Human Tissue Cold Shipment

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Introduction and Motivation

- This project centered on the design and manufacture of a specialized cold shipment container able to keep human tissue (umbilical cords) at a temperature of 2-8°C for a minimum of 24-48 hours.
- Current transportation methods using a Styrofoam cooler led to significant financial losses and missed research opportunities due to rejected biomaterials.

Figure 1. Final Cold Tissue Shipment Product

- Stem cells harvested from umbilical cords are used in both research and therapeutic applications.
- Stem cells have the potential to treat a wide range of diseases and conditions, including blood cancers, heart failure, diabetes, and certain neurological disorders [1].

Device Design

Main Body
- Three separate chambers shown in Figure 2
- Insulation layer situated beneath the main chambers

Lid
- Integrated O-ring seals for a secure moisture barrier
- Built-in insulation layer
- Reinforced strap slots for secure fastening

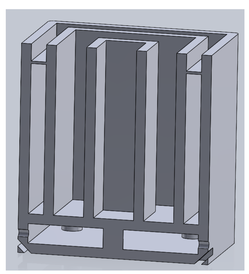

Figure 2. Half-section CAD Model

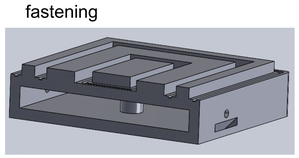

Figure 3. Half-section of the Lid

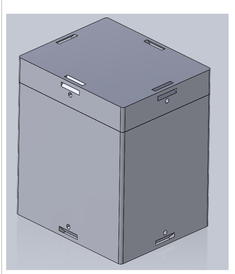

Figure 4. Full CAD design model

Materials
- Main body and lid made from Acrylonitrile butadiene (ABS)
- Straps are Velcro
- Rubber O-ring and silicone caulk

Assembly
- Velcro Straps feed through the slots in the lid and body
- Tightening the Velcro down once lid is in place
- The insulation chambers in both the lid and the bottom of the body were bonded to the desired areas with glue to correct inconsistencies from the 3D-printing process.

Manufacturing Methods

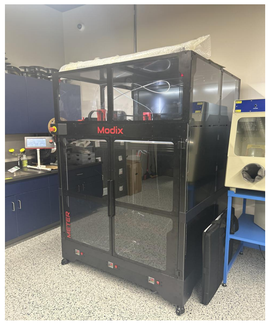

Figure 5. Modix Big-Meter manufactured the lid and bottom insulation chamber

Modix Big-Meter:
- Able to print large scale prints (1mx1mx1m)
- Supposed to be Faster than standard printers and much more precise
- Attachments to utilize 5kg spool and utilize different heads

Modix Complications:
- Had to create our own spool holder due to the sizing constraints in the printer location
- Many Calibration issues causing the prints to stagger in the x direction mid print
- Issues with sealing in the door forced the prints to lift in the corners off the build plate

Qidi Tech X-Max
- Very fast printing, with very detailed prints
- Can print relatively big models (.3mx.3mx.3m)
- Printer can either be completely enclosed or open depending on material
- Very advanced settings, many different variables easy to change

Qidi Tech X-Max Problems:
- Due to complexity of splicing software, ABS took multiple attempts to get the setting correct

Figure 6. QIDI X-Max3 manufactured the body

Testing / Results

Sterilization Testing
- Conducted to ensure device could be effectively sterilized between shipments
- Bacterial species staphylococcus epidermidis on agar and in tryptic soy broth (TSB)

Turbidity via plate reader:
- Acrylonitrile Butadiene Styrene (ABS) sample from our senior design group.
- All samples such as PP and ABS without sterilization are similar to empty cells
- TPU is antimicrobial, leading to unexpected result for turbidity

	Empty	ABS	PP	TPU
	1	2	3	4
Control A	0.048	0.049	0.049	0.049
Sterilized B	0.048	0.050	0.050	0.048
No Sterilization C	0.048	0.384	0.287	0.049

Figure 7. Plate reader results for turbidity with three samples of each material, measurements in NTU

Testing / Results

Bacteria Growth:
- Agar plate sections:
  1. C: No bacteria, no sterilization
  2. B: Bacteria, no sterilization
  3. S: Bacteria and sterilization

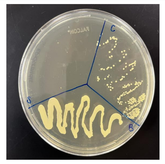

Figure 8. Bacteria growth plate

- These results demonstrate that the sterilization method using 70% isopropyl alcohol was effective in eliminating all bacterial presence.

Tensile Testing
- Stress-strain curves confirmed uniform mechanical performance across samples.
- 15 ABS dogbone specimens printed horizontally; 5 valid tests selected per ASTM D638.
- Average **maximum load**: **243.3 lbf**
- Average **tensile stress at max load**: **2037.8 psi**
- Demonstrated consistent **ductility**, with average **strain at max load**: **0.020 in/in**

Figure 9. Tensile Testing specimen

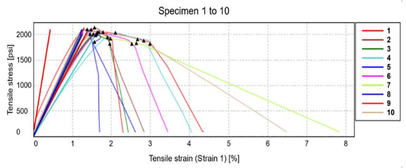

Figure 10. Tensile Testing Stress-Strain Curve

Compression Testing
- Validated ABS's ability to resist stacking and transit forces.
- 6 cylindrical ABS specimens tested; 5 valid results used.
- Average **compressive stress at max force**: **20.16 MPa**
- Average **maximum force sustained**: **10.03 kN**
- Specimens showed consistent deformation profiles across trials.

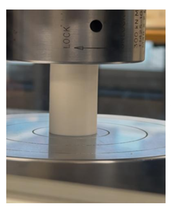

Figure 11. Compression Testing specimen

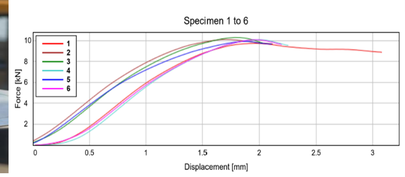

Figure 13. Compression Testing Max Load

Moisture Testing
- To assess the moisture resistance of our 3D-printed ABS material, we performed a dye penetrant test on specimens that replicated the wall thicknesses of the final cooler design.
- After applying the dye, no penetration was observed on the opposite side of the specimens, indicating that the material effectively prevents moisture ingress. These results validate that the cooler's design will provide reliable protection against moisture during transport, ensuring the integrity of the contents.

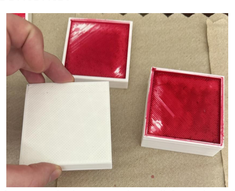

Figure 14. Dye penetration results on 3D printed (ABS) specimen

Testing / Results

InTemp365:
- Temperature sensors and logging allow real-time validation during transport
- Bluetooth temperature logger with up to 1-year data storage
- Ideal for Cold Chain, CRT, and Frozen shipments
- Mobile app for easy setup, alarms, and data downloads
- Optional CX Gateway for remote alerts and automatic downloads

Specs:
- Range: -30°C to 70°C (-22°F to 158°F)
- Accuracy: ±0.5°C to ±1.0°C
- Resolution: 0.04°C

Figure 15. InTemp365 measuring device [2]

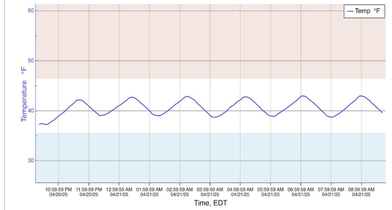

Figure 16. Generic data graph provided by the InTemp365

- The InTemp mobile app directly connects to the device.
- The temperature thresholds are represented in red and blue.
- It time-stamps each measurement every hour.

Conclusions

- Cooler maintains internal temperatures of 2 -8 °C for 24-48 hours
- Structural design withstood handling stress in testing and meets ASTM D638 standards
- Moisture barrier passed ASTM E-1417 testing to prevent internal condensation
- Cooler dimensions fall within original shipping requirements
- Temperature sensors and logging allow real-time validation during transport
- Container can be reused, promoting sustainable practices
- Design demonstrates real-world feasibility for tissue shipment

Literature Cited

[1] "Stem cells: What they are and what they do," Mayo Clinic, https://www.mayoclinic.org/tests-procedures/bone-marrow-transplant/in-depth/stem-cells/art-20048117.
[2] Bluetooth 365 day multiple-use temperature data logger CX503 | INTEMP Monitoring Solutions, https://www.onsetcomp.com/intemp/products/data-loggers/cx503.

Acknowledgements

MECHTEK
TRINE University Angola, Indiana
TRINE innovation 1

Contacts

Tanner Goff | Clay Dean | Trevor McKinnon | Isaac Henry