducted through and the thermal conductivity of that material. Then, as the heat conducts *out towards the outer layer of the pipe material, the heat is diffused to the environment in two different ways: convection and radiation. Heat loss by radiation is primarily affected by changes in ε (emissivity) of the outer material. Thus, by increasing ε, the heat loss by radiation is increased. Therefore, the heat loss by convection is decreased. Convection will always play a role in releasing heat to the environment in this case, but a lesser role when ε is increased. This explains why the heat loss by radiation increases as heat loss by convection decreases, but it doesn't explain why the total amount of heat loss is higher with a material of higher emissivity.*

Changing the color and increasing the emissivity of the jacket means that the jacket with higher emissivity is able to emit and absorb energy at more wavelengths than the jacket with the lower emissivity. This increases the total amount of energy that is possible to dissipate through radiation. This explains why, in this case, the jacket with higher emissivity facilitates larger amounts of heat transfer than the jacket with lower emissivity.