Lockers

The product in our product-service system will be the lockers. These lockers contain food in paper bags for a short time (around the 5 to 10 minutes). The lockers with food in them must conform to some food laws. One of these laws says that food must be kept at a specific temperature to make sure the food hygiene and safety is kept high. The law says this temperature for warm food must be 60 °C or higher, and cold food must be kept at 7 °C or lower.

Technique:

To make sure that the insight of the box is cold or warm, there are many techniques to make it this temperature. After some research, there is chosen to go for an already existing technique for cooling lockers. The technique is found by LockTec who is already producing cooled lockers for multiple purposes. This technique can also be used for heating lockers. It works as follows:

Positive points about this technique are that:

1. It is energy efficient: Only the lockers that are in-use are switched on
2. There is modularity: Each locker comes with its own cooling and heating system
3. Flexibility is high: there can be easily added more blocks of lockers
4. The cooling system is closed: there is no need for specialist during the installation of the boxes
5. Continue working during failures: if one locker fails, the others in the blocks continue to work

Each module has its own cooling/heating system, so that a locker system can both heat or cool the inside. This also means that 2 lockers next to each other can supply a total customer order if items have different temperature requirements (a cold bottle of soda and a warm meal) All locker modules can be connected to each other. The columns are controlled by an intelligent cool and heat locker system.

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Competition:

LockTec already has a technique that offers cooled or heated lockers (they are mostly focussed on the cooling part). They can be seen as a competitor. This does not mean that the product-service system we developed, will fail when bringing it into the market. It means that the idea of the heated or cooled lockers is realistic because another company sees potential in it and already sells it and makes profit on it. That does not take away the fact that it a competitor of us. The most important question stays on why we are different from them. First of all the only offer the lockers. They say that they can add software of companies that purchase the lockers to it. This means that they combine their product with the service of another company that buys the boxes. We are focussing of both the product and service and want to make profit and create more customer benefits by combining both into a hybrid offering. The boxes do not have a function without the service and the other way around. Next to combining a service and product, where they only offer a product, is that we also using the locker modules for more purposes. We use the doors of the lockers to show advertisements during the non-peak hours. And the third reasons why we are different than them is that LockTec mostly focuses on cooled purposes. This is only a small part of our idea and purpose on why we want to have the lockers. Most of the time we are going to use the lockers for heating purposes. There are more small differences like the size of the lockers and the whole module, the size of the terminal and the printing option in the terminal for printing barcodes to open the lockers if the cell phones aren’t working or are empty. This is why we are different from LockTec.

Energy estimation:

When using the boxes, energy is needed to make the heating or cooling system work. We've performed a few calculations in order to make an estimation on how much energy the whole system needs if it is working,. There are different situations with cooling or heating the box.

4 situations:

1. From room temperature, 18°C, to 60 °C
2. From room temperature, 18 °C, to 7 °C
3. From 7 °C to 60 °C,
4. From 60°C to 7°C

The heat (Q) is calculated per locker in the 3 situations with the following formula:

$Q = c \times m \times \Delta T$

Where $\Delta T = T_{end} - T_{start}$

$M = \rho * V$

cwater = 4.18 kJ/kg°C Air = 1.002 kJ/kg°C

V = 0.25x.3x.25 m^3

ρ = 1000 kg/m^3

Then is calculated how long a meal will be in the locker and how much of the time the locker is in use in an hour. The worst scenario is that a meal will be in the locker for 10 minutes and that the locker is in full use the whole hour. This gives a worst case scenario as follows:

Situation 1: 3291.75 joule = watt/seconds
For 10 minutes in the locker and 6 meals per hour (60 minutes in use) gives: 11850.3 kwH

Situation 2: -862.125 joule = watt/seconds
For 10 minutes in the locker and 6 meals per hour (60 minutes in use) gives: -3106.65 kwH

Situation 3: 4153.875 joule = watt/seconds
For 10 minutes in the locker and 6 meals per hour (60 minutes in use) gives: 14953.95 kwH

Situation 4: -4153.875 joule = watt/seconds
For 10 minutes in the locker and 6 meals per hour (60 minutes in use) gives: -14953.95 kwH

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In this calculation it is assumed to heat water, while in the real situation you're heating air and a meal that is already on a high temperature. Also the air in the locker, will still be a little hot after the meal is gone,(this is not calculated in the following calculation). Assuming the heat of the meal (warm meal) is already around the 60 °C (assuming this is water) and the air around it is around the 18 °C and the cold meal is already around the 10 °C with a temperature of air around it around the 18 °C either. Only the air should be chilled or heated around the meal to keep it at a steady, good temperature. A more real situation calculation leads to the following numbers

Situation 1: 0.4725 joule = watt/seconds
For 3 minutes in the locker and 20 meals per hour (60 minutes in use) gives: 1.701 kwH

Situation 2: -117.68625 joule = watt/seconds
For 3 minutes in the locker and 20 meals per hour (60 minutes in use) gives: -423.6705 kwH

Situation 3: 0.59625 joule = watt/seconds
For 3 minutes in the locker and 20 meals per hour (60 minutes in use) gives: 2.1465 kwH

Situation 4: -118.1587 joule = watt/seconds
For 3 minutes in the locker and 20 meals per hour (60 minutes in use) gives: -425.3715 kwH

One module contains 10 lockers. They work on one energy source. This means that 10 lockers together must have the following energy in the 4 situations:

Situation 1:	851 watt per order	17.01 KwH
Situation 2:	211836 watt per order	-4237 KwH
Situation 3:	1073 watt per order	21 KwH
Situation 4:	-212686 watt per order	-4254 KwH

Assume that one energy is connected to a 230V, 16A phase. This means that there can be produced 230*16=3680 watt. This is enough if you look at the situation where it must go from 7 °C to 60 °C or 18 °C to 60 °C and this the worst case if you need to restart every time. Then this amount of power is needed. Most of the time the lockers still contain a certain heat because of earlier heating action. To maintain the heat, around the 10% of the power is needed. So maybe it is more energy efficient during peak times to maintain the temperature at a certain level. The only problem is that if you need more cold lockers or more warm lockers, that is costs more energy to change the temperature, but as calculated, this is "only" 851 watt.

Instead of using a normal 230V, 16A fase, there can also be a fase of 400V and 25A. This means that the power generated is 400*25=10000W. This is enough to have 30 lockers connected to this one source in the worst situation (situation 2 and 4).

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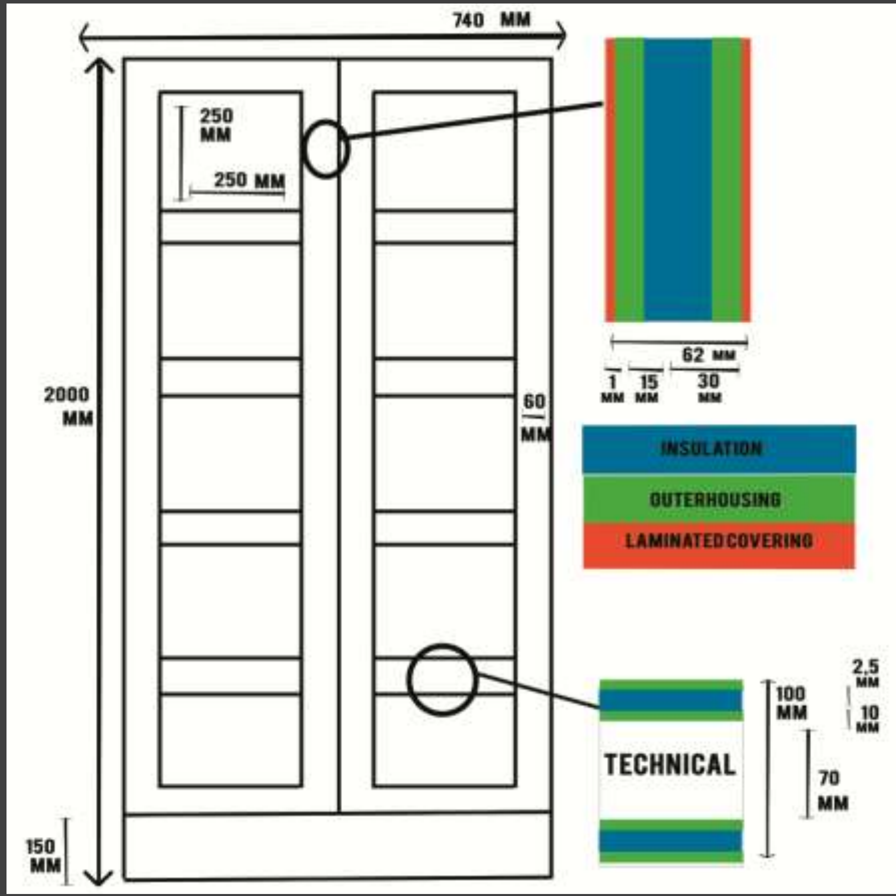
Materials:

The lockers are made from 4 different materials. The 4 different materials have different places in the lockers and different requirements.

1. Laminated cover
2. Insulation material
3. Impact resistant outer housing
4. Internal perforated shelving material
5. Outer housing locker door

Each locker consists of a double locker column. In here is placed the cooling or heating system that works for every locker.

The door is also made of a material. This material will be the same as the impact resistant/ outer housing: coated steel. This covers the door. In the inside is insulation material and space for technical stuff of the barcode scanners and led lights which are placed on the front of the door.



For most of the materials a list of 3 options was created for materials with the help of CES (cambridge engineering selector). Graphs made in CES and used to select materials can be found on the last page of this document.

1. Laminated cover

Parameters:

- Recycle, Down cycle
- Resistance
  - Water
    - Fresh, Excellent resistance
    - Salt, Excellent
  - Acids
    - Weak, Excellent
    - Strong, Excellent
  - Alkalis
    - Weak, Excellent
    - Strong, Excellent
  - UV radiation, Good

Material: PP (polypropylene) (impact copolymer, UV stabilized)
Polymer: 80- 90%
Impact modifier: 10 - 20 %
Density: 899 - 909 kg/m3
Price: 2,0381 euro/kg
CO2 Footprint, primary production: 2,77 - 3,06 kg/kg
CO2 Footprint Recycling: 0,94 - 1,04 kg/kg
Recycle fraction in current supply: 5,26 - 5,81 %

We choose this material because it is almost a pure material which helps with recycling it better. Other options for the laminated covering were most of the time mixed polymers with a lower recycle fraction.

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2. Insulation material

Parameters:

- Recycle, Down cycle
- Low thermal conductivity <<1 W/m
- Low density preferred

Material: Polyurethane Foam (PUR)

- Thermal conductivity = 0,025 - 0,028 W/m Celsius (~ 0,0265)
- 100% polymeer
- Density: 30-34 kg / kubieke meter (32)
- 5.7610 - 6.3416 EURO/kg = ~ 193.641 EURO/ kubieke meter
- Options for Down cycling, Combust for energy recovery, Landfill, No option for Recycling
- CO2 footprint primary production = 4,95 - 5,46 kg (CO2)/kg(material)
- Combustion CO2 = 2 - 2,1 kg/kg
- Fraction recycled and gedowncycled PUR in totale wereldwijde omloop: onbekend ga uit van 0*
- Specific heat Capacity = 1.65 *10^3 - 1.7 *10^3 thermal J/kg Celsius
- Excellent tegen water en is slow burning

Other options: Cellulose, Polyetherimide honeycomb 0,048 specific gravity, and Polyetherimide honeycomb 0,045 specific gravity

We choose this material because out of the options we found, this was the only material that was slow burning and can resist water. This has also the best thermal conductivity out of the 4 options. The other options had the same values for recycling, down cycling, co2 production, etc.

3. Impact resistant outer housing

Parameters:

- Recycle, Downcycle
- Resistance
  - Water
    - Fresh, Excellent/ Acceptable
    - Salt, Excellent/ Acceptable
  - Weak Acids, Excellent/Acceptable
  - Strong akalis, Excellent/Acceptable

Material: coated steel, steel, terne coated
93,6 - 93,7 % Fe
Density: 7,85e3 - 7,9e3 kg/m3
Price: 1,0995 - 1,1710 EURO/kg
Young's Modulus: 1,85e11 - 2e11 Pa
All filtered resistances are acceptable with the exception of weak alkalis which is excellent.
CO_2 footprint, primary production 2,46 - 2,91 kg/kg
CO_2 footprint recycling 0,635 - 0,702 kg/kg
Recycle fraction in current supply: 52,3 - 57,8 %

Other options: Coated steel, Stainless steel, tern coated and aluminium 2026, T3511

There was a choice between Steel or Stainless steel. Steel is 3 times cheaper and has a 2 times lower CO_2 footprint at both production and recycling. Only disadvantage is that is scores low on the filters of chemical resistance. We guess this isn't that big of a problem because the outer housing is covered with a laminated layer which will protect against these things. The inner housing is of course cleaned with chemicals, but with the right cleaning description, it will be fine because it is also not good for the food to get in touch with chemicals.

4. Internal perforated shelving material

There are many choices for the internal part of the lockers. It has been decided to use the same material as the impact resistant outer housing, in this case: coated steel. This means that less different materials are used, which helps with the recycling and de-assembling of the lockers.

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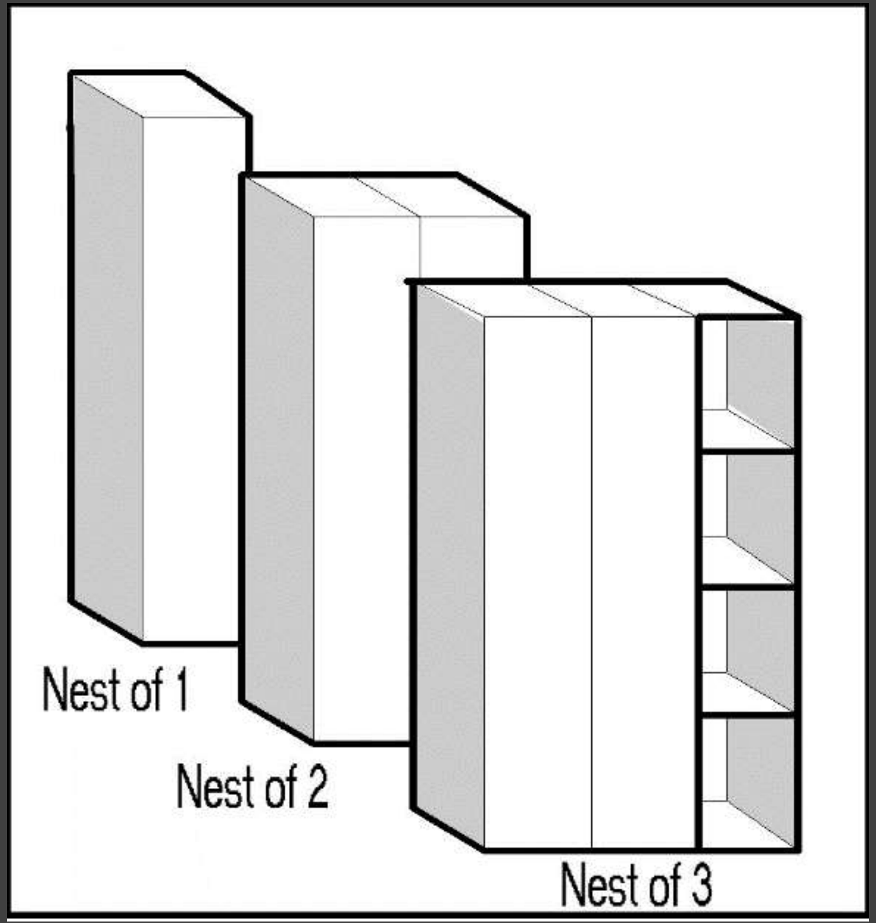
5. Outer housing locker door

For the outer housing of the locker door we also needed a material. We had various options here and the choice was between aluminium and coated steel. After comparing them we came to the following conclusion: Option 1, the coated steel, has a 2,5 times higher Young's Modulus (This results in less material in the same shape with equal deformation when force is applied on that shape). The coated steel has a ~30% higher Recycle fraction in current supply, over 4,5 times lower CO_2 footprint at the primary production and 4 times lower CO_2 footprint when recycling. Option 3, the aluminium is almost 1,5 times cheaper per/m3, but this does not weigh up to its previously stated disadvantages. That is why we choose coated steel for the outer housing of the door of the locker. This means that less different materials are used, which helps in recycling and de-assembling of the lockers.



Modularity:

After deciding how the heat and cooling system in the lockers must work and what materials the lockers are made of, it is important to decide how many lockers form 1 module (i.o.w. nest), how the lockers are adaptable and how the modularity is.

Can you add one locker a time, which has a profit that it is easy to repair, or do you choose nests (which can consists of 1, 2, 3, nests, etc.) to form one module. Then the questions comes how many lockers form one nest. Because our lockers are small we choose to have 1 nest with 5 compartments and beneath that a space for the heating equipment or other technical stuff.

Here are the negative and positive points of individual lockers or a nest:

Positive points one locker	Negative points one locker	Positive points 5 lockers together	Negative points 5 lockers together
Easy to repair	Adding one locker a time will not be done because it is a big industry	Adding one nest of 5 lockers is more logical because there will be plenty of lockers and adding one doesn't add up.	When the temperature system fails, 5 lockers will be out of order instead of 1
Easy to adapt to quantity needed lockers	Adding one locker doesn't give the symmetric look and wall look you want to have.	One general energy point can be used for one nest. (All the lockers can be connected separately to the source)	
		You just roll 1 block (10 lockers) to the place. It costs less time to install it at the final place.	

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We have chosen to go for a nest that exists of 5 lockers. We have chosen to have 2 nests form 1 module of lockers (10 lockers total). This is done because of a few reasons:

- Adding one module of lockers (2 nests together, 10 lockers total) is more logical because there will be plenty of lockers and adding one by one doesn't add up.
- One general energy point can be used for one module. (All the lockers can be connected separately to the source, so switched on if needed)
- You just roll 1 module (10 lockers) to the place. It costs less time to install it at the final place.
- You can still repair one locker is it is broken. The rest of the lockers can still be used because they have their own system for heating or cooling. They only share an energy source.

LED

The lockers do of course have doors. On the outside of these doors LED lighting and a barcode scanner. is placed. The LED lightning will show a number and a color during the peak times which will help people find their locker with food in it more easily and quickly. During non-peak times, the led-lightning can be used to show advertisements (Static or dynamic). All the doors, and therefore the screens, are connected to each other. This means that they will form a massive screen together. An example of the LED screens that form a massive screen together and shows how we want to apply it, is as follows:

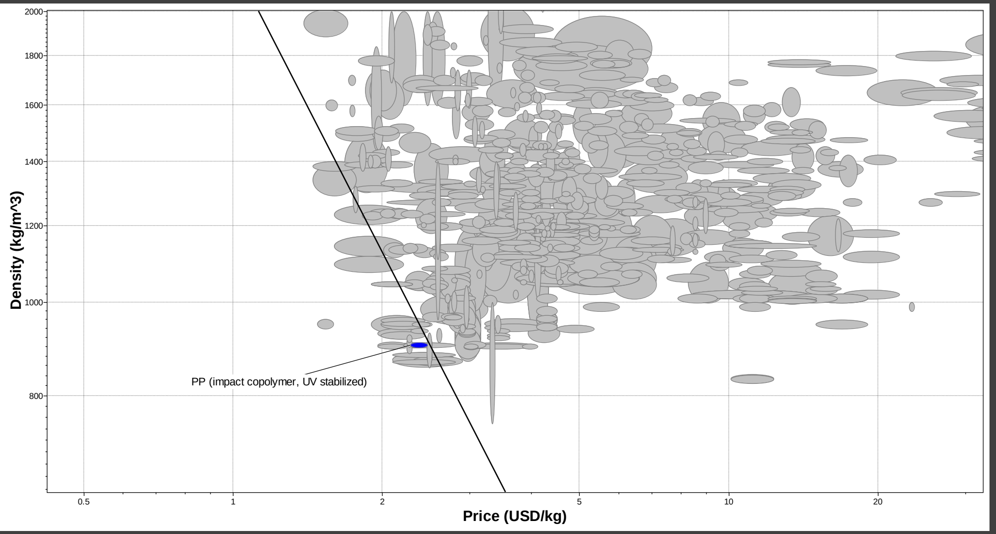
https://www.youtube.com/watch?v=tbojKqY2TpM

Scanners

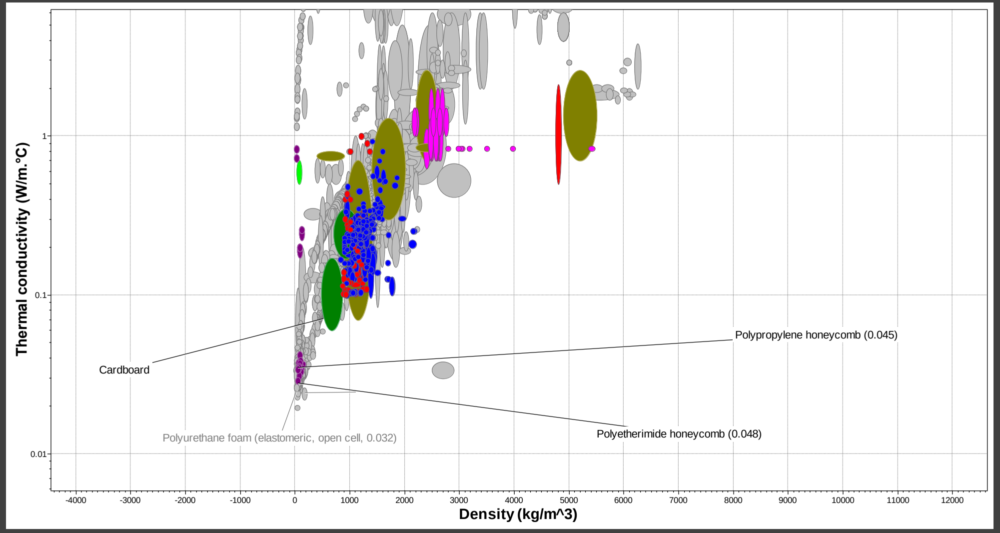
These scanners will be CCD readers, also known as LED scanners. CCD-readers use hundreds of small light-sensitive sensors, which all measure the light directly in front of it. All sensors together generate a voltage pattern that is identical to the pattern of the barcode.
The main difference between a CCD scanner and a 'regular' laser-scanner is that a CCD scanner reads ambient light instead of reflected light. This makes the sensor more suitable for our lockers that will be emitting LED light themselves as well. Even though a CCD scanner is very accurate, even when other LED light is in play, we choose to turn of the LEDs of the locker that will be opened for a short time to ensure that the scanning will run smoothly.

Graphs in CES

Laminated cover



insulation material



Impact resistant

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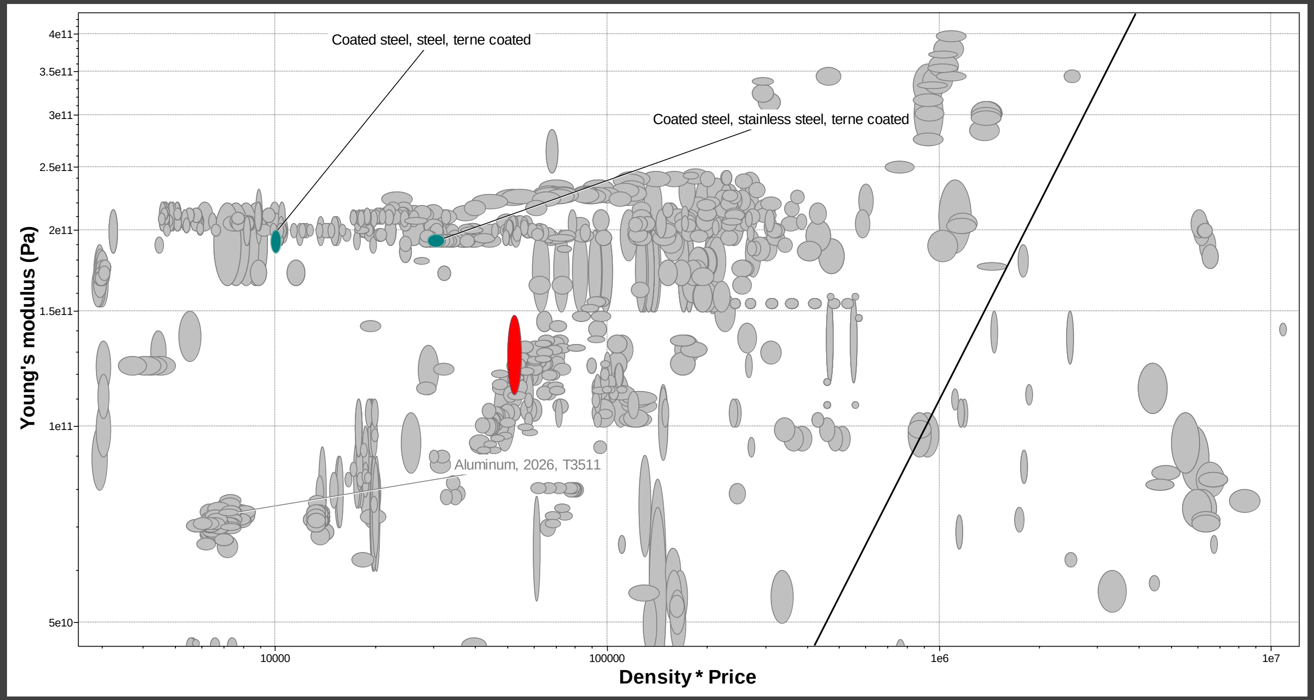
outer housing



Sources used in this document

http://www.locktec.com/fileadmin/pdf/Product_Leaflet_Locktec_cool_lockers_english.pdf

http://www.locktec.com/en/products/locksafe-cool-lockers/