Graphical user interface

Description automatically generated

Thickness of box walls: **0.05 m** (L)

Pallet size: 1.5 x 1.2 x 1.1m

Box Top & bottom: 1150 x 2600 = 2.99m2

Box Sides: 1150 x 1700 = 1.955 m2

Box Front & back: 2600 x 1700 = 4.42 m2

Total box internal surface area = (2.99+1.955+4.42) x 2 = **18.73 m2**

Latent heat of vaporization of liquid nitrogen: **1.992 × 105 J/kg**

Specific Heat Capacity of Gaseous Nitrogen: **1040 J/kg.K**

Thermal conductivity of extruded polystyrene: **0.025W/m∙K (k)**

Diagram

Description automatically generated

**Assuming ambient temp = 25°C (T2)**

**Temp inside box = -20****°C (T1)**

Rate of heat flow **Q = -k\*(T1-T2)/L**

= -0.025\*(-20-25)/0.05

= 22.5W/m2

Box Heat Flow Wattage = 22.5 \* 18.73 = **421W**

Heat to vaporize 1kg of liquid N2 and bring gas temp up from -196**°C** to -20**°C (176°C difference)** = 199,200 + (1040\*176) = **382,240J**

Time to use up 1kg liquid N2 = 382,240/421 = 907sec = **15min** (0.25hr)

Amount of liquid N2 use per day = (24/0.25) **= 96L**

**Notes:**

1. This calculation assumes the box is “flattened” for ease of calculation, it does not take into considerations the “corner” effects of the box, which would likely increase the heat flow into the box.
2. This calculations also does not take into consideration the metal support bar that cuts through the insulated box thereby also increasing the heat flow in, requiring more liquid N2.
3. The door opening is also not considered in this calculation. The door seals will probably not be as good as the ideal situation where the polystyrene is glued together. This will be another additional source of heat gain.

**Recommendations:**

1. Increase the box wall thickness to at least 10cm, that will half the liquid N2 consumption.
2. Reduce the external ambient temperature in the warehouse by trapping the cool gaseous N2 coming out of the cold boxes. Cutting the temp differential by 10**°C** (reducing ambient temp from 25**°C** to 15**°C**) will reduce liquid nitrogen consumption by 22%. However, this creates a dangerous environment in the warehouse whereby ambient oxygen in the warehouse space will be displaced and there will be little or no oxygen in the warehouse.