Open Ended Problem #10

Nuclear Emergency

Group Work Okay, Due 12/13/2023 at beginning of class
(Don't be afraid to "Google" for reasonable assumptions; just provide references!)

The year is 2040, and we have got some serious problems! A foreign country has infected your local light water nuclear reactor with their version of a Stuxnet worm. Unlike Stuxnet however, this virus targets the reactor cooling and reactivity control systems, resulting in a slow heat-up and eventual meltdown of the fuel. Thankfully, you, as a successful chemical engineer with expertise in material science, are available to help! The reactor manager is interested in placing some type of shell around the containment building dome, which could prevent the release of radionuclides to the nearby town in which you and many others live as a result of the meltdown accident. In order for this to work, the shell should not fail at an internal pressure of 500 psia, and a temperature of 400 °C. Further, it should be able to conduct 30 MW of heat from the inside of the shell to the outside, so as to prevent further core damage. Finally, this shell should be made of a material that will be able to be machined into the desired dome shape. Alternatively, the manager is willing to consider a smaller shield constructed directly around the pressure vessel of the reactor. In this case, the material should be able to resist a pressure of 2500 psi and a temperature of 700 °C. The conduction requirement for this shield is the same as for the larger shield dome. However, none of the alloying components in this shield should be smaller in atomic number than 9, so as to avoid neutron activation in the material. Pick a material and configuration that will allow you to protect the public from the effects of this disaster.

1) What is this problem actually asking for? What is the final value you are being asked to find?

2) Draw a sketch that indicates the actual problem.

3) a) What physical laws apply to this problem?
b) Indicate equations, correlations, and/or formulae that can model these laws.
c) What are the potential limitations of these equations?

4) What assumptions should be made to utilize the equations/correlations/formulae listed in part 3b?

a) List ALL the assumptions that you need to in order to solve the problem.

b) Justify your assumptions (**references**, reasoning, judgment, common sense, etc.)

5) What are the physical properties (list assumed or referenced values) used in this problem?

6) What type of material and configuration should be used in this problem?

a) Select a material that has the appropriate thermal conductivity, and yield strength, and neutron absorption properties for this problem.
b) What thickness is required to provide the necessary protection?

c) Repeat this problem for both the vessel shield and the containment shield.
d) Select between the two shield designs based on performance, shape, cost, and machinability of your material.

7) Verify your answer... Does it look reasonable? Anything odd about the calculation?
    1) For the material selected, what is the cost for each configuration? Is this a reasonable cost?
    2) Does this solution (your material shield) have any impact on:
        (i) public health, (i.e. state of well being of people in both physiological and psychological senses)
        (ii) public safety, (i.e. the mitigation of hazards through risk analysis; prevention of physical harm to people from unit, process or plant operations)
        (iii) or public welfare? (i.e. the provision of the basic needs of people)
    3) With the use of your proposed solution, are there any significant impacts:
        (i) Globally? (i.e. consideration of connectivity and being part of a worldwide community, or general improvement of infrastructure and quality of life)
        (ii) Socially? (i.e. issues that affect interpersonal interactions, human/human relationships etc.)
        (iii) Culturally? (i.e. characteristics and knowledge of a particular group of people and their values, encompassing customs, traditions, language, religion, cuisine, music, arts, holidays, worldview, and outlook, etc.)
        (iv) Are there any significant impacts of not using any solution?
    4) What are the environmental impacts (i.e. protection of local and global ecosystems) of using your solution? Are they more or less severe than the impacts of not using any shield for this scenario?
    5) What kind of economic impacts should be considered for your solution? What are the economic impacts of NOT providing a solution?
    6) Based on all of the above factors, give a final decision as to whether your solution should be employed.