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Handling Hot Oil in a Commercial Restaurant

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ENGINEERING DESIGN 3 FINAL REPORT

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Executive Summary

In many small restaurants, the disposal of hot, used cooking oil is one of the most undesired and dangerous tasks performed by workers. Employees often carry heavy containers of extremely hot oil, and in many cases with very little or no protection. As a result, burns are common in restaurants that use deep fryers. We decided to resolve this problem by inventing an inexpensive device that will help promote worker safety and make the oil disposal process more convenient and efficient. Our proposed final design is made of an insulated, locking stainless steel container attached to a hydraulic scissor lifting system. The device uses a foot pump and a series of linked, crossed members to mechanically lift the waste oil above the desired height of one meter where it can then flow out through a valve due to gravity. This design will allow workers to move the oil safely around the kitchen, while reducing the total occurrence of injuries caused by the disposal of hot oil.

Section 1: Introduction

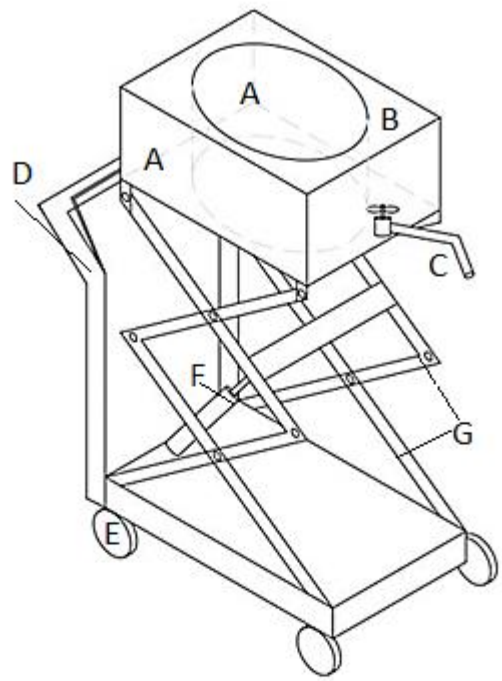
In the food industry, many commonly consumed products such as French fries, onion rings, certain poultry dishes and donuts are cooked using a deep fryer (USDA, 2012). The food is submerged in oil at 160^0C (CDC, 2013) until a safe inside food temperature is reached. Due to the extremely high temperatures of cooking oil in deep fryers, handling and disposing of the oil can be very dangerous. Both oil transfer between a fryer and container as well as draining of a container's oil often result in splashes or spills. The food service industry has a higher record of burns than any other employment sector (Silberstein, 2014). Handling deep fryers' oil is the main cause of these restaurant burns in Canada (CCOHS, 2005).The National Council for Occupational Safety and Health compiled survey results based on fast-food restaurant employees in the United States. Restaurant employees mentioned that there were safety concerns associated with the handling of deep fryers as 54% of the people surveyed indicated that they were burned working with the deep fryers and 39% when handling hot fluids (Hart Research Associates, 2015) such as used cooking oil.

There is a major safety problem regarding the current technology used to move and dispose of hot cooking oil: employees are often forced to carry a pot filled with hot cooking oil, which is evidently an extremely dangerous task. The container must be held away from the body which is physically demanding on the employee carrying it. The person emptying the fryer must also maneuver through a tight kitchen with many corners, coworkers and clutter. Due to the high pace nature of the kitchen, handling hot oil must be done with great care. There is therefore a need to make handling this oil in restaurants a safer task. The client is defined as someone in the food industry who desires to increase the occupational safety of their employees.This need has business, social and economic implications. The client would have to become aware of the social concerns surrounding the occupational safety of current oil handling methods, in order to purchase improved technology. The design of a more advanced technology to handle used cooking oil would greatly contribute to enhancing safety in the food industry's restaurant workplaces.

Our goal was to design a tool or process that will help reduce the risk of injuries for restaurant employees when handling hot oil with the following objectives:

- **Lower the risk of injuries and increase the overall safety of employees**
- **Price should not exceed 350$**
- **Whole process of filling, moving and emptying should not exceed 20-30 minutes**
- **Must be compatible with most common fryers**
- **Must be small enough to fit under outlet spout of fryers**
- **Should be as small as possible to facilitate storage**

To design our device, we selected a set of criteria including safety, compatibility and simplicity, as well as constraints including overall price, process completion time and size. These are defined in more detail in our previous design proposal. (Handling Hot Oil in a Commercial Restaurant, 2014) After much contemplation and rigorous evaluation of existing alternatives tackling the current system such as vacuum pump filters, integrated piping systems, and oil disposal caddy systems similar to those of Frontline International ©, our proposed design was a mechanical lifting device that incorporated a scissor lifting system, stainless steel insulated oil tank that can be emptied using a safety valve, and wheels for facilitated displacement that use a hand operated braking system. An initial drawing of the device we created in the first part of the course is shown below in figure 1. The processes of specialization, prototyping and testing of this initial design will be explained in detail throughout this report, as well as our final recommendations for future improvements we could potentially consider before its official commercialization



Section 2: Specification and Analysis

Figure 1: *An isometric autoCAD drawing of our initial design. We can clearly identify the stainless steel layers of the oil disposal tank (A) , the thermal insulation (B), the safety valve (C), the hand lock mechanism (D), the wheels (E), the hydraulic cylinder (F), and the scissor lifting mechanism (G).*

2.1 SPECIFICATION

2.1 DETERMINATION OF OUR FINAL COMPONENTS

A list of the various main components of our design was presented to the class at the beginning of the semester. We proceeded by evaluating all of the alternatives to each of the components rigorously and selected the ones that we strongly believed would show distinction in the device's performance. The components that we assessed were principally the locking system for the wheels, the design and shape of the tank, and the lifting mechanism.

2.1.1 WHEEL LOCKING SYSTEM

An important feature of the final oil lifting device design is to include wheel locking system. The final locking system that is incorporated in our design is featured in a US patent issued in 2008, by D'Arca et al. The document fully describes a hand triggered braking system that was initially designed for shopping carts. At rest, the system is engaged and the wheels are locked in place using gravity. The user deactivates the brake by applying force to a primary handle, allowing the wheels to move. Otherwise, when the handle is not pushed down, the brake would be applied. The use of a hand operated brake is a useful safety feature that would make applying the brake very easy for the device operator. Figures 2 and 3 show the details of this mechanism and how it is physically constructed.

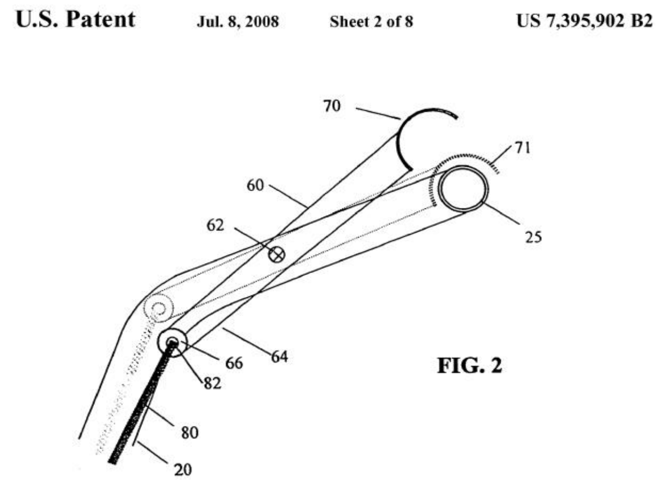


Figure 2: *An illustration of the proposed hand locking system that will be incorporated in our final design. Here is the handle that will initiate movement of the waste tank. The user would apply a force at (70), lifting the linkage rod which is connected to the braking system. (D'Arca et al, 2008)*

Our selection of this mechanism can be justified by our desire to respect our criteria of safety. In order to minimize the probability of the oil tank moving without the presence of a user, we selected this design for it proved to be the type of system that would be the most efficient at conforming to the requirements of our task. If mishandled, the hot oil container could be extremely dangerous, and chances of spilling and loss of the

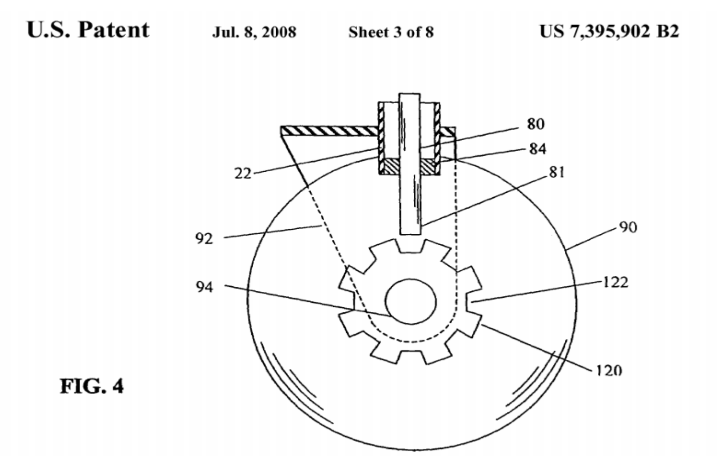


Figure 3: *Here we can see the braking mechanism itself on the wheel. (120) shows a breaking gear that is used to immobilize the wheel when not in use. The gear, which will be made of plastic, is only capable of moving once the linkage rod is removed from one of the respective the indents. (D'Arca et al., 2008)*

waste oil from the interior of the tank are significantly increased once the design is in motion. Incorporating this design helps to eliminate this risk, and preserve employee safety.

2.1.2 TANK DESIGN

The selected shape of the used oil container in the final design is rectangular. Having a rectangular container base will contribute to the overall stability of the oil lifting mechanism by providing an evenly distributed load. The interior base of the container design will have symmetrical downward slopes on each side of the valve to help ease the outward flow of the used cooking oil. Facilitating the oil flow will make the used cooking oil discharging process into the outside disposal bins more time efficient. The slopes will also help prevent any used cooking oil from remaining at the bottom of the container. To design the dimensions of the tank we used spec sheets that were retrieved from Frontline International, a company that designs caddies for waste oil disposal for many large restaurant chains. We decided that this would

The container material selections for the final design include polyurethane foam in-between two layers of stainless steel. The container will have insulated handles and a lid lock to make it safe for restaurant employees who handle the container. Polyurethane foam with thermal conductivity of k = 0.03 W/mK (Engineering Toolbox, 2014b) is commonly used in the food industry for insulating hot items. Stainless steel is also used in many food applications and is extremely durable, making it a good material selection for the final design.

2.1.3 LIFTING MECHANISM

To design our lifting system, we first needed to collect measurements needed that specified the required height to be achieved by the raising of the scissor members. This was done with relevant dimensions that we obtained from the Macdonald Campus Food Lab. These include the distance from the floor to the bottom of the release valve, as well as the depth from the valve to where our device would hit the fryer. The following dimensions are recorded in the table 1 below, and were used to develop the scissor mechanism for our final design.

	Ground to top of oil discharge pipe (vertical distance)	Ground to bottom of oil discharge pipe (vertical distance)	Fryer to outside of oil discharge pipe (horizontal distance)	Fryer to inside of oil discharge pipe (horizontal distance)	Ball valve inner diameter	Discharge pipe inner diameter (screw end)
Food Lab	21.5 in 54 cm	20.75 in 52.5 cm	8 ¼ in 21in	7 in 21 cm	¾ in 1.9 cm	1 ¼ in 3.2 cm

Table 1: The required measurements that were needed for the design of the scissor lift

	Regular bin height	Max bin height
Sanimax (Height of waste Bin)	36 in 91.5 cm	41 in 104 cm

Table 2: Definition of the design height needed to be reached by the scissor lift.

The scissor lift material selection of the final design is stainless steel. Stainless steel has many properties that make it a suitable material choice for this purpose. This material is rust and scratch resistant. These properties will facilitate cleaning of the scissor lift and make it durable for multiple uses. Cleaning may be required if the scissor lift gets any cooking oil or other kitchen residues on the surfaces. Also, stainless steel will be able to handle weather elements such as snow or rain, when the oil lifting device is taken outside to discharge the used cooking oil into the disposal bins. Another primary reason for the selection of stainless steel for the scissor lift material is due to the structural strength of this material. Stainless steel has a high structural strength and will be able to support the used cooking oil load of approximately 45kg.

2.1.4 HYDRAULIC CYLINDER

A hydraulic cylinder was selected for our design due to its many advantages. Hydraulic cylinders have very large mechanical advantages and even the smallest ones can support much more than our maximum design load. By selecting a single acting hydraulic cylinder, we gain the ability to lower the tank with gravity without any effort on the user's part. A small hydraulic cylinder is enough for our purposes so it would not take up much space in our design. The hydraulic cylinder also has the benefit of having a wide variety of options with which it can be raised including a lever and a foot pump.

SCISSOR LIFT CALCULATIONS

Another kind of caddy with a hydraulic (manual pump), or lifting the caddy itself to collect the liquid. Redesigning a container on wheels with a lock: insulated to reduce the danger for the transporter. Also easy to haul with a liquid mass of 100-120 lbs . A mechanical lifting device will be able to move the oil while also lifting it upwards. This device will reduce strain caused on the person using the device.

2.1.5 DESIGN DRAWINGS

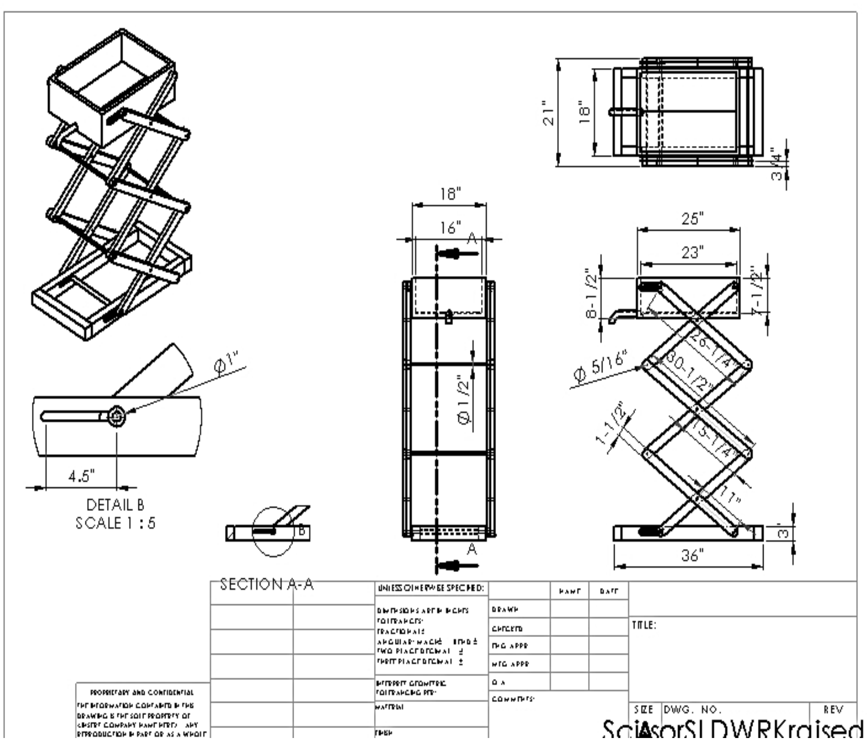


__Figure 4:__ autoCAD rendering of our final design. Side view.

2.2 ANALYSIS

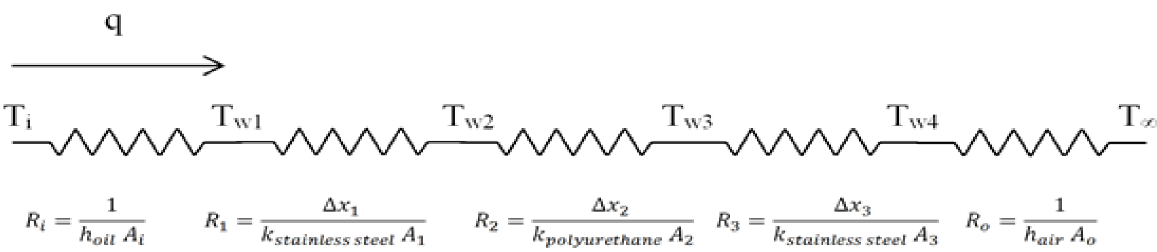
2.2.1 HEAT TRANSFER ANALYSIS

The heat transfer through the insulated container on the oil lifting device can be illustrated through a thermal circuit diagram. The heat transfer through the various layers creates a heat flow q. During conductive heat transfer which occurs as a result of a temperature gradient, material thickness, material thermal conductivity and area contribute to the flow resistance. In contrast, during convective heat transfer which is due to fluid or molecular motion, the material heat transfer coefficient and area creates the flow resistance.

Between the hot used cooking oil at temperature T_i and the inner stainless steel at T_{w1} an inside convective resistance $R_i = \frac{1}{h_{oil}\, A_i}$ will be present. The temperature of hot used cooking oil can vary based on the type of food product, type of oil and the cooking time. The commonly used cooking temperature of 160°C (CDC, 2013) will be used for the inside cooking oil temperature T_i in order to design for the maximum heat transfer to have a safe design. Through the inner stainless steel at temperature T_{w1} and outer stainless steel at T_{w2} a conductive resistance $R_1 = \frac{\Delta x_1}{k_{stainless\ steel}\, A_1}$ will be present. The next layer on the container is the polyurethane insulation. The conductive resistance through the polyurethane insulation across the temperature gradient from T_{w2} until the stainless steel temperature T_{w3} can be written as $R_2 = \frac{\Delta x_2}{k_{polyurethane}\, A_2}$ since the contact resistance between the stainless steel and polyurethane insulation will be small. A second layer of stainless steel will be present to cover the insulation. Similarly, another conductive resistance will be present through this second stainless steel layer over the temperature gradient from T_{w3} until the outer stainless steel temperature T_{w4} which can be expressed as $R_3 = \frac{\Delta x_3}{k_{stainless\ steel}\, A_3}$ since the contact resistance between insulation and stainless steel is once again small. Finally, between the outer stainless steel temperature T_{w4} and the ambient air at T_∞ there will be an outside air natural convective resistance that can be expressed as $R_o = \frac{1}{h_{air}\, A_o}$.The ambient air temperature T∞ in the food industries or restaurants will be at room temperature. Room temperature is approximately 20°C.

The temperature of the insulated container is essential to consider ensuring both safe handling and transportation of the used cooking oil. The temperature of the insulated container must therefore be safe to touch at T_{w4}. A safe outside temperature of 37 ^{0}C which corresponds to body temperature will be selected. This temperature will enhance the occupational safety of using the oil lifting device.

Thermal Circuit Diagram:



$$R_i = \frac{1}{h_{oil}\, A_i}$$

Where R_i = inside convective resistance (K/W)

h_{oil} =cooking oil heat transfer coefficient=263 W/m^{2}K

A_i = inner container area (m^2)

$$R_1 = \frac{\Delta x_1}{k_{stainless\ steel}\, A_1}$$

Where R_1=conductive resistance through first stainless steel layer (K/W)

Δx_1=thickness of first stainless steel layer (m)

$k_{stainless\ steel}$=thermal conductivity of stainless steel=16 W/mK

A_1=area of first stainless steel (m^2)

$$R_2 = \frac{\Delta x_2}{k_{polyurethane}\, A_2}$$

Where R_2=conductive resistance through polyurethane foam (K/W)

Δx_2=polyurethane foam thickness (m)

$k_{polyurethane}$=polyurethane foam thermal conductivity=0.066W/mK

A_2=area polyurethane foam (m^2)

$$R_3 = \frac{\Delta x_3}{k_{stainless\ steel}\, A_3}$$

Where R_3=conductive resistance through second stainless layer (K/W)

Δx_3=thickness of second stainless steel layer (m)

$k_{stainless\ steel}$=stainless steel thermal conductivity=16.2 W/mK

A_3=area of second stainless steel (m^2)

$$R_o = \frac{1}{h_{air}\,A_o}$$

Where R_o=outer convective resistance (K/W)
h_{air}= air heat transfer coefficient =10W/ m^2K
A_o=outer container area (m^2)

(Sumnu et al., 2009)(The Engineering Toolbox 2014b)(The Engineering Toolbox 2014a)(Venkatesan et al., 2001; Engineering Handbook, 2000.)

2.3 ANALYSIS USING COMSOL

The tank will consist of three layers: an outside stainless steel layer, a middle layer made of polyurethane insulation and an inner steel layer. The default values for these layers based on the proposed design are 0.3175cm (⅛ in), 1.905 cm (¾ in) and 0.3175cm (⅛ in) respectively. However, we intend to make these easily modifiable using proper parametrization in Comsol.

The mathematical equations that we used for our model were retrieved directly from Comsol and were defined as:

$$\rho C_p \frac{\partial T}{\partial t} + \rho C_p u \nabla T = \nabla.(k \nabla T) + Q \quad \textit{(Equation 1)}$$

$$-n.(-k\nabla T) = h(T_{ext} - T) \qquad \textit{(Equation 2)}$$

These equations are the time dependent equations that define the heat transfer through our system. Equation 1 describes the conjugate heat transfer through the solids and the fluid, and equation 2 describes the convective heat flux induced by the ambient air.

The variables used in these equations are:

ρ	Density of the material	(kg/m^3)
Cρ	Heat Capacitance of the material	(J/KgK)
k	Thermal conductivity constant	(W/mk)
∂T/∂t	Rate of temperature change	(K/m)
Q	Heat source	(W/m^3)
H	Convective heat transfer coefficient	
u	Velocity Field	(m/s)
T	Temperature	(K, kelvin)
∇	Gradient vector differential operator	

In equation 1, the terms $\rho C_p \frac{\partial T}{\partial t} = \nabla(-k\nabla T) + Q$ define the temperature profile in an immobile solid for a time-dependent heat transfer problem. The expression $\rho C_p \frac{\partial T}{\partial t}$ is the change in energy per unit volume in the material according to the rage of change of temperature with respect to time. The $(-k\nabla T)$ term defines the convective heat flux in the solid which is a function of the temperature gradient. The term $\rho C_p u \nabla T$ is the change per in energy per unit volume for the fluid, oil. In this case, the fluid is stationary so the velocity field is null. For equation 2, we are stating that the conduction through the solid is equal to the inward heat flux caused by air convection. These two equations are fundamental equations of heat transfer and will be used to characterize our model according to the specific properties of our material and boundary conditions.

Our initial boundary conditions were chosen with respect to the function and conditions of use of our design. We are assuming that the hot waste oil has just been removed from the fryer, and is ready to be displacement before disposal. An initial temperature of 433.15 K is adequate, for it is a typical oil temperature used for frying produce in restaurants. We also assumed that the ambient temperature is equal to 293.15 K. We are also assuming that the oil is completely immobile inside the tank, and that all materials are uniformly made and therefore have constant properties all throughout their respective media.

The thermal properties of the various materials used in our design that will be needed to compute the model are listed below:

Canola oil

Heat Capacitance (Cp)	**1913**	[J/KgK]
Density (ρ)	915	[Kg/m^3]
Thermal conductivity constant (K)	0.18	[W/mK]

Polyurethane

Heat Capacitance (Cp)	1826.2031	[J/KgK]
Density (ρ)	374	[Kg/m^3]
Thermal conductivity constant (K)	0.066	[W/mK]

Stainless Steel 304 (Food Grade)

Heat Capacitance (Cp)	500	[J/KgK]
Density (ρ)	8000	[Kg/m^3]
Thermal conductivity constant (K)	16.2	[W/mK]

(Venkatesan et al., 2001; Engineering Handbook, 2000.)

Here is an illustration of the oil tank shown in Comsol and this figure shows its principal geometry. We can see that we have greatly simplified the geometry for the tank is completely sealed, and does not possess a locking lid as shown in previous designs. This was done in order to make the mathematical computations of the model less complex. However, while it is important to note that there is no longer a separation between the oil and the exterior, the lid will be insulated similar to what is shown in figure 1. Stainless steel 304 was used for the containment chamber. Because the design must correspond to the standards of devices used to handle and prepare food grade materials, this was an ideal choice of material. This type of steel is capable of resisting corrosion in architecture, is used in most food processing applications and is known to be highly resistant to most chemicals (Engineering Handbook, 2000). Initially we thought of putting a filter in the device to make the oil reusable, but the presence of the filter is not needed to model the process of heat transfer through the various materials of the tank. In between the outer and inner layers of stainless steel is a layer of polyurethane foam to insulate

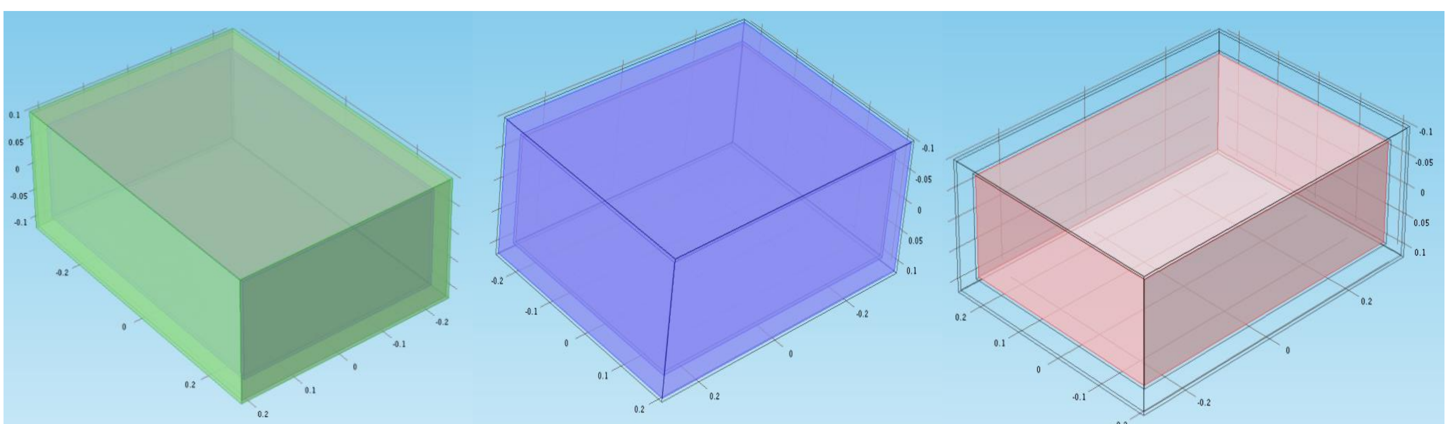


Figure 5: *The basic geometry we used to create our model. This image shows the two outer (light green) and inner (dark green) layers of the waste tank which are both made of stainless steel 304. The purple surface represents the layer of polyurethane foam that is to be placed between the two layers of steel as a means of insulation. The red prism is the containment chamber where the oil (canola) will be once emptied from the*

the hot oil and reduce heat transfer within the system. Polyurethane is a common insulator used for most food products, as well as in conjunction with stainless steel panels, as this is why we thought its selection would be the most appropriate for our design. (Evonik, 2014)

To validate our model, we decided to run a time dependent simulation in Comsol. Initial values of the inside temperature of the oil, as well as the other components of the system were given in the study section. We wanted to test whether after a short period of time (100s) the outside surface of the tank would be at a safe temperature for human contact. To perform this experiment, the ambient temperature was set to a fixed value and we also defined an inward heat flux through the exterior boundary for convection. We then decided to model the heat transfer process from the oil through all the various layers composing the tank. As the oil's temperature continuously decreased with loss of heat, its viscosity increased. Ideally, to permit optimum drainage of the oil, the oil must remain hot. In hopes of the insulation performing correctly, and allowing the outside steel layer to reach a safe exterior temperature (310 K)

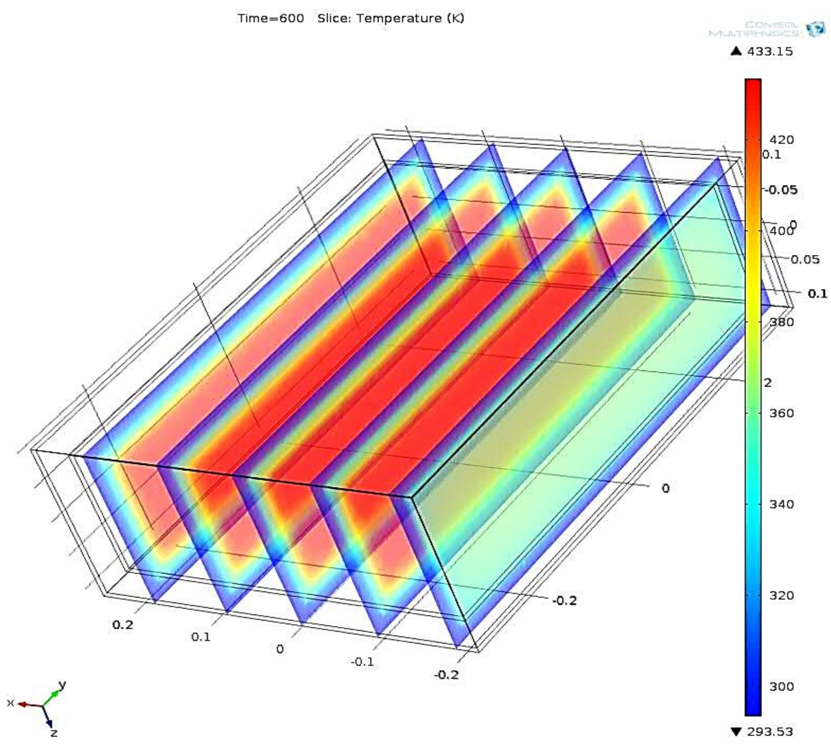


Figure 6: *A slice plot of our system computed on Comsol after 600s. From the figure we can see that the yellow layer is increasing in thickness, this means that heat from the oil is gradually being released towards the outer surface.*

immediately after it has been filled, we decided to run the simulation for a relatively short time period of (around 100s).

Results taken from the model show that after 100s, heat from the oil slowly dissipates throughout the insulation layer, but overall is maintained inside the inner steel layer. Significant changes only begin to occur after 600s. Once the heat passes through the insulation, it penetrates through the polyurethane layer but then has trouble reaching the second layer of steel, for at this time the outer layer is still at a temperature of around 293 K (296K, precisely). In a period of approximately 10 minutes, there was only a 3 degree increase for the outer layer. An acceptable, safe temperature is about 37 degrees Celsius, and our insulation is able to keep the oil 10 degrees lower than the required threshold.

Section 3: Prototyping

3.1 COST ESTIMATE

Prototype cost estimate

Component	Price ($)
Caster Wheels	11.00
Locking Caster Wheels	14.70
1X2s	7.08
Storage Box	17.42
6ft long ½"Copper pipe	8.97
Bolts	10.99
Hex Nuts	6.29
Hydraulic cylinder	14.45
Subtotal	**107.33**
Total	**123.41**

Final product cost estimate

Component	Price ($)
Wheels with stoppers	22.72
2in x 2in Steel Tube (Frame)	30.72
1-½in x ¾in Steel Rectangular Tube (Scissors)	111.68
Container for oil (stainless)	~300
Safety valve	25.99
Screws	~5
Bolts, Nuts, Washers	~30
Hydraulic Cylinder	~30
Insulation	19.29
Hinges	24.79
Mesh Filter	30.99
Total	**640.52**

Table 3: Cost estimate performed for the prototype and final design. Sources: Reno depot, home depot, amazon.ca, ebay.ca, www.metalsdepot.com

3.2 DESCRIPTION OF PROTOTYPE

The oil lifting device prototype will be a proof of concept of the design. The aspect of the design that the prototype will focus on is the movability of the device. Since the main objective of the prototype is the movability of the device, a container of the desired dimensions will be used in the physical model to represent the insulated container with the locking lid. The prototype should be able to easily be lowered and raised to the correct heights. The trial device has to reach the spout height that discharges oil from various deep fryers when in the lowered position. The prototype should therefore meet the design criteria of compatibility by being able to work with the variety of pre-existing fryers within the food industry. Also, the prototype must reach the higher disposal bin heights to empty the used oil contents when in the raised position. The prototype should once again demonstrate compatibility with the different oil disposal bins that are available. The prototype should be able to be raised to a position that is high enough to safely empty the container.

The lifting device prototype will be on four wheels and should be easy to move around by the user. The prototype should be able to turn and move around corners. The prototype has to be able to move on different types of terrain. The trial device must be able to move on restaurant floors that could be wet or slippery. Therefore, the wheels will have to have good traction. The prototype should also be movable outside where there can often be lots of snow or ice. The prototype will be constructed in a way to facilitate movement in all weather conditions.

Additionally, the device must fit through any standard door with ease. Being able to travel through doorways is necessary for the size constraint. There are several standard door widths which include 81.28 cm (32 in), 86.36 cm (34 in) and 91.44 cm (36 in). The prototype will be constructed to allow for it to be moved through the lower standard door width of 81.28 cm. There has to be enough clearance so the device moves easily through the doors. Therefore the width of the prototype must be less than 81.28 cm (32 in). Also, the size of the prototype would facilitate moving the device or storing it when space is limited. The prototype should also meet the design simplicity criteria. This trial device has to be easy to use. The movability of the oil lifting prototype will be used to test this important criteria. Most importantly, the prototype should be safe to use. Overall, the proof of concept will provide useful insights into the oil lifting design.

3.3 PROTOTYPE CONSTRUCTION

To begin the building phase of prototyping, we had to first acquire the construction materials. The group made its way to the Réno Depot in Pointe-Claire. There we purchased: a plastic box of similar size to our designed container, two regular caster wheels and two locking caster wheels, a 6 foot long section of half-inch type M copper tubing, four 8 foot long standard SPF 1X2s, four 5/16-in coupling nuts, a box of 5/16-in X 24-UNRF bolts of two and a half inch length along with a box of both the complementary nuts and washers. We then made our way to Walmart where we purchased four angle brackets and a 2-ton rated hydraulic bottle jack. The Macdonald Campus Machine Shop made a generous donation where we were also able to acquire: 2X3s, maple hardwood which we cut into 1X2s, half-inch steel piping, some spare pieces of angle bars, 1/8-in thick pieces of flat bar, sheet metal for the sliders and outer brackets, as well as few extra screws, nuts and bolts of varying sizes.

The first step in construction was building the scissors. The wooden 1X2s were cut to the appropriate length and holes were drilled in the designated locations. The scissor members were then bolted together with the 5/16-in nuts and bolts while always placing a washer between the member and the bolts, nuts or other wooden member. This created two scissors sections which needed to be connected with cross-bracing piping. To build the cross-bracing, the 6 foot long section of copper tubing was cut into four equal parts of 18 inches and nuts were welded onto each end of the tube. The copper tubing was then used to connect the two scissor sections.

The bar, on which the horizontal force of the hydraulic cylinder is applied, was then made in a similar fashion to the copper cross-bracing. A coupling nut was welded on to each end of this steel pipe which was cut to the appropriate length. This piece will later be connected to the scissor, once the frame has been built.

Next, the rectangular frame was built with 2X3s. The purchased brackets were placed on the inside of the frame to ensure it stayed square. Sheet metal was then cut and bent to be placed on the outside corners of the frame. This was to ensure that the force of the hydraulic cylinder on the frame did not pull apart the pieces of the frame. Then two small pieces of angle bar were cut, perforated and screwed into the top of the frame. These pieces are both perforated so that the ends of the scissor lift could be fixed to them with nuts, bolts and washers. Afterwards, two 1/8-in thick strips of steel were bent in a handle-like shape to allow the horizontal bar to slide within. They were then perforated and screwed into the top of the frame. The horizontal bar was then placed within the bent strips and the free ends of the scissors were bolted to each end of the bar.

Once the scissor was fixed to the frame the hydraulic cylinder could be installed. The hydraulic cylinder was then mounted onto the inside end of the frame by perforating the cylinder's base and the frame, and then bolting them together.

The sliders were made of sheet metal which was bent into a shape with a C-like cross section to allow two washers and the head of the bolt to slide within. They were made about the length of the box to spread the weight over a greater area. They were then bolted to the box after having perforated the box and the sliders. To connect the ends of the scissor which were designed to be fixed, the member ends where bolted into a coupling nut placed within a small section of steel pipe which was also bolted into from the inside of the box. This was done to prevent the bolts from bending since there is gap between the scissor ends and the box. The ends of the scissor that were designed to slide, could then be connected to the sliders with a bolt with the head end in the slider.

Finally, the four caster wheels were screwed into the bottom of the frame to facilitate the displacement of the prototype.

3.4 TESTING

3.4.1 GOALS OF TESTING

It is necessary to identify potential hazards, associated risks and ways to minimize or ideally prevent them in engineering design. The oil lifting device should come with clear instructions and some labelling signs on the device itself as it is important that the design is used as intended. The final design device should have caution labels so that the users of the device are aware of the risks that are associated with improper usage of the oil lifting device. Some practices to ensure safe operating conditions of the oil lifting device include:

- The oil lifting device is in the completely lowered position with the wheel brake system engaged prior to filling with used cooking oil from the deep fryer.
- The used cooking oil is emptied from the deep fryer into the oil lifting device container up to the marked safe fill line.
- The container's lid is completely locked once filled with used cooking oil.
- The oil lifting device is moved only in the completely lowered position.
- The oil lifting device's brake system is engaged prior to raising the device to dispose of used cooking oil in the outside bins.
- The used cooking oil should be discharged from the oil lifting device into the disposal bins to prevent viscosity increase or solidification of oil.

The Canadian Food Inspection System Implementation Group or CFISIG (2004) provides a food retail and food services code which has certain elements that apply to the oil lifting device design. The code states that food equipment should be durable under typical usage conditions. The food retail and food services code and Canada Occupational Health and Safety regulations mentions that any food contact surfaces should be anti-corrosive, smooth, non-absorbent and easy to clean to prevent contamination. Therefore, stainless steel is a good material selection for the container layers and scissor lift. The use of stainless steel becomes increasingly important if used cooking oil is reused after filtration for further cooking applications (CFISIG 2004 and Government of Canada 2015). THE NSF Commercial Food Equipment Standards provide useful guidelines that pertain to the design of equipment to be used in the food industry (NSF 2015). Some of the standards that provide valuable insight into the construction of this device are NSF2 Food Equipment, NSF21 - Thermoplastic Refuse Containers, NSF51 - Food Equipment Materials and CWA 15596 - Code of Practice on Cleanability of Commercial Food Equipment Used in the Retail and Catering Sectors.

There are also many organizations that help contribute to providing safe working conditions. Canada's Workplace Health and Safety Committees are required by federal jurisdiction to make changes to enhance the occupational safety within workplaces. Therefore, in the food industry the use of the oil lifting device will be helpful to increase restaurant employee's safety (Government of Canada, 2014). Additionally groups such as the Canadian Centre for Occupational Health and Safety or CCOHS and the National Council for Occupational Safety and Health or COSH promote safe working environments, provide information and training. (COSh 2015 and CCOHS 2015)The Canadian Society of Safety Engineering or CSSE is a leading safety, health and environmental society. The CSSE has many safety awareness events and offers related training sessions (CSSE, 2014). Therefore, the design of a more advanced technology to handle used cooking oil would greatly contribute to enhancing safety in the food industry's restaurant workplaces.

3.4.2 TESTS CONDUCTED

The first test performed on our prototype was a test for sturdiness. Since hot oil is a hazardous material, it is imperative that the oil be lifted in a smooth fashion. The first iteration of our prototype had unacceptable wobbliness issues. However, we were able to overcome these issues with careful modifications of our design. The first step was to make sure that our design was as symmetrical as possible. Imperfections in our design were causing one side to move in a slightly different path to the other side, leading to wobbliness. Another cause of wobbliness was the twisting of some parts of the frame under a load. We were able to overcome this problem by reinforcing key locations. Finally, the top of our design was also unstable due to the space between the scissor lift and the tank. This allowed for unintended lateral motion. By adding spacers (see figure 7), we were able to restrict this motion and greatly stabilize our tank.

***Figure 7:** Spacer used to stabilize the*

Another important test to determine if our design reached its design target height. This test was a success but only if you take into account the limitations of our prototype. The tank that we used was not designed to our final design specifications but was in fact significantly taller. This meant that we were unable to test if our design would fit underneath a fryer but it would be able to if our tank was shorter. In terms of maximum height, our prototype exceeded the required height by 10 cm which we viewed as a success. This success was caused by proper dimensioning of our prototype and the correct stroke distance of the hydraulic cylinder.

In terms mobility and maneuverability, our prototype exceeded expectations. Due to its four caster wheels, it was able to maneuver around tight corners with no difficulty at all. We believe that it could easily be used even in a cluttered kitchen. However, the use of four caster wheels did have an unexpected drawback. The wheels swiveled so easily that when we raise the scissor lift our prototype, the wheels have a tendency to rock back and forth. This could prove to be dangerous in the final design if it happened at maximum load. Our prototype was also narrow enough to fit through standard 863mm wide doors which was one of our design criteria.

Figure 8: *Failure of the wood in the initial prototype scissor lift.*

The first version of our prototype experienced catastrophic failure when we were testing it under a load. The members of the scissor lift were initially built out of 1”x2” SPF (spruce-pine-fir). These members were of low quality which meant that they had a finger joints. These joints are much weaker than the rest of the wood and are prone to failure. This is exactly what happened to our initial scissor lift, as can be seen in Figure 8. We were able to overcome this problem by rebuilding the entire the scissor lift out of maple which is a much stronger material. It also has the benefit of not having any finger joints.

Another problem that our design experienced under load was the bending of the bar where the force from the hydraulic cylinder was applied. The bar that we used for this purpose in our prototype has a hollow steel bar which was unable to handle the high forces applied in the middle. We fixed this issue by spot welding a reinforcing angle bar to the back side of the pipe. In general, to avoid bending, the best solution is to maximize the second moment of area, I, represented by the following equation:

$$\boldsymbol{I = \int_a y^2 dA} \qquad \textbf{\textit{(Equation 3)}}$$

where y is the distance from the centroid and A is area.

A common example of maximizing of second moment of area is in the “I” shape in I-beams.

3.5 MECHANICAL ANALYSIS

An analysis of the stresses in the horizontal bar of the prototype was performed to determine the maximum allowable force which could be applied to the center of the bar without plastic deformation. Since the horizontal bar is actually a steel pipe reinforced with an angle bar, it acts as a non-prismatic bar and was assumed to have simple supports with a centre load. Stress concentration at the points where the reinforced section begins was also taken into account. The critical point was found to be at the stress concentration and the maximum allowable force using a safety factor of 1.5 was found to be 303 pounds of force. Deflection in the bar was also calculated for this force and found to be 0.016 inches at the centre and 0.00857 inches at the critical point.

An analysis of the forces in the scissors was then performed to calculate the maximum allowable weight that could be lifted by the scissor lift prototype with respect to the applied horizontal force. Weight of the scissor itself was assumed to be negligible. The following equation was found:

$$F = \frac{\left(1 + \frac{2L}{l}\right) W}{tan\ \theta}$$

OR

$$W = \frac{F \tan\ \theta}{\left(1 + \frac{2L}{l}\right)}$$

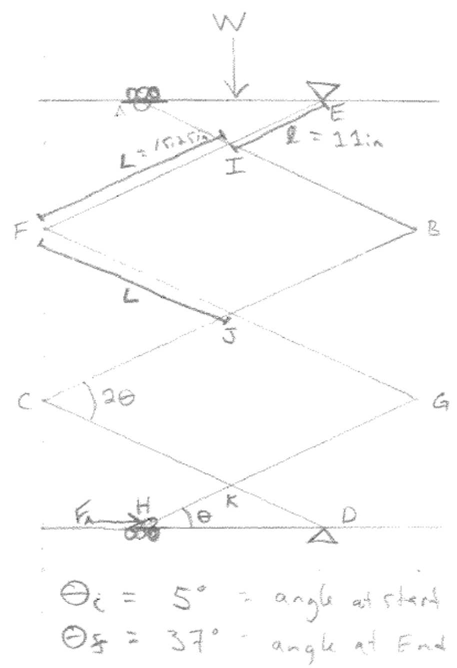


Figure 10: Diagram showing the forces acting on the scissor.

F = horizontal force applied
W = Weight on scissor
θ = angle of the scissor members
L = large distance between pins on members
l = small distance between pins on members

Once all valued were enter into the previous equation, it was found that the prototype could only support a force of 7 pounds without permanently deforming the horizontal bar on which the force is applied. This is a very small weight and leads us to choose a much stronger bar for the final design. This is because the final design would need to be able to lift a maximum weight of 120 pounds which requires 5175 pounds of horizontal force to lift. This also demonstrates that the hydraulic cylinder on the prototype would be insufficient and should be changed to a 3-ton rating.

Section 4: Revision and Optimization

Through the construction of our prototype and the simulations done using Comsol, we were able to prove that the design is feasible and is capable of mechanically lifting weight, as well as properly concealing the hot oil from the user and maintaining the outer layer of the waste at a safe, comfortable temperature for the employee. However, many improvements and changes are required to make this design perform to the best of its potential ability. After testing our design and performing a stress and strain analysis on its members, we were able to come up with a list of specific ramifications that would improve its overall performance, resistance and reduce its entire price.

- ***Consider another material for the scissor members and add lubrication:***

From figure 8, we can discern that the use of wood for our final design would definitely not make it strong enough to support the required design height. Using another material is strongly recommended to reduce cases of failure in the metal bar connected to the hydraulic cylinder. Our suggestion is to use A513 steel or aluminum structural rectangular tubes of the same size of those that were used in the prototype. These would significantly strengthen the scissor members, making them a lot sturdier and performant. The addition of lubricant in the scissor joints would also make the sliding movement more continuous and smooth, facilitating use and reducing the risk of accidents. Further tests would need to be done to figure out which material would be able to deliver the most optimal results, while keeping the price of the overall device affordable.

- ***Obtaining a better quality hydraulic cylinder and reinforcing the bar on which the force is applied:***

Because the hydraulic cylinder applies a lateral force to the system in order to lift it upwards, a great deal of strength is needed to push the design weight. A strong pressure force is applied to the horizontal bar due to the small point of application from the cylinder, which causes the bar to bend. To prevent this, it was suggested by supervisors at the engineering shop that we use a rectangular hollow bar instead, which would be much more resistant to bending. Having a better quality hydraulic cylinder would also improve the overall lifting capacity of our design and make the lifting process more, but consequently would make the design more costly. Once again, further calculations must be made in order to justify this, and really know whether it is the best option for our finalized design.

- ***Installing a spring and foot pump to raise the scissors instead of a hand pump***

The addition of a foot pump would facilitate the use of the apparatus for the employee. Although the tank will be insulated, it is not advisable for the worker to have to bend down under the hot oil disposal tank to raise the liquid by hand. If ever the device would be unstable, the tank could tip and fall directly onto the employee. Repeatedly having to bend down is a cumbersome task, we want to avoid this situation for it may make the design less attractive to the potential stakeholder.

Section 5: Conclusion

There is a need for new and innovative technologies for the handling of waste oil in commercial restaurants. Through the construction of our prototype, we were able to achieve our goal of proof of concept for our waste oil handling device. This device would drastically improve the safety of restaurant employees compared to business-as-usual methods. This device is also attractive to restaurant owners due to its relatively low cost and its compatibility with most restaurant designs. Finally, our device will help organizations such as the CSST promote safety in the workplace.

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