Science Project – Mr. Adamson
Katie Russell
Date: March 22, 2009

Question:

- What environmentally benign chemicals or materials can be used with water to match the phase change characteristics of commercial -23ºC phase change gels (made with a high concentration of salt)?

Phase change: When a sate of matter changes from one form to another.

There are four states, or phases, of matter. They are:

- Solid
- Liquid
- Gas
- Plasma (however, some may say plasma is a form of gas)

Hypothesis:

- Each gel mixture will have a different solid to liquid phase temperature.

Equipment and Material List

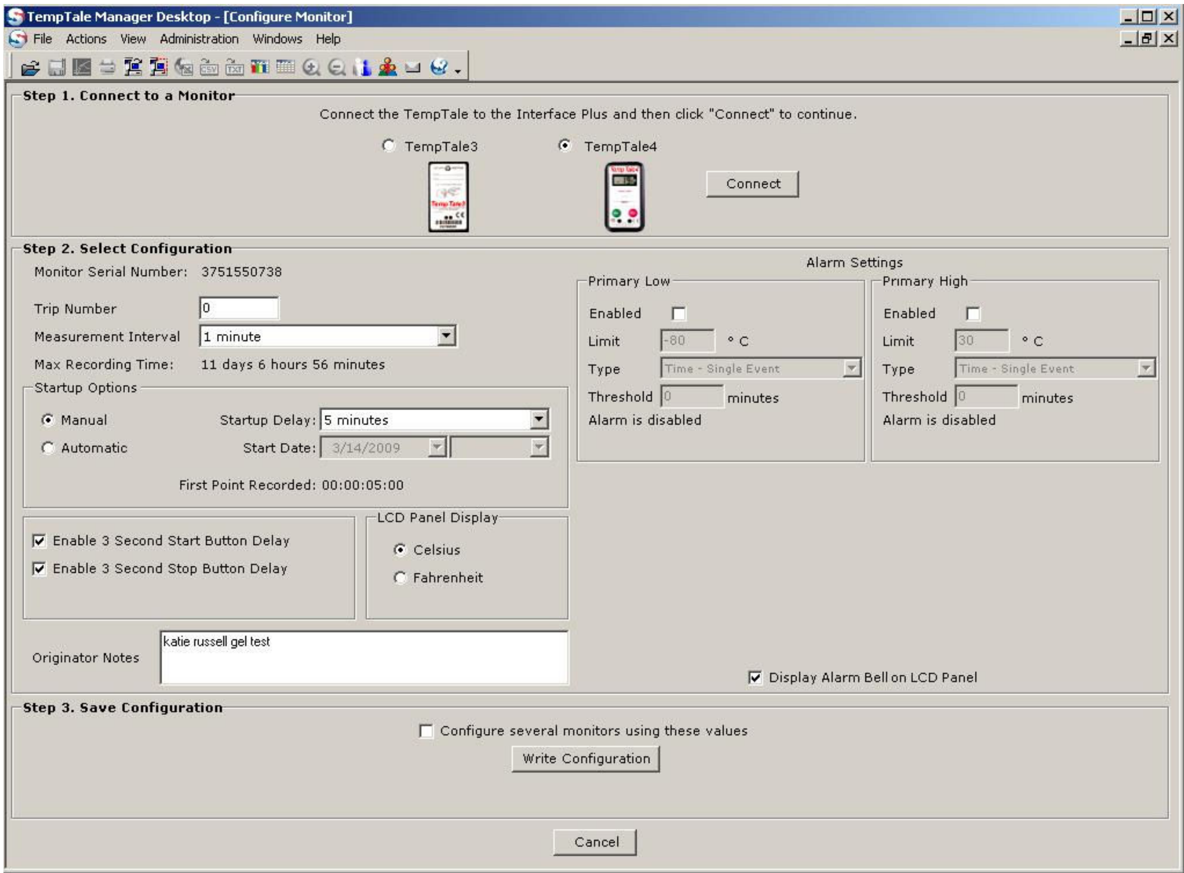
- Commercial Gel Packs
  - ColdIce phase change material -10° F FORMULA
  - ThermoSafe – U-tek® phase change material. (-10ºF/-23ºC)
- Saw Dust (common wood)
- Table Salt (Sodium chloride) - NaCl (CAS number 7647-14-5)
  - Solubility in water 35.9 g/100 mL (25 °C)
- Baking Soda (Sodium bicarbonate) - $NaHCO_3$ (CAS number 144-55-8)
  - Solubility in water 7.8 g/100 ml (18 °C)
- Potassium formate - $CHKO_2$ (CAS number 590-29-4)
  - Solubility in water 3.28 g/100 mL at 0 °C / 5.98 g/100 mL at 120 °C
- Sodium Sulfate Anhydrous - Na_2SO_4 (CAS number 7757-82-6)
  - Solubility in water 4.76 g/100 ml (0 °C) / 42.7 g/100 ml (100 °C
- Guar Gum (CAS number 9000-30-0)
  - A polysacharide (a long chain made of sugars) made of the sugars galactose and mannose.
- 16 Temperature data loggers w/ software (TempTale 4 – Sensitech)
- 7 Insulative containers (Invirtogen "Mini")
- 7 Nalgene 500ml wide mouth square bottles
- 7 Polyethylene bags
- Deep Freezer (-80°C) or 40 lbs dry ice pellets/blocks (Airgas)
- 1 Data logger sheet
- 1 Gram scale
- 1 Graduated cylinder
- 1 Mixing bowl
- 1 Mixing whisk
- 3 spoons
- 3 plastics beakers
- 1 Bag heat sealer
- Proper safety equipment
  - Gloves, eye protection, dust filter mask

Procedure

1. Collect all materials
2. Put on proper safety equipment (gloves, eye protection, dust filter mask)

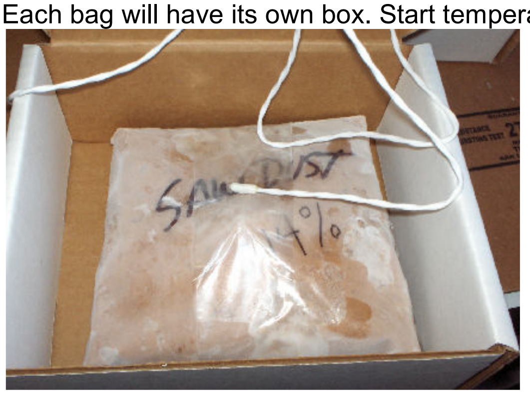
3. Mix each gel recipe
    - Make sure all equipment is clear and dry
    - Determine quantity of material desired and determine component weights based on percentages
        - Example: 91% water, 7% saw dust, 2% Guar Gum
            - 500 grams = 455 grams water, 35 grams saw dust, 10 grams Guar Gum
    - Weight out each component into plastics beakers (zero scale to empty beaker weight).
    - Mix dry powers together in bowl with mixing whisk.
    - Mix in water and whisk for 5 minutes.

    - Measure out mixture and place in container (bottle or bag)
    - Seal container
    - Let stand for 24 hours before freezing (industry advise – needs to “setup”)
4. Freeze containers below -50C with dry ice or deep freezer for a minimum of 24 hours to remove most all of the heat energy.
5. Program TempTale4 temperature data loggers – use the following settings



6. Place temperature probes
   - For bottles - remove container from dry ice, drill probe hole, and place the temperature probe in probe hole. Place inside insulative cooler. Each bottle will have its own insulative cooler. Start temperature data logger.

   - For bags - remove container from dry ice, tape temperature probe to side of bag. Place inside a box to reduce air flow effect. Each bag will have its own box. Start temperature data logger.



7. Start ambient temperature logger.
8. Run test until temperature of all containers reaches the same temperature as the ambient temperature logger.

9. Turn off all data loggers.
10. Down load data loggers and analyze data.

Data & Observations

- Mixture
  - Determining amounts – I used the internet and Wikipedia (http://www.wikipedia.org/) to learn about the chemical properties and their solubility. As some of the solubility information was presented at 0°C and 100°C in water – I had to calculate what the right amount should be at normal room temperature (20°C). Below is an example of that work:

Temp F°	Temp C°	Potassium (grams)		Na_2SO_4 (grams)	
32	0	**3.28**	3.28	**4.76**	4.76
50	10		3.55		8.554
68	20		3.82		12.348
86	30		4.09		16.142
104	40		4.36		19.936
122	50		4.63		23.73
140	60		4.9		27.524
158	70		5.17		31.318
176	80		5.44		35.112
194	90		5.71		38.906
212	100	**5.98**	5.98	**42.7**	42.7

  - Gel Recipe
    - ColdIce phase change material -10° F FORMULA
      - Company provided on MSDS sheet 80% water, 18% salt, 2% Guar Gum (by weight)
    - ThermoSafe – U-tek® phase change material. (-10ºF/-23ºC)
      - Formulation company secret
    - Saw Dust (pykrete formula + guar gum as thickener)
      - 86% water, 12% saw dust, 2% Guar Gum (by weight)
      - 91% water, 7% saw dust, 2% Guar Gum (by weight)
    - Table Salt (Sodium chloride)
      - 80% water, 18% Sodium chloride, 2% Guar Gum (by weight)
    - Baking Soda (Sodium bicarbonate)
      - 88% water, 10% Sodium bicarbonate, 2% Guar Gum (by weight)
    - Potassium formate
      - 94% water, 4% Potassium formate, 2% Guar Gum (by weight)
    - Sodium Sulfate Anhydrous
      - 85% water, 13% Sodium Sulfate Anhydrous, 2% Guar Gum (by weight)

  - Below is the amount of materials I used (by weight) to fill a 500 ml bottles and poly bag with each solution. As the weight, volume, and solubility was different for each mixture – I focused on making sure the bottles contained 500 ml and the remaining mixture volume when into the poly bag. This resulted in some poly bag not being as full as the others.

	Baking Soda		Potassium Formate		Sodium Sulfate		Saw Dust 12%		Saw Dust 7%		Salt 18%	
	Grams	Percentage	Grams	Percentage	Grams	Percentage	Grams	Percentage	Grams	Percentage	Grams	Percentage
Water	880	88%	940	94%	850	85%	1000	86%	455	91%	800	80%
Chemical	100	10%	40	4%	130	13%	140	12%	35	7%	180	18%
Guar Gum	20	2%	20	2%	20	2%	20	2%	10	2%	20	2%
		100%		100%		100%		100%		100%		100%

- Freezing the mixtures – My father took the bottles and bags to his work and placed in a -80°C deep freezer. He said that we could achieve the same results if we placed them an insulative cooler with 40 lbs of dry ice for over 24 hours. He packed the frozen bottles and bags in a cooler with dry ice to bring home so we could run the experiment in our garage.
- Temperature probe placement – I placed a drinking straw in each bottle so the probe head would be in the center of the frozen mixture. This did not work out as the mixture expanded so much that it crushed the straw. I had to use a drill to bore a hole in the center of the frozen mixture before inserting the probe head. For the poly bag, I just taped the probe head on side of the frozen bag. This was difficult as the tape did not want to stick to the frozen bag due to frost build up – so I wrapped it around the bag so the tape would stick to itself.
- Pictures of the experiment

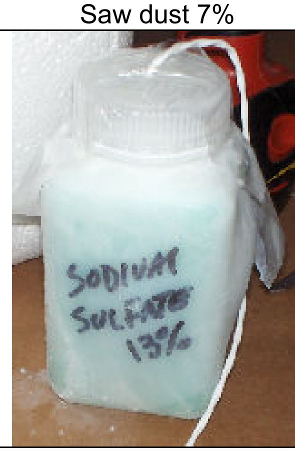
Saw Dust 14%

Salt 18%

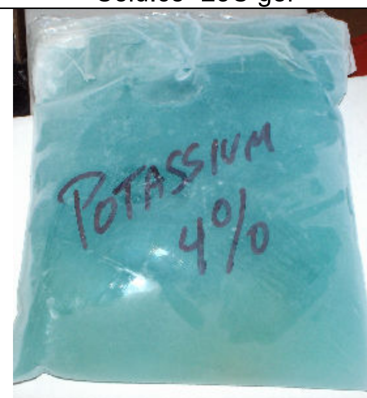
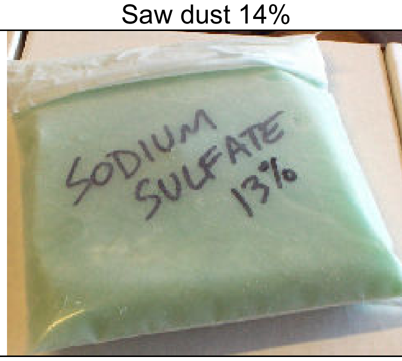
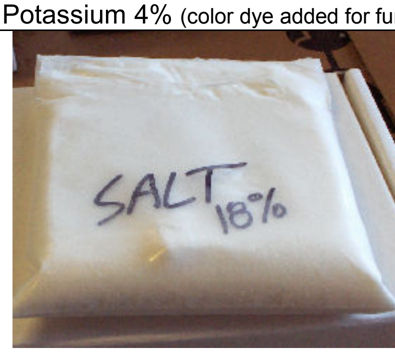
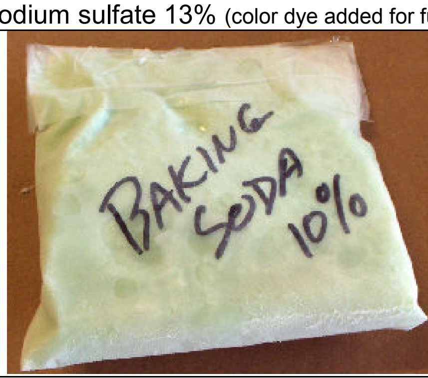
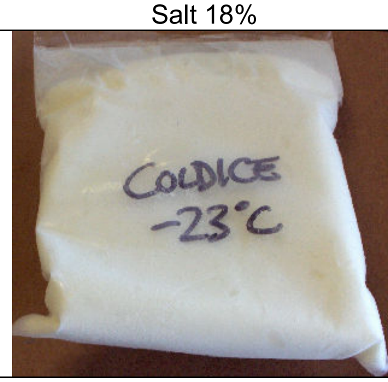
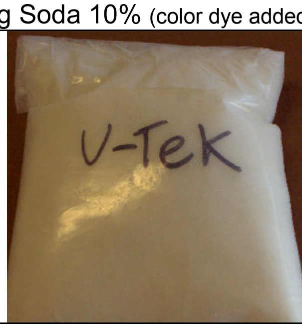
Potassium 4% (color dye added for fun)

Saw dust 7%

Baking soda 10% (color dye added for fun)

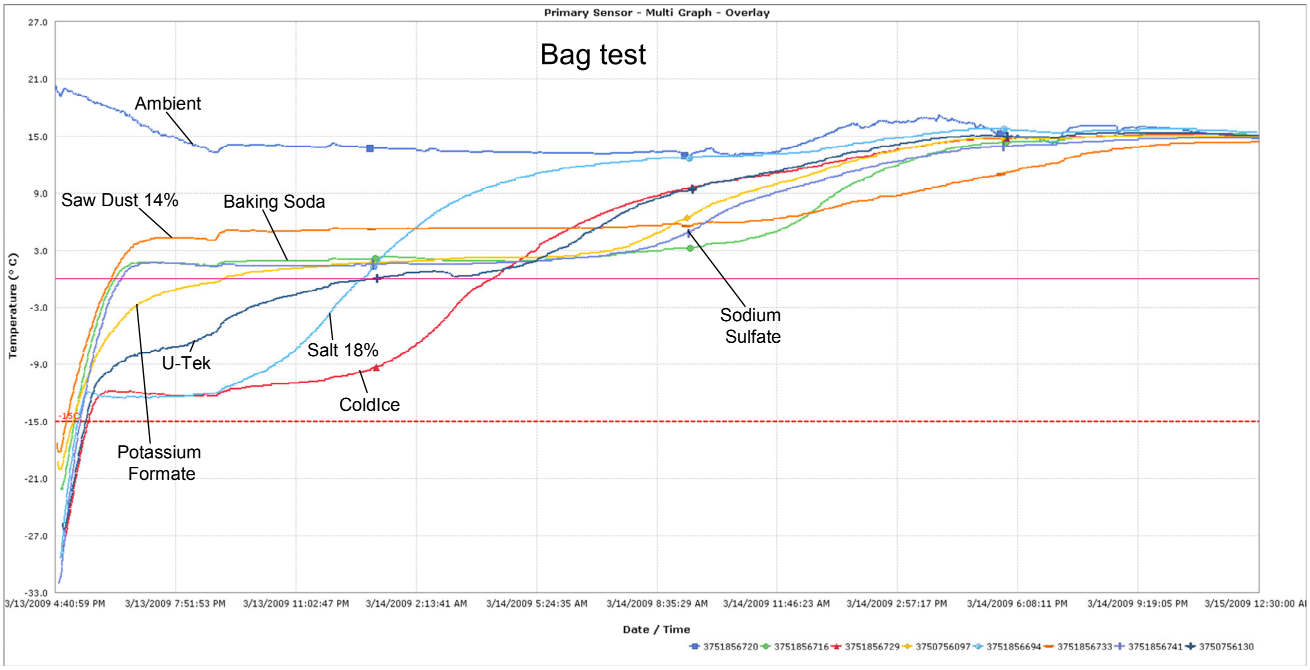


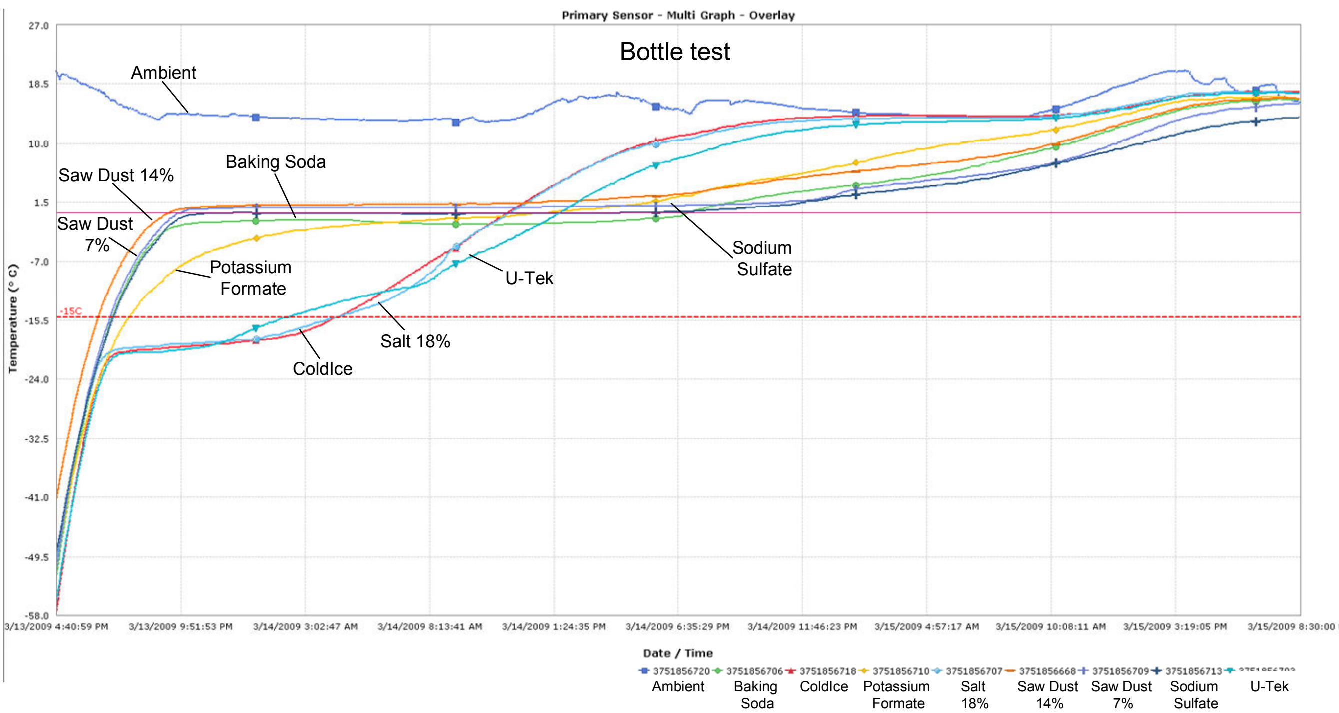
Sodium sulfate 13% (color dye added for fun)

	
Thermosafe U-Tek -23C gel	ColdIce -23C gel
	
Saw dust 14%	Potassium 4% (color dye added for fun)
	
Sodium sulfate 13% (color dye added for fun)	Salt 18%
	
Baking Soda 10% (color dye added for fun)	ColdIce -23C gel
	
Themosafe U-Tek -23C gel	

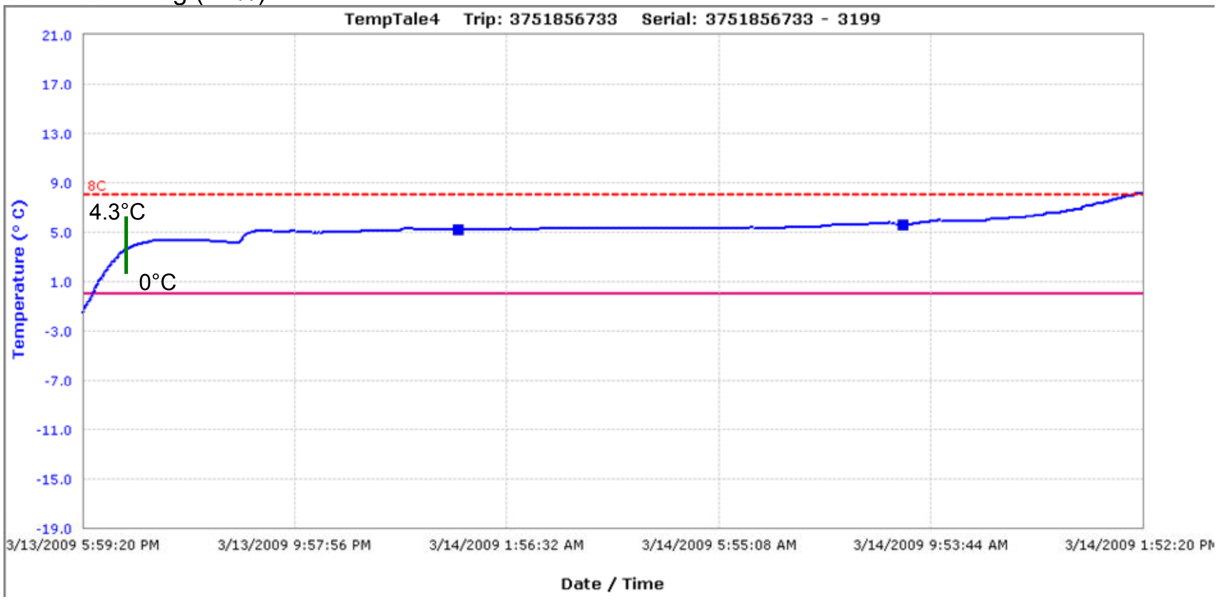
Results

- The results showed that different chemical mixtures had different phase change temperatures.
- The bagged gel had higher temperature reading than the bottle gel. I believe this is because the bag gels were monitored on the surface which was also exposed to the ambient air temperature while the bottle gels where monitored in the center of the gel material.

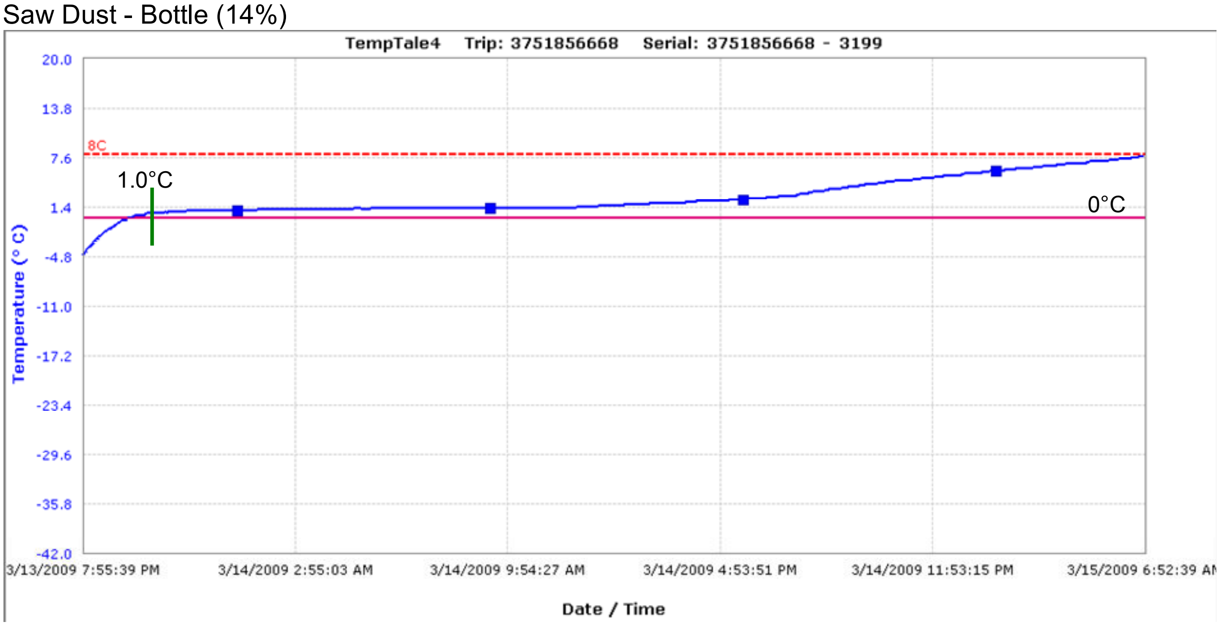




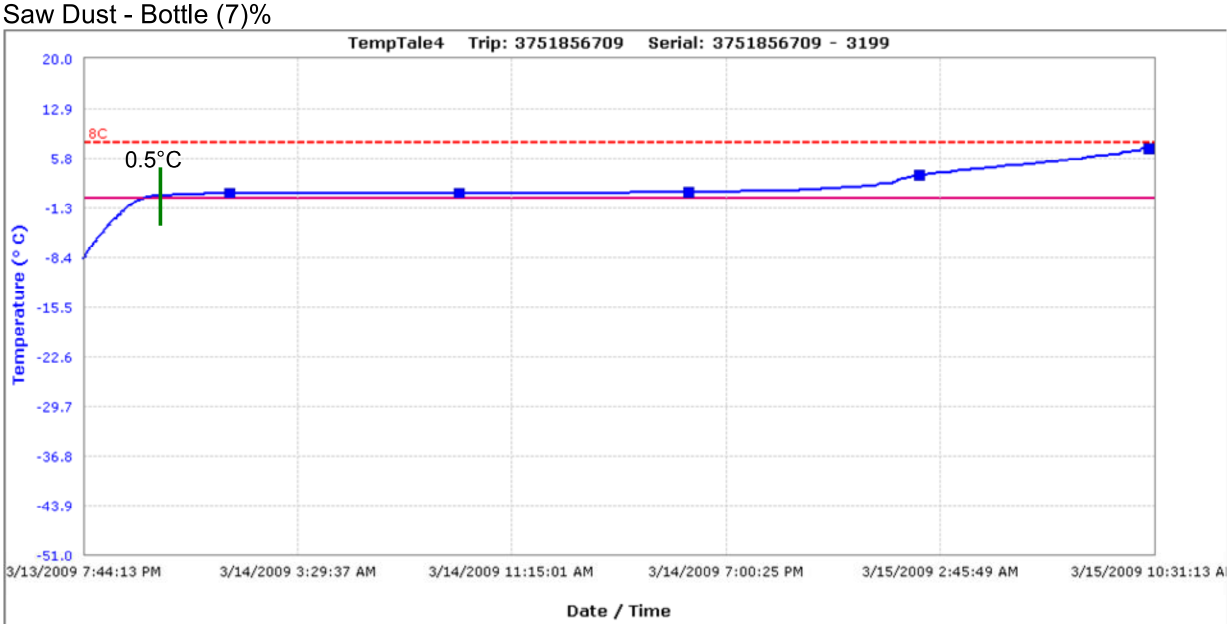
- Saw Dust - Bag (14%)



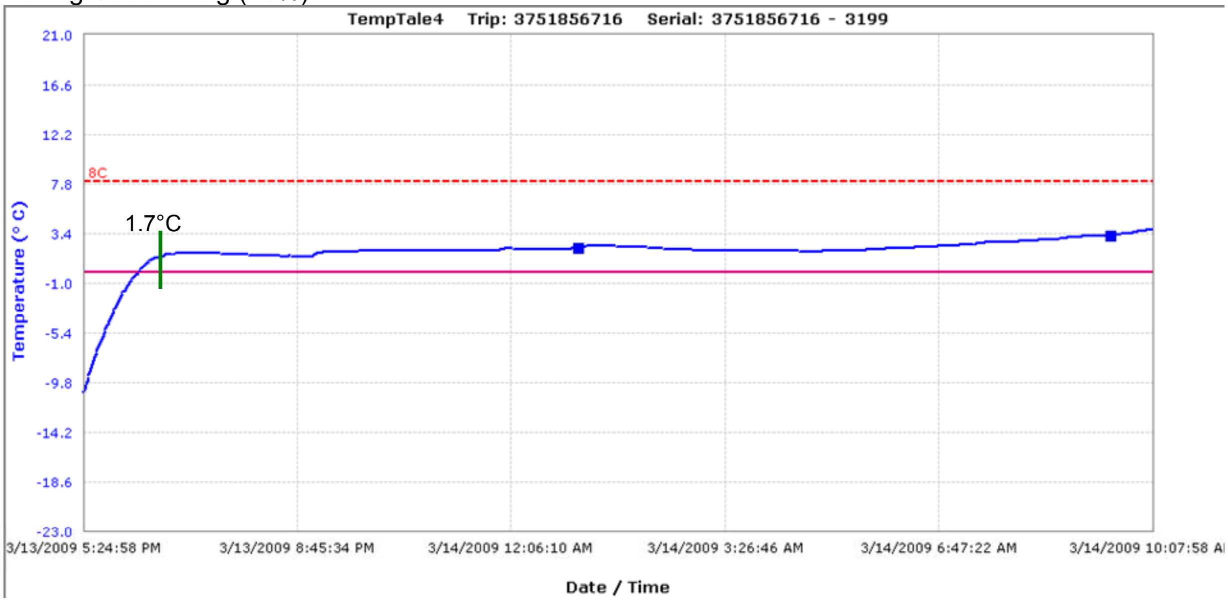
- Saw Dust - Bottle (14%)



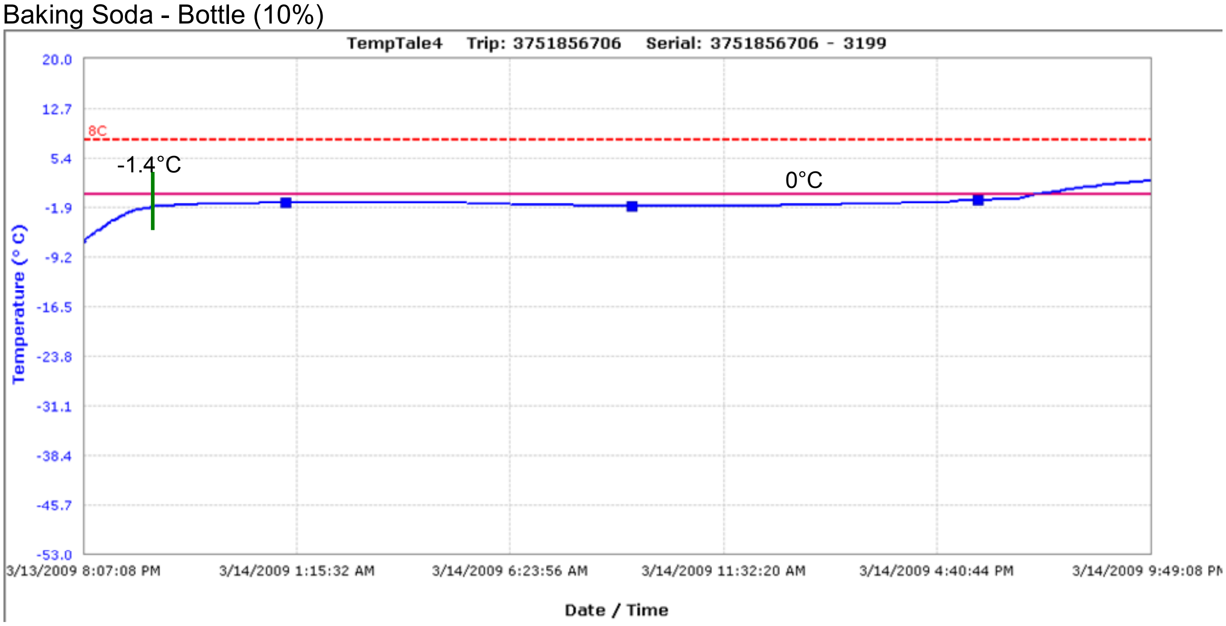
- Saw Dust - Bottle (7)%



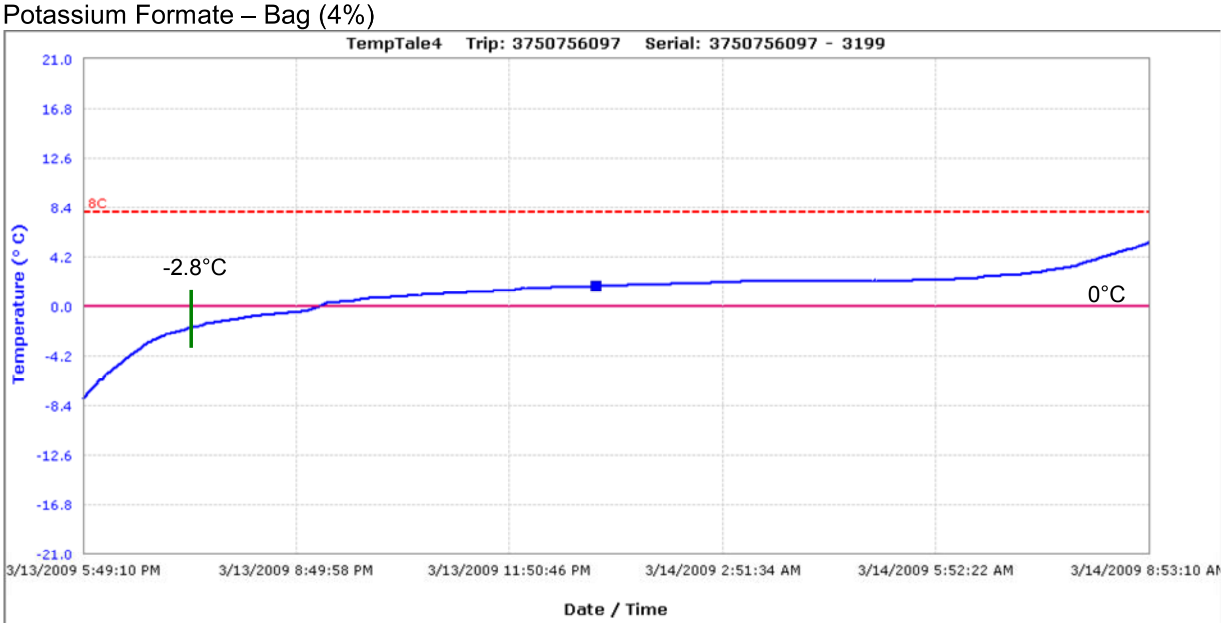
- Baking Soda – Bag (10%)



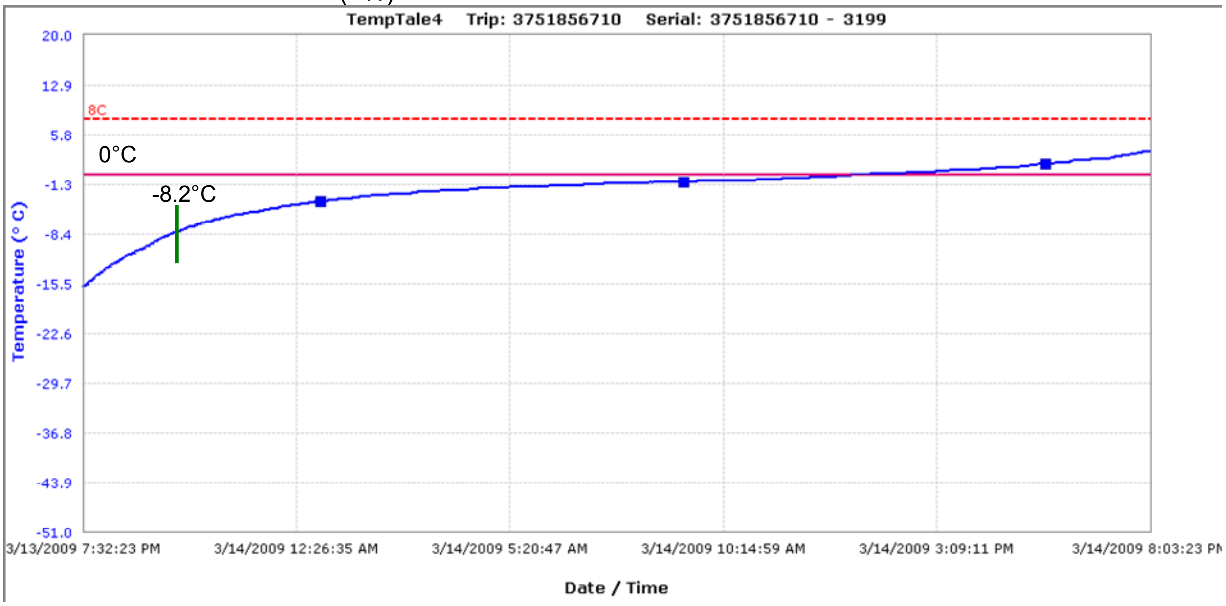
- Baking Soda - Bottle (10%)



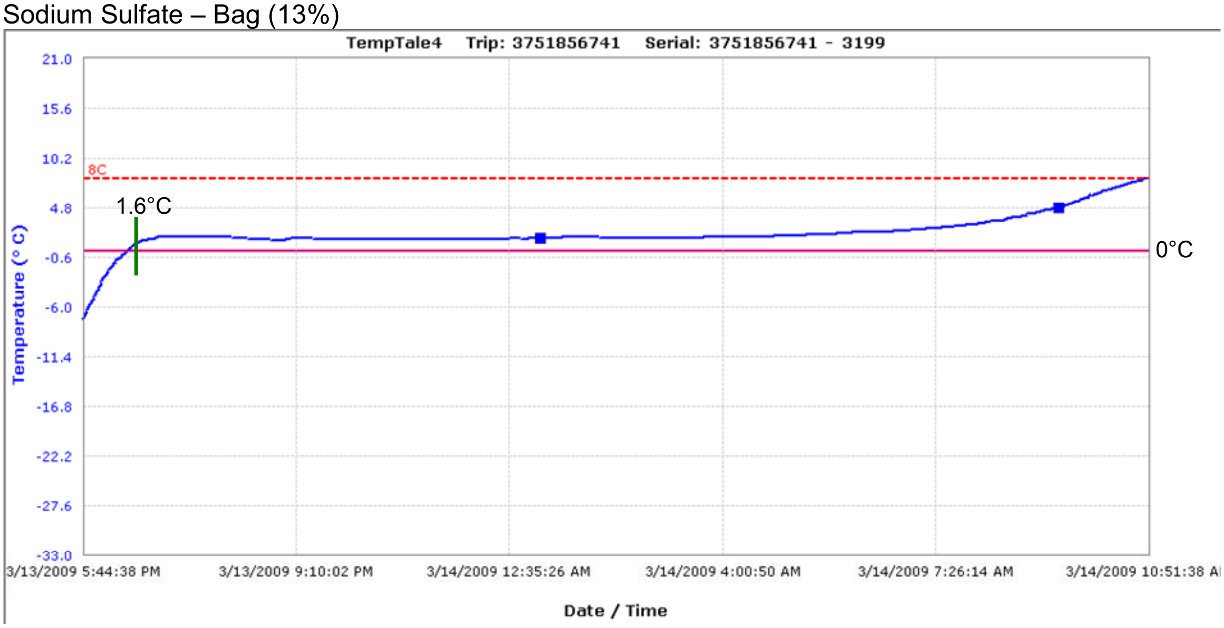
- Potassium Formate – Bag (4%)



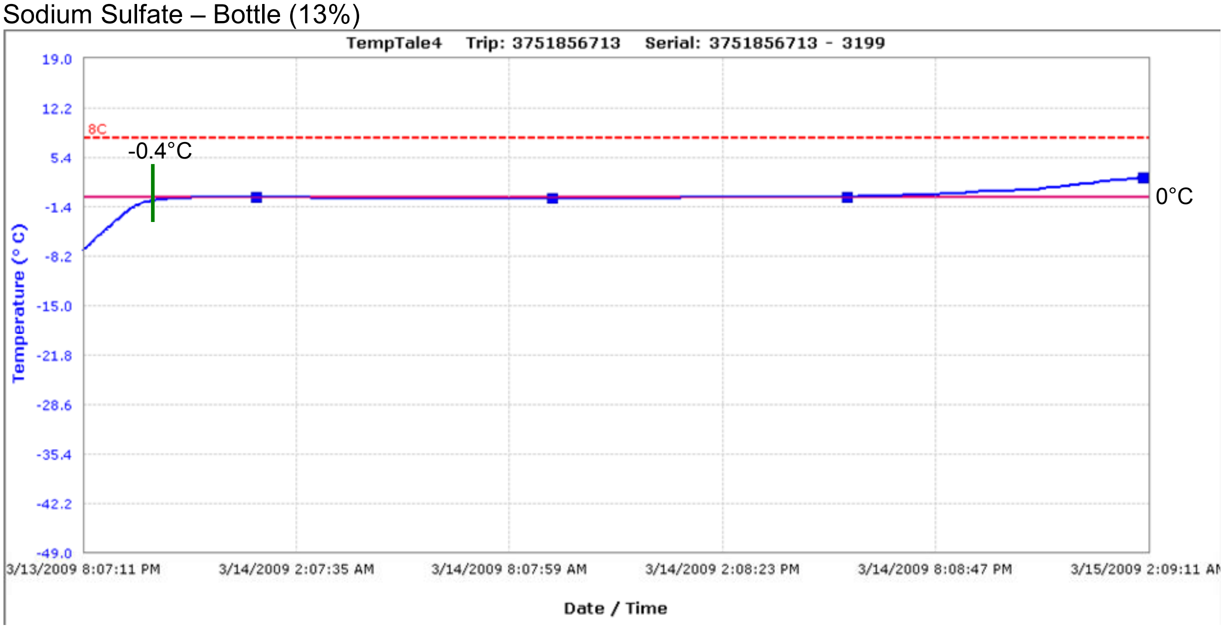
- Potassium Formate – Bottle (4%)



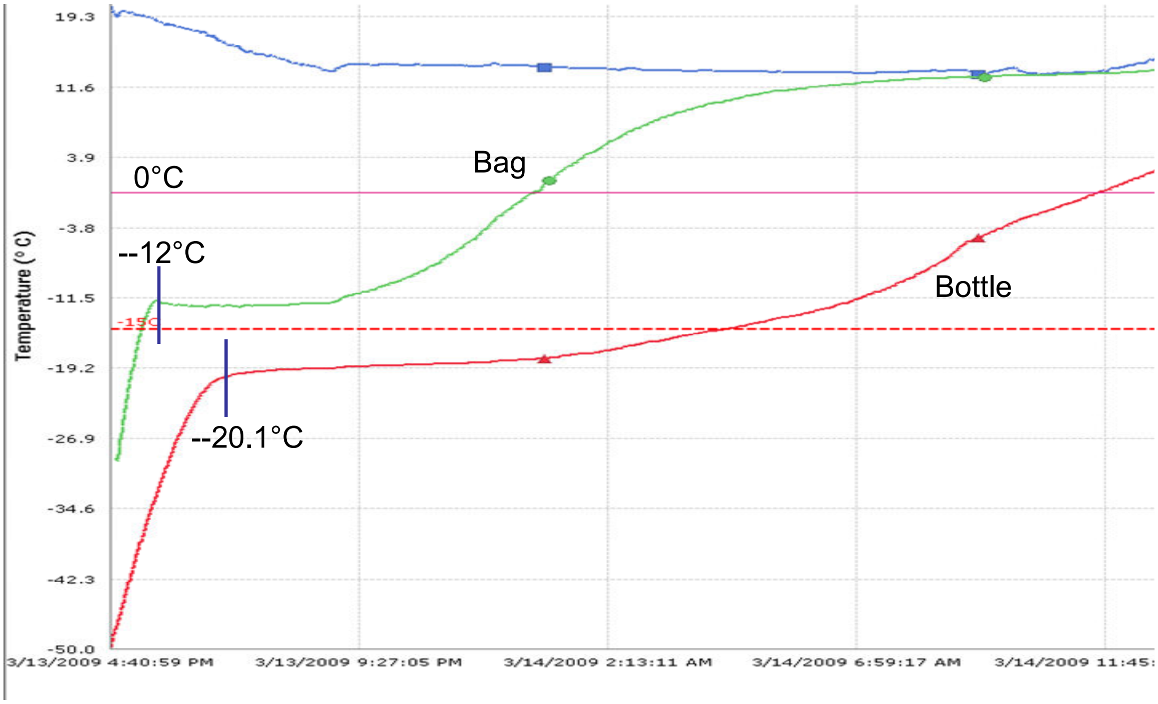
- Sodium Sulfate – Bag (13%)



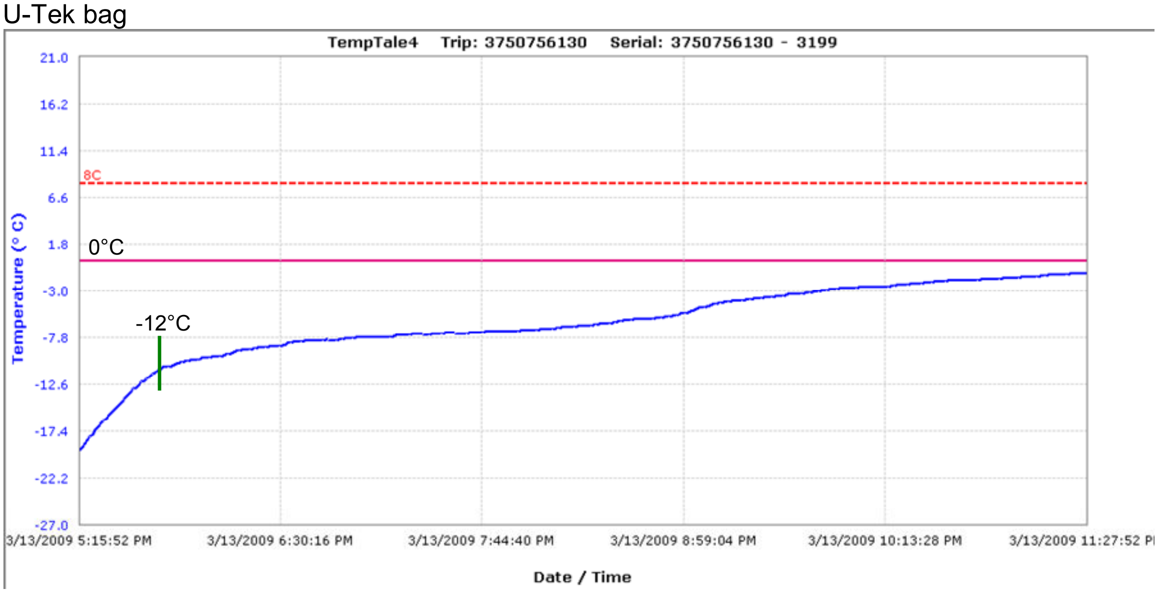
- Sodium Sulfate – Bottle (13%)



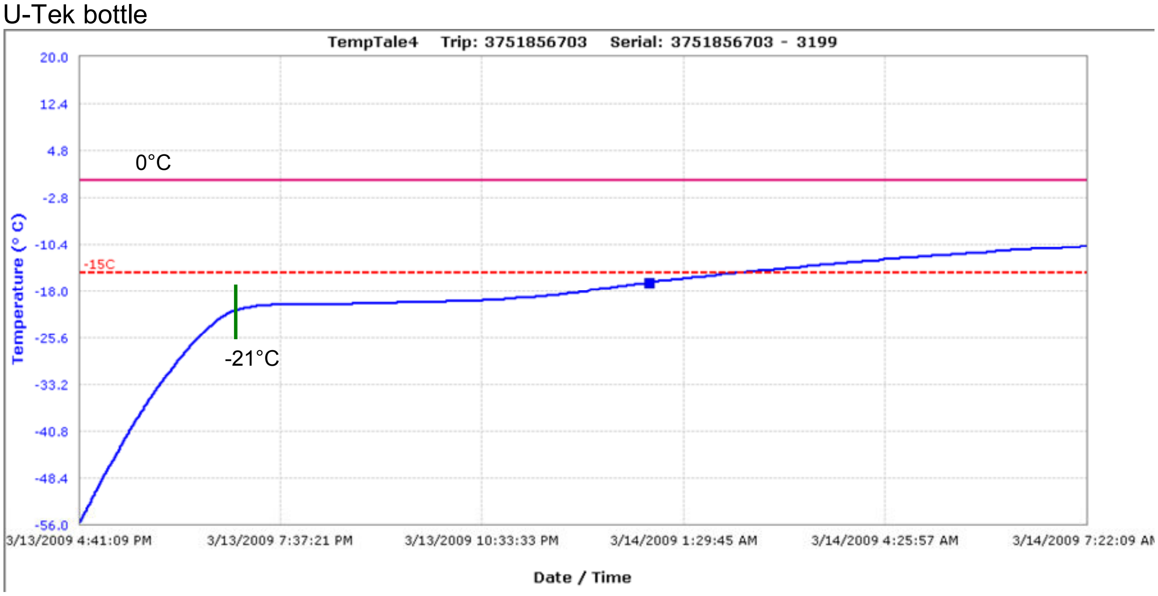
- Salt



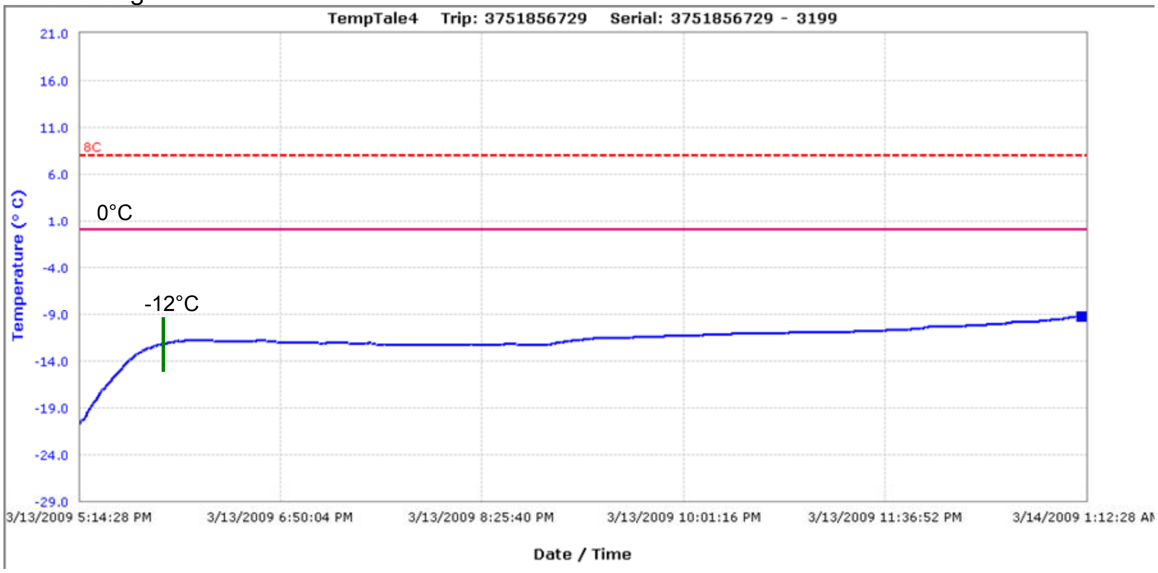
- U-Tek bag



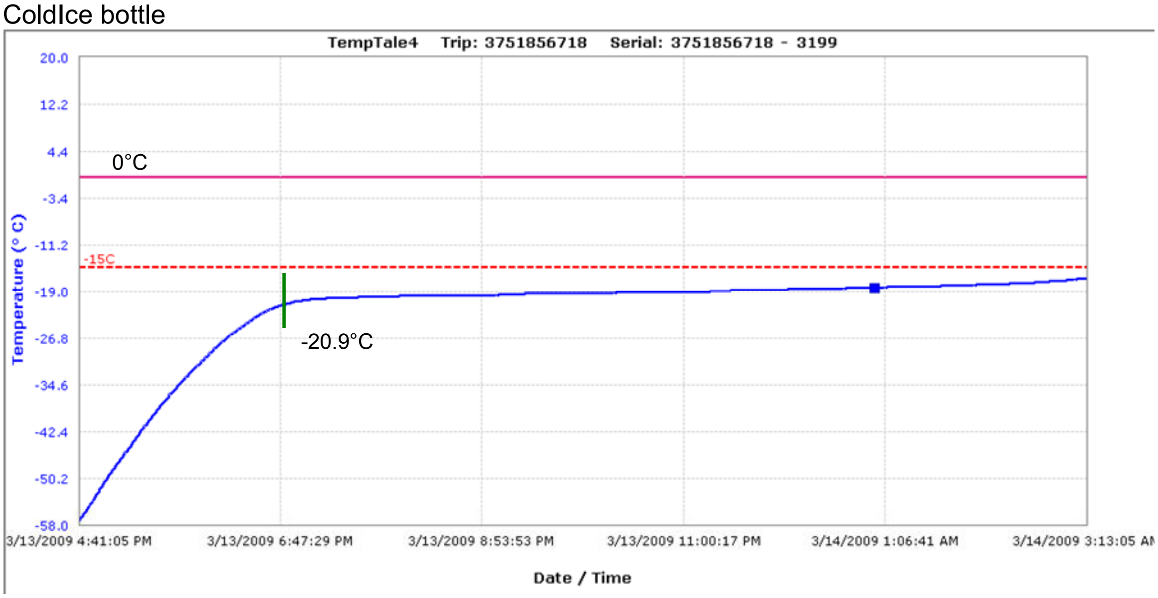
- U-Tek bottle



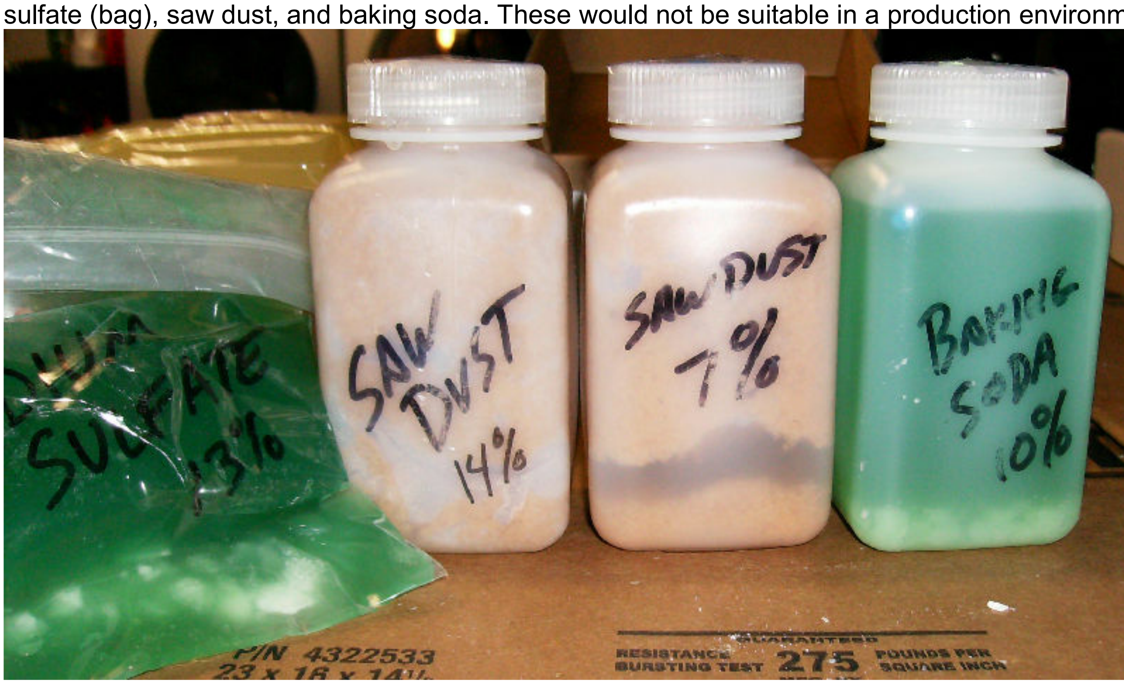
- ColdIce bag



- ColdIce bottle



- The only mixture was close to the commercial -23ºC phase change gels was made with 18% Salt
- Post-test: Some of the mixtures separated after being in a liquid state for over a week. Those were sodium sulfate (bag), saw dust, and baking soda. These would not be suitable in a production environment.



Conclusion

- I learned that it is hard (yet not impossible) to replicate the performance of commercial phase change gels without using things that are not good for the environment.

Follow-up Question:

- Which one of these mixtures is to most economical and easy to manufacture?

  None of the mixtures that were good for the environment and easy to manufacture matched the results of the commercial products, however, the salt mixture was the closest. Yet, salt is very corrosive and considered bad for the environment.

  The saw dust mixture phased at temperatures close to refrigerator temperatures; that means that this mixture could be used to help keep things at refrigerator temperatures, something that bio-tech companies are looking for.

Notes: The bag tests were different from the bottle tests because the probe was placed on the outside of the bag whereas for the bottles the probes were placed in the middle of the mixture.

CAS registry numbers are unique numerical identifiers for chemical elements, compounds, polymers, biological sequences, mixtures and alloys. They are also referred to as CAS numbers, CAS RNs or CAS #s.

Chemical Abstracts Service (CAS), a division of the American Chemical Society, assigns these identifiers to every chemical that has been described in the literature. The intention is to make database searches more convenient, as chemicals often have many names. Almost all molecule databases today allow searching by CAS number.

Special thanks: I would like to thank my dad, Paul Russell, for helping me with my project by helping obtain the various chemicals, test equipment, and helping run the experiment and analyze the results.