Milestones in Civilization
from the
Cryogenic point of View
Class of 2008

The First Cryogenic Wager

Cornelius Drebbel

King James 1

- In 1620 Cornelius Drebbel bet King James 1 that he could turn summer into winter in Westminster Abbey. Drebbel added salt to a ice and snow mixture in several jars and turned a fan to blow air over the jars. This turned warm air to cold air and was the first attempt at an air conditioning system.

1773: Johan Goeze Discovers Water Bear

The first Tardigrade, commonly known as the "water bear" was observed. One of the most resilient animals on earth, the water bear can survive temperatures 151°C, -272°C. (1° warmer than absolute zero), 5,700 grays of X-ray radiation (humans can withstand 10- 20 grays), with .01% of normal body water content, and has been proven able to survive in the vacuum of space.

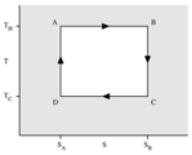
This animal is a heavily researched organism in the field of Cryobiology, and has been the center of research for a lot of cryonic preservation studies to discover how it is so successful at stopping and starting its metabolism in order to survive such extremes. Its discovery was surely a milestone in cryogenic history, as the research of its unusual capability helped to found a biological need for Cryogenics

William A. Alvarez
PHY 4550

Nicolas Léonard Sadi Carnot June 1, 1796 -
The Father of Thermodynamics August 24, 1832

French Physicist who theoretically discovered the principles of heat engines, the Carnot Cycle, as well as the concept of entropy within the second law of thermodynamics.

Carnot realized that thermodynamic cycles can be reversed. From this came the first practical definiton of entropy.



By reversing the cycle in a heat engine, the process will work as a heat pump or a refrigeration cycle. This process of reversibility allowed physicists to make systems colder using the technology available to them at the time.

Michael Chin [image courtesy wikipedia]

1834 – Charles Thilorier

Discovered solid CO_2, later to be named "Dry Ice", by opening a container of liquid CO_2 to look inside, the evaporation caused cooling which formed solid crystals in the container.

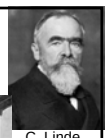
Important for:

- Ice Cream making
- CO_2 source
- Carbonation of liquids
- Blast Cleaning
- Spooky Halloween Decorations

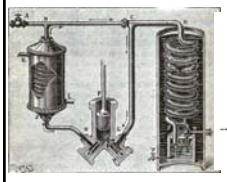
Dry Ice Pellets

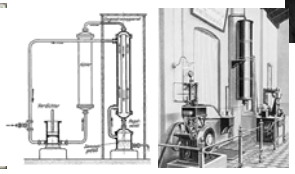
Spooky Jack-o-Lantern

Marcus Bagnell

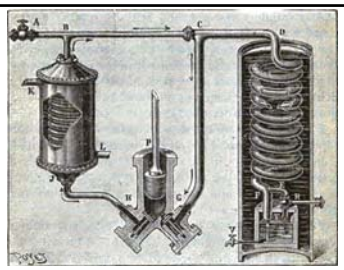


C. Linde



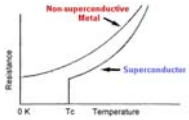


The Hampson-Linde Cycle, independently patented by W. Hampson and C. Linde in 1895, utilizes the Joule-Thomson effect to cool gases (air) by letting the gas molecules expand freely against the atmosphere. In essence, the gas is doing work against the atmosphere by lifting and/or heating it, and thereby it loses energy in the form of heat (and thus it is cooled). Linde was the first to use this mechanism to liquefy air in 1895. His air liquefaction machine is shown here (Liquid Air and The Liquefaction of Gases)



The air enters through the pump at *G*, is forced through *H* compressed and thereby heated. The heat is removed in the condenser, *J*, and the compressed air at the temperature of water goes on to *D*. Pipe *B* is of smaller diameter and runs straight on to D and is bent in a coil which descends to *E* & *T*. Note that from *C* to *F* pipe *B* is surrounded by a second pipe concentric with it and it is this outer pipe which is connected to the pump suction. From *D* it descends in the inner pipe of the double coil, expands through *R* and is cooled. Then it passes through *T* and up through *F*, the outer pipe of the coil. Here it cools the air in the inner pipe of the double coil. **Thus the air reaches the valve *R* at a lower temperature than before, so that is constantly falling in temperature, and reaches *R* at lower and lower temperatures, until eventually the critical temperature of liquid air is reached and passed and the liquid air begins to collect in the chamber**. It can be collected at the faucet *V*.

1911 – Onnes discovered superconductivity



Superconductors are materials that have no resistance to the flow of electricity. Superconductivity was discovered in 1911 by Heike Kamerlingh Onnes, who was studying the resistance of solid mercury at cryogenic temperatures using the recently-discovered liquid helium as a refrigerant. At the temperature of 4.2 K, he observed that the resistance abruptly disappeared. Later, in 1913, he won a Nobel Prize in physics for his research in this area.

Onnes studied mercury in what state?

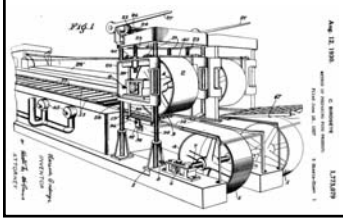
A. Gas
B. Liquid
C. Solid
D. Plasma
E. Florida

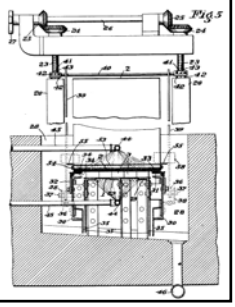
Clarence Birdseye

Flash Freezing of Food

By freezing the food at a much higher rate, ice crystals that would normally puncture cell walls are kept from growing too large, thus allowing flavor to be preserved.

After the food is packed tightly box container with thin walls, the container is then put on a conveyor belt which compresses the food product between two metal plates which are kept at below -17° C. The plates are cooled through the use of 'freezing fluids' (from patent).

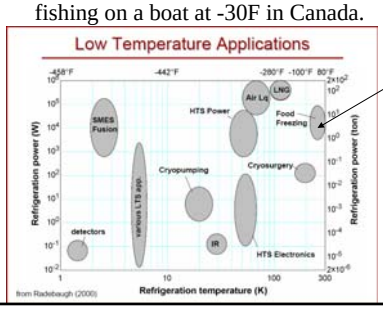




Flash Freezing Food

What is it?

- It is a technique that freezes food quickly.
- Discovered by Clarence Birdseye in 1912 while fishing on a boat at -30F in Canada.



Why using it?

- Contrary to regular freezing, flash freezing does not make ice crystals to grow, minimizing cellular damage, therefore food tastes better.
- It preserves moisture.
- Food last longer.
- Kill some worms and their larvae.
- Provides fruits and vegetables all year-round.
- Fishing ships can go far into the ocean for days.
- Ultimately, It let cities to expand.

Some Cryogenic Substances Used

- Liquid Carbon Dioxide
- Solid Carbon Dioxide (Dry Ice)
- Nitrogen
- Argon
- Hydrocarbons
- Cryoprotectants (i.e. ethylene gl propylene glycol, glycerol)

Common Techniques

- Food is placed in direct contact with cryogen substance (i.e. immersed in Liquid nitrogen o placed with carbon dioxide pellets – "dry ice"
- Food is placed between to metal plates that a frozen by circulating cryogenic liquids inside the plates (i.e. Calcium Chloride; frozen vegetables w/ square shape).

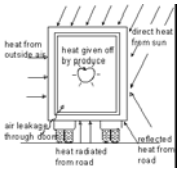
Contact Belt Freezer

Techniques (cont.)

- Food is frozen by placing it into freezer tunnels (a.k.a cryogenic freezers) where a cool substance flows (i.e nitrogen vapor -40 C; carbon dioxide).
- Food is later transported and n cryogenic freezers.

Cryogenic Freezers

Trucks are insulated and refrigerated.



Some food products that use Cryogenic Flash Freezing

Fish

Meat

French Fries

Frozen Vegetables

Frozen Fruits

References

Smith, P.G, Introduction to food process Engineering, Springer 2003.

Fellows, Peter, Food Processing Technology: Principles and Practice, Woodhead Publishing 2000.

University of Oregon, http://www.uoregon.edu/~rjd/absolute.htm.

University of Texas, http://www.uthct.edu/drmom/sushi.asp

Oregon State University, http://oregonstate.edu/dept/ncs/newsarch/2007/Feb07/deepseafish.html

University of Wisconsin, http://www.irc.wisc.edu/file.php?id=190.

Images:

thepauperedchef.com

http://images.jupiterimages.com/common/detail/98/64/23476498.jpg

http://www.happybumblebee.com/blog/i/BLOG_060212114539_BUMBL/Image/2006/March/Smoothie/20060327_IMG_9442.jpg

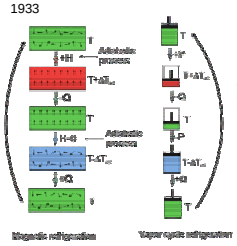
http://semba.utk.edu/travelogue%202004/images/Photo1011000.jpg

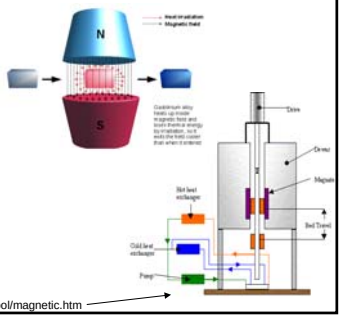
http://www.advancedfreezer.com/contact_belt.html

Magnetic Cooling

First time at temperatures below 1K – 1933

- Fundamental principles by Debye (1926) and Giauque (1927)
- The first experiments with this method were carried out by Giauque and MacDougall in 1933



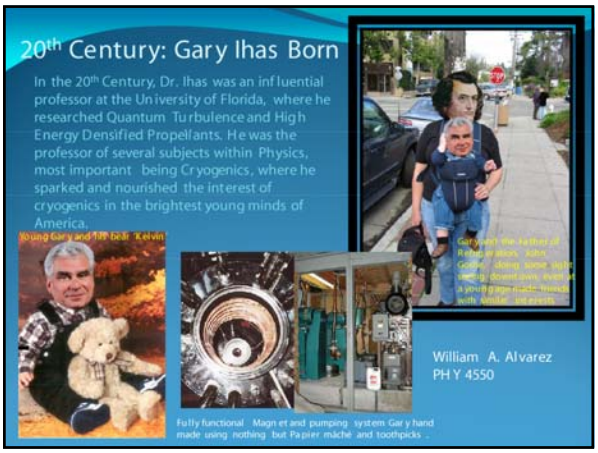


Analogy between magnetic and conventional refrigeration.

http://projects.bre.co.uk/cool/magnetic.htm

How many moving parts are there in the demagnetization refrigerator?

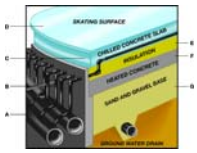
A. Zero or
B. One
C. Two
D. Five
E. ~10^{23}



By James Stankowicz

Ice Rinks and Zambonis

This combination allows us to enjoy figure skating, hockey, speed skating, and curling regardless of location and time of year.

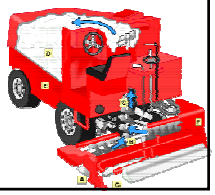


Making Ice

A - Coolant pumped from refrigeration system (often water mixed with antifreeze or salt)
B - The coolant(<0°C) is pumped into a concrete slab
C - The concrete slab cools to just below 0°C, freezing the water on top of it
D - The actual skating surface is often alternating layers of ice and paint
E - Insulation allows the ice layer to expand and contrast as required
F - Heated concrete protects the base layer from freezing and cracking
G - The rink base supports weight and contains a ground water drain
The Glaciarium in Chelsea, London was the first such mechanical ice rink, and opened in 1876

Maintaining Ice (Zamboniing)

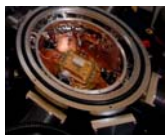
A - A large blade cuts and removes old ice
B & C - Augers transport the cut ice to the front of the Zamboni
D - The bucket where the cut ice is stored is emptied after every use
E & F - A water supply is pumped into a blaster, that sprays the cut ice, loosening debris, and preparing the old ice to bond with the new water molecules
G - A rubber squeegee removes the dirty water and lays down warm water which bonds well with the loosened ice, resulting in one smooth layer instead of two separate layers
Frank J. Zamboni invented the engine powered Ice Resurfacer in 1949



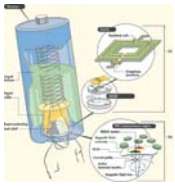
Rodrigo I. Ocampo

Cryogenics in Supercomputing

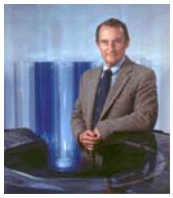
- On earlier supercomputers the processors and memory are submerged in cryogenics fluids to lower the temperature at which they work fastest
- Electrical resistance in metal alloys reduces dramatically at cryogenic temperatures sometimes behaving as superconductors
- Very large-scale integrated circuits of older supercomputers depending on their size, capacity and power level, need varying levels of heat dissipation up to 25 kW at 80K
- The baseboards operate fully immersed in a bath of liquid nitrogen



Georgia Institute of Technology 500GHz. Cryogenically cooled down to 9K



Brain imaging device to measure brain waves. Superconducting Quantum Interference Device (SQUID)



Seymour Cray: inventor of the supercomputer and cryogenic cooling

Space Cryogenics – Application to Telescopes

- Most important in infrared astronomy due to telescopes emitting infrared radiation, producing distorted, noisy images.
- First used in the IRAS(1983) and COBE(1989) missions using dewars of liquid helium. However, liquid cryogens vaporize, limiting the mission lifetime.
- Solid cryogens such as neon, hydrogen, and nitrogen are also used, but can only reach about 6 K
- New systems have been developed and placed on missions such as the Spitzer Space Telescope using closed cycle refrigerators, allowing temperatures to reach as low as 0.05 K

Cryogenic Milepebbles: The Frozen Zoo

- Modern zoos cryogenically preserve animal and plant genetic material
- Despite human destructiveness, species can now survive apparent extinction
- True impact on civilization will be recognized in generations to come… but the seeds have been sown today due to cryogenics

Thermoacoustic Refrigerator

1990

None of this work would have been possible if it had not been for the work of Greg Swift at Los Alamos National Laboratory. His work on the thermodynamics of the thermoacoustic process led to the development of prototype refrigerators in 1990. These models applied the thermoacoustic effect to the stirling engine.

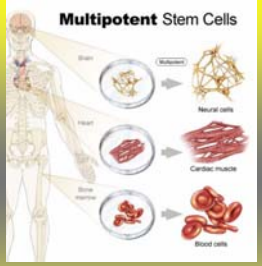
This device uses sound waves for cooling instead of chemical refrigerants linked to global warming. It has a simple design and has no moving parts. In 1999 Steven Garrett developed the first working thermoacoustic refrigerator to be used outside a lab.

1999

Ben and Jerry's sponsored Dr Steven Garrett at Penn State to create thermoacoustic freezers to replace the conventional freezers in their stores.

Charles Harriott

Cryogenic Preservation of Umbilical Cord Blood



- Stem Cells are widely regarded as the future of modern medicine.
- Umbilical cord blood is rich in stem cells which is collected at birth and cryogenically banked.
- Stem Cells from cord blood have been thawed and used to cure the owner of the blood as well as siblings, parents, and donor matches of diseases previously thought incurable.
- The collected blood is processed to decrease sample volume and stored directly in liquid nitrogen with a cryoprotectant. The duration of storage does not adversely effect cell quantity.

Cryosurgery

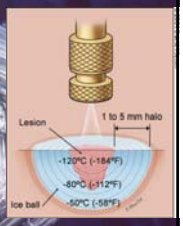
And It's use for common skin conditions

Can be used to treat:

- **Warts Moles Skin Tags**
- **Solar Keratoses**
- **Small Skin Cancers**
- **Various Internal Disorders**

Advantages Include:

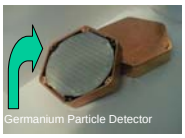
- **Short prep time**
- **Low infection risk**
- **Minimal Scarring**
- **No Sutures**
- **No expensive supplies**



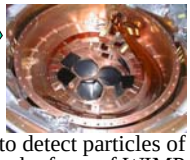
Cryosurgery devices. *(Left)* Cotton-tip applicator. *(Center)* Liquid nitrogen spray. *(Right)* Cryoprobe.

Timed spot freeze technique used to treat a malignancy demonstrating freeze ball formation

Cryogenic Dark Matter Search (CDMS)



Cryostat Used in CDMS



- The CDMS is an experiment designed to detect particles of dark matter passing through the earth in the form of WIMPs (Weakly Interacting Massive Particles).
- Semiconducting Germanium plates the size of a hockey puck are cooled to milikelvin temperatures at underground facilities (to reduce background noise) and the dark matter particles passing through these detectors cause a slight rise in temperature due to interactions with the Germanium nuclei.

What is the STP boiling point of LN_2?

A. 4.2 K
B. 20 K
C. 77 K
D. 87 K
E. 90 K