

Thermal Design Project: Temperature-Controlled Shipping Unit

Your company has identified a potential market for a temperature-controlled unit for shipping biospecimens between hospitals and laboratories, and has launched an R&D effort to develop an early prototype for this product. Your company plans the prototype development is in two phases: cooling system development and developing an automated control for the cooling system. The first development phase is assigned to your thermal-design team, subject to the conditions and constraints specified below. Your task is to provide an initial design for the cooling system in order to fabricate an early prototype for testing.

1. Design objectives:
 - a. To identify environmental conditions for product operation.
 - b. To provide a detailed design of the cooling unit.
 - c. To provide drawings for manufactured parts of the unit.
 - d. To identify and provide specs of off-the-shelf parts to be purchased and integrated into the system,
 - e. To provide cost estimation for the prototype (not the cost estimations for the mass-production units).
 - f. To map the thermal conditions under which the cooling system is likely to meet the required operational conditions.
 - g. To provide guidelines on how to integrate a automated temperature-control mechanism.

2. Specific requirements:
 - a. World-wide distribution.
 - b. The inner shape of the cooling chamber is cylindrical, having a height of 10 cm and diameter of 5 cm.
 - c. The system should be capable of maintaining a constant temperature T_{set} for a period of at least 12 hours, where T_{set} varies between the teams of the thermal design class: $+4^{\circ}\text{C}$, -20°C , -70°C , -120°C
 - d. The cooling chamber should reach T_{set} within 10 minutes.
 - e. T_{set} is measured at the inner surface of the wall of the cooling chamber.

- f. The system should be able to function in a closed, parked car, during the summer. The car should not be modified.
- g. System power consumption should not exceed 12 V and 6 Amps (a regular car battery).
- h. The unit should be designed for minimum size.
- i. The unit should be designed for minimum weight.
- j. Emphasis should be given to quick and easy cooling chamber loading/unloading.

3. Design constraints:

- a. The cooling mechanism must not be based on a refrigeration cycle.
- b. For the purpose of this phase of development, you have a budget of 40 hours per team member of your thermal design group.