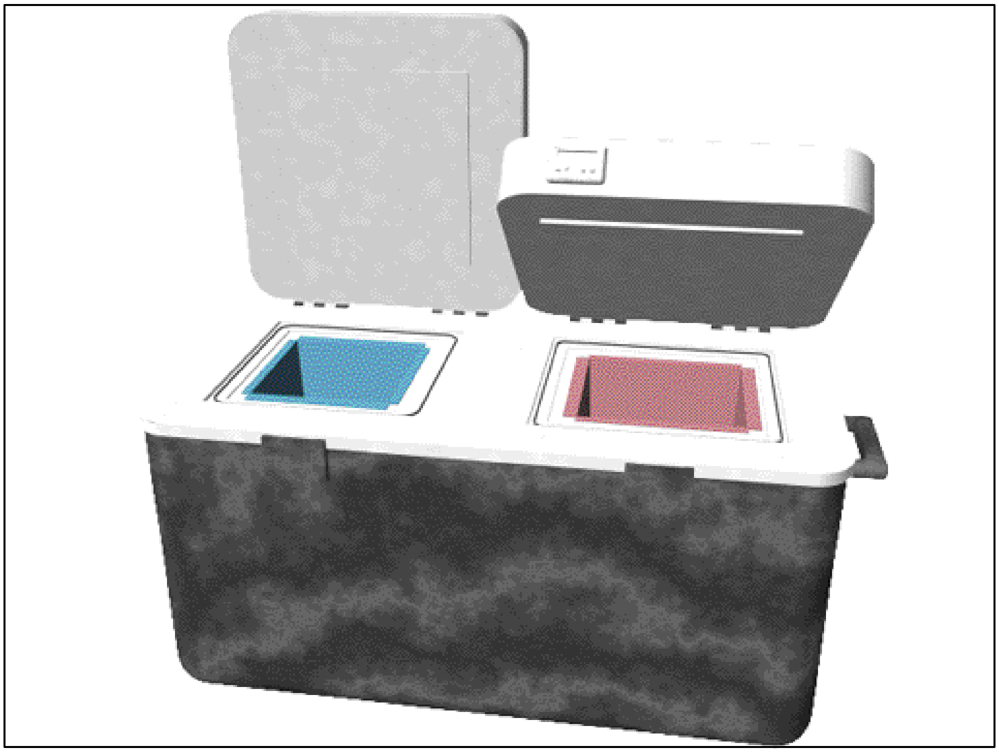
The Vaccine CO2ler

Reaching beyond the limits…



Background

Says Dr Gro Harlem Brundtland, Director-General of the World Health Organization, "Nearly two million children worldwide still die needlessly each year of vaccine-preventable illnesses." The majority of these deaths occurs in developing nations all over the world, specifically in remote villages.

The problem, it turns out, is not lack of funding to produce and transport these life-saving vaccines, but rather a technological gap in a transportation issue, known in the health industry as the Cold Chain. Vaccines must be kept within a temperature range of 2 to 8 degrees Celsius from the time of manufacture to the point of administration. Once the vaccines leave this temperature range, they are considered damaged and must be thrown away. Keeping vaccines within this tight temperature range turns out to be difficult as they are shipped to more and more remote locations, with layovers and flight cancellations often causing the shipments to take several days to reach their final destination. A corollary to this problem is the inconvenience of having to re-pack ice at various steps of the transport.

The current method of keeping vaccines at temperature (used by charity organizations such as Doctors Without Borders) is to pack them with ice into a standard foam cooler. This works as long as ice is readily available every few hours to replace what has melted. As the vaccines get further away from developed cities, electricity, and therefore refrigeration and freezing capabilities dwindle. The result of this is a small radius of area around the final point of electricity to which the vaccines can be transported before spoiling. Although this ice-packed cooler is a very inexpensive option, it comes at the high price of occasionally spoiling shipments of vaccines. Not only does this become a monetary expense, but the damage also occurs at the cost of many lives.

Finally, dry ice and paraffin powered coolers are available which can hold the necessary temperature for a few days. Unfortunately, none of these are tailored to the market of transporting vaccines to the third world, presumably because this is a low-profit market. The various existing products are either too large, too expensive, or don't hold their temperatures long enough to ensure that vaccines will make the entire journey without needing to re-fuel. In addition, the majority of these containers are rent-only, which further drives up the price of transport.

Innovation

The CO_2ler is a rugged, dry ice-powered portable vaccine cooler which can keep vaccines at proper temperature for up to 6 days at 90F ambient temperature. The name CO_2ler comes from the fact that dry ice is carbon dioxide, or CO_2. In addition to the dry ice, 6 D-cell batteries are used to power fans which assist the control system in maintaining the required temperature. The CO_2ler has 14 liter vaccine capacity to match the 10 liter dry ice capacity. It weighs 35 pounds without dry ice, vaccines, or batteries. When dry ice, vaccines, and batteries are added to the weight, it totals around 50 pounds. The CO_2ler is the size of a large ice cooler, approximately 3ft by 2ft by 2ft, and, depending on the vaccine type and packaging method, can carry up to 30,000 doses.

Inside the CO_2ler are two chambers – one for vaccines and one for dry ice. There are separate lids for these chambers so that vaccines can be removed from the cooler one by one without gaining too much ambient heat through opening the dry ice lid. These lids are marked so as to ensure that vaccines and dry ice are put in their proper compartments. Attached to the bottom of the dry ice chamber is an aluminum heat exchanger, or series of air passages in thermal communication with the dry ice. Air circulates through the vaccine chamber and returns to the heat exchanger for cooling, never mixing with the carbon dioxide air in the dry ice chamber. See Figure 1. This is important because vaccines cannot risk being exposed to such chemicals.

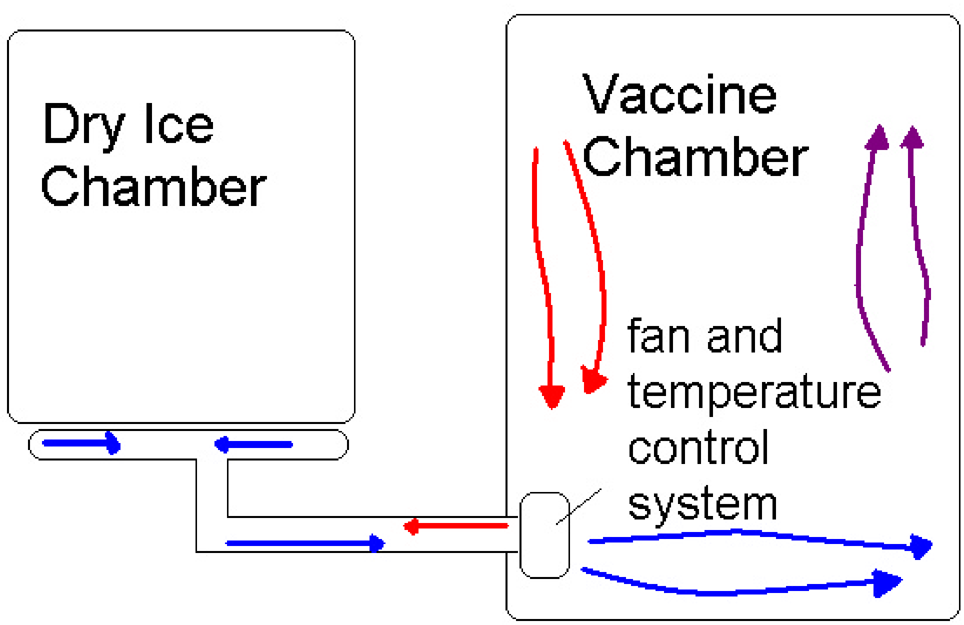


Figure 1. ***Schematic of Air Circulation Through Inside of CO_2ler.***

The user interface to the cooler is a simple selectable menu, as show below in Figure 2. When the cooler is first powered, the cooler is in 'locked' mode. To unlock, user follows instructions on screen to push 'up', 'down', and 'enter' buttons. Once the cooler is unlocked, there are several menu options for setup. The first menu option is to view current settings. When no settings have been made for vaccine cooling, this option, when selected, prompts the user to select preferences. The second menu option is to select the type of vaccine user wants to keep cool. The CO_2ler has some pre-programmed vaccines in the menu. Different vaccines require different temperature ranges, though the majority are in the 2-8 C range. The CO_2ler is optimized for this temperature range but can hold temperatures as low as -20 degrees Celsius for up to 2 days. If the desired vaccine is not pre-programmed into the menu, it is possible for the user to choose 'custom' and to define his or her own desired temperature, acceptable deviation, and critical temperature. The critical temperature is the temperature at which the vaccine is considered spoiled. If the vaccine reaches its critical temperature, a flashing alarm will appear on the display screen until the cooler is turned off. This ensures that, in case anything goes wrong, ineffective vaccines will be identified. Once the mode on the cooler has been set, the control system automatically goes into 'locked' mode to prevent changes in preferences if buttons are accidentally pushed during shipment.

Figure 2. ***Photograph of CO_2ler User Interface.***

The control system within the CO_2ler is a very simple one, with a temperature sensor in the middle of the inside surface of the vaccine chamber lid. Because of convection, this would be the highest temperature location in the chamber. If the sensor detects that the temperature of the vaccine chamber has exceeded the acceptable deviation, the fan is turned on. With the fan running, the cold air from the heat exchanger is pulled into the vaccine chamber, lowering its temperature. When the temperature falls below the acceptable deviation, the fan is simply shut off. Because the vast majority of places vaccines are needed have ambient temperatures greater than the desired vaccine temperature, there is not much concern about the vaccines getting too cold. For this reason, no heating system was installed in the CO_2ler to prevent against over-cooling.

Before the transport of vaccines can begin, the dry ice chamber must be completely filled with either a block of dry ice or dry ice pellets. Dry ice is readily available in any major city of a developed nation which might be manufacturing vaccines. It is also relatively cheap, with each 10 liter payload costing approximately seven dollars. In addition to the dry ice, 6 fresh D-cell batteries must be used. The number of batteries required is based on a worst-case calculation of how much power the fan and control system would need if they were in use constantly for 6 days (the upper time limit of keeping the CO_2ler at temperature). D-cells were chosen because they also are readily available in a major city of a developed nation from which the journey of the vaccines might originate.

The CO_2ler is able to hold its low temperature for such a long duration not only because of the dry ice and batteries, but because of the high-performance insulation used. The insulation is an evacuated polystyrene whose thermal conductivity is half that of air. A thermal reflector is used as a lining to the CO_2ler both on the inside of the insulation and on the outside to make the insulation even more effective.

The CO_2ler has been subjected to drop tests to ensure that it is rugged enough to be transported by companies such as Federal Express or on any commercial air carrier. It was designed so that it could be used throughout the cold chain both to increase number of reachable patients and to improve the logistics of this transport problem.

In the design of the CO_2ler, tradeoffs had to be made between total size, payload, and cold time. Because of the high price of vaccines, it is worth the cost of shipping a large container with a comparatively small payload if it means the vaccines are guaranteed to reach their destination at proper temperature. As the goal of the CO_2ler was to transport vaccines to the most remote villages, which currently are unreachable due to the cold chain, cold time was optimized with a minimum payload size of 14 liters. Fourteen liters is large enough to hold enough condensed packaged vaccines for all the children in a medium-sized village.

The average cost per use of the CO_2ler, based on a conservative lifecycle estimate of 50 trips per container, is $20, including dry ice and fresh batteries. Although this technology at first appears to be far more expensive than its most prevalent competition, a styrofoam cooler packed with ice, it in fact saves money in preventing expensive vaccines from ever spoiling.

Because of the simple design of the CO_2ler, the cooler scales quite nicely and the design could quite simply be changed to accommodate a larger payload at the price of a shorter cold time. Alternatively, the price of the CO_2ler could be reduced by using a cheap insulation rather than the high-performance evacuated polystyrene, thus shortening the cold time. This design can be easily changed to meet the user’s needs.

Implementation

A fully function prototype of the CO_2ler has been made and tested, and full-scale manufacturing plans have been thought out. A business plan has been though through and written for the scenario that a company is started in order to manufacture the CO_2ler. Potential customers have been contacted and interviewed for improvement ideas.

The transport of vaccines to developing nations, a $320 million per year market, is not the only market for the CO_2ler. There are also chemical, pharmaceutical, and medical research companies in the United States which must transport samples and products at specific temperatures. This secondary market is extremely large, with $3.5 billion spent each year in perishable cargo. Between these two markets, the CO_2ler has great potential.

At this point, two options exist for turning the CO_2ler into a marketable product after a patent is obtained. First, the patent could be licensed to a shipping company, such as Federal Express. This is a strong implementation plan because return of empty containers would be easy. Second, a company could be started selling vaccine coolers exclusively. It is difficult to determine whether or not this would be an appealing option to customers, but based on business plan assumptions (see Appendix A), could be a profitable business.

One of the greatest challenges to the CO_2ler is limitations created by dry ice, which is considered a hazardous material and prompts a fee by air freight companies. With more time and funding, it would be wise to further investigate alternative coolants.

Another challenge to the CO_2ler is the wide range of requirements in the field. Based on travel time and distance, transportation mode, vaccine type and packaging type, and village size, various ratios of total cooler size to payload size are appropriate. Although it is easy to change the design and produce a different balance of total size, payload, and cold time, this requires manufacturing a new product, instead of making quick modifications to an existing one. Making the CO_2ler more modular would greatly increase its utility.

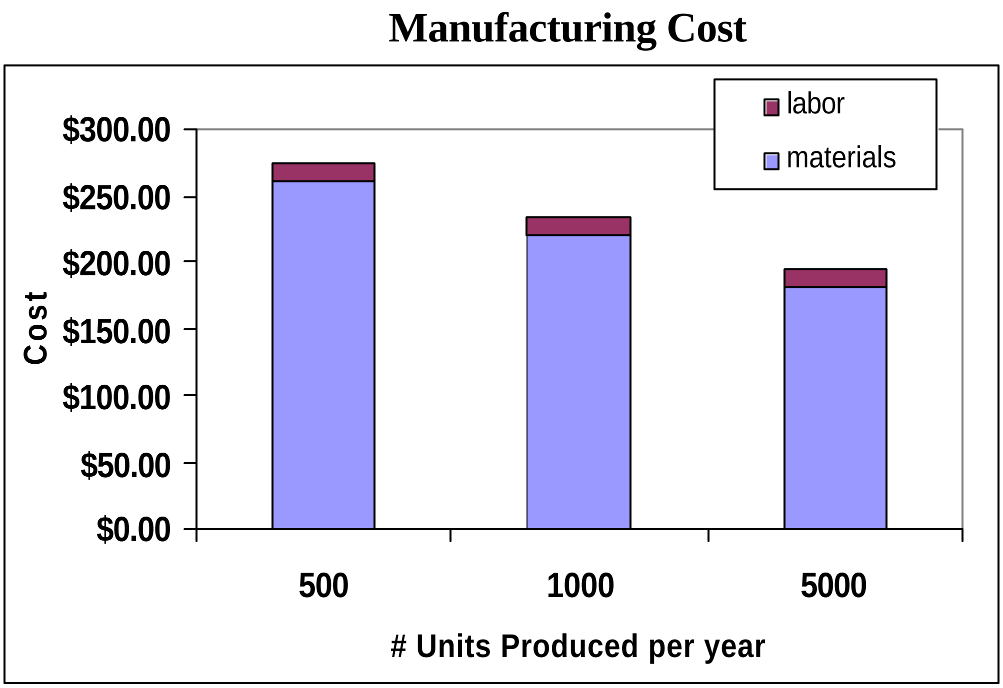
In an effort to further develop this product, contacts at both Federal Express and at the Tropical and Geographic Medical Center in the Division of Infectious Diseases at Massachusetts General Hospital (MGH) will be utilized. These two potential customers can help illuminate improvement areas.

Summary

The CO_2ler is a low-cost solution to the cold chain, and can be used not only to save the lives of the millions of children dying each year of preventable diseases, but also to improve the logistics of the cold chain, creating convenience for charitable organizations attempting to transport vaccines.

With its secondary market as a support, the CO_2ler is a viable product which, with some work, could be a vast improvement to the current system.

Appendix A. Business Plan



Projections:

Cooler Cost: $470
Steady-State Sales: 6,000
Profit Margin: 10%
IRR: 31%