Instituto Superior de Engenharia do Porto

Lab Project III (LAPR3)

FSIAP – Physics Component

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Group 1 | Class 2DF

1130872 – Rui Costa
1201518 – Ana Albergaria
1201592 – Marta Ribeiro
1200049 – João Wolff
1201284 – Diogo Violante

Professor

João Lopes

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1. Introduction

For the class of LAPR3, on the Physics component, the group had to elaborate a report detailing some information relevant to the integrative project (**US416**) that complements the document elaborated on the previous iteration.

This project consists of a cargo shipment company who needs to calculate the thermal resistance of its shipment containers, as well as the materials to be used, among other details.

The present document aims to provide the reader with all the information about the new iteration of the project, such as the necessary energy of each container, of each type, given the exterior temperature and travel time.

1.1 Contextualization

The **US416** of the integrative project states the following:

As ship's master I intend to submit a summary document, with the following items.
Acceptance criteria:
- Present in a document (summary)(pdf), the necessary energy of each container, of each type (internal temperatures), with an external temperature of 20 ºC, and a travel time of 2h30.
- Present in a summary document, pdf, the total energy to supply, to the set of containers, in an established trip, assuming that all containers have the same behaviour.
- Present in a summary document, pdf, the energy to supply to the container load, in one trip (or route), as a function of the position of the containers on the vessel, and of the interior temperature of the two types of containers considered.
- Present in a summary document, pdf, the number of generators required for the voyage, or sectors of the trip.

This means that a shipment/trip consists of multiple, stacked, containers, and we must calculate the total energy supply needed to keep the containers at the required internal temperature during an entire trip.

Given the way the containers are stored during the voyage, part of our work consisted in determining what surface area of the containers was exposed to the exterior and what area was not exposed (either touching the ground or other containers). This is because we must assume the exterior temperature affects the "external" exposed area in a way and the non-exposed area in another way.

The following sections describe the User Stories required on the current iteration of the project, that are relevant to the calculations and information presented on US416.

2. US412 – Necessary Energy Supply

On US412, we were required to calculate the necessary energy supply for each container, of each type. Each trip is assumed to be 2h30m long, at an external temperature of 20ºC. We also assume there are 40 containers on the trip, with all the sides fully exposed.

For context, there are two types of containers:

- 25 containers with an interior temperature of 7ºC. The walls are made of 3 layers, a 0.003m layer of iron (k=55), a 0.09m layer of rock wool (k=0.045) and a 0.007m layer of wood (k=0.13).
- 15 containers with an interior temperature of -5ºC. The walls are made of 3 layers as well, a 0.003m layer of iron (k=55), a 0.09m layer of phenolic foam (k=0.023) and a 0.007m layer of cork (k=0.038).

For the 7ºC containers, we obtained an energy of 4129946.4978 J/s.

For the -5ºC containers, we obtained an energy of 3981272.0474 J/s.

After multiplying the values, we determined that the total energy supply required is 162.9677 MJ/s.

These values were obtained using the following formulas:

$$Q = \frac{\Delta q}{\Delta t} = \frac{\Delta(T_1 - T_2)}{R_t}$$

Rt = r1 + r2 + r3, with R = thickness/(KxA)

3. US413 – Necessary Energy Supply given multiple sections on a trip

On a trip with two sections of 1h30m and 1h45m, and an external temperature of 20ºC and 28ºC respectively, using the same 40 containers described on the previous section of this document, we determined that a total of 268.6309 MJ/s were required for the trip.

On US413, we used the same formulas as US412, but adapted to calculate the energy twice, once for each section of the trip. Afterwards, we calculated the sum of both in terms of energy and multiplied the time for each section with the external temperature during that section.

4. US414 – Necessary Energy Supply accounting the exposed sides of the containers

US414 differs from US413 in the fact that the energy calculated varies depending on which sides of the containers are exposed to the exterior temperature. This means that, to calculate the energy, we must know/identify which sides of the containers are exposed to the "sun" and which sides are facing other containers.

For this User Story, we used the same set of containers, times, and temperatures of the US413, but we had to identify which sides of the containers were exposed. Since we have 40 containers with a dimension of 2.5m x 2.5m x 6m, laid out in a 5 x 2 x 4 disposition, resulting in:

- 8 containers with sides ab + bc exposed, which we designated as type 0
- 4 containers with sides ab + bc + ac exposed, designated as type 1
- 8 containers with sides ab, designated as type 2
- 20 containers with sides bc, designated as type 3

With this data, we can calculate the energy for the first part of the trip by using the full area of the containers. But on the second part of the trip, the new temperature only affects the exposed sides of the containers, so we must calculate separate values of energy for the external area at 28ºC, and the non-exposed part still as 20ºC.

This led to us to a total of 225.0765 MJ/s required for a trip.

For context, this is 43.5544 million J/s less than the energy we needed for the same trip without considering the "protected" and exposed sides of the containers.

5. US415 – Auxiliary Power Equipment

This User Story is defined as knowing how many auxiliary power equipment are needed for the trip, knowing that each generator supplies a maximum of 75 KW.

Now, using the same data as US412 (2h30m trip; 20ºC external temperature), we have a total consumption of 162.9677 MJ/s. Since this refers to the total energy/work, we can simply divide this number (162.9677 MJ/s) by 9000 (number of seconds in a 2h30m trip), leading us to a total of 18KW needed for these containers. This means that only one 75KW generator unit should be enough to power a single trip.