

Cold Chain Management: Temperature Monitoring Solutions

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Current Problem

- CDC administers over \$3 billion of vaccine to low-socioeconomic families through Vaccines for Children (VFC) program each year
- Storage temperature control is vital to maintaining vaccine potency
 - Storage outside 2 °C to 8 °C range can render vaccines ineffective
 - A meta-analysis published in *Vaccine* estimated 14 to 35% of delivered vaccines are subjected to inappropriate storage temperatures
- Social and economic costs of improperly stored vaccines
 - Cost of manufacturing and delivering vaccine wasted
 - Vaccine delivery delayed
 - Reported vaccination rates are erroneously high
 - Recipients are not protected
- Better vaccine cold chain management through improved temperature monitoring practices
 - Decrease incidence of waste
 - Improve consumer confidence
 - Increase effective inoculation rates

Cold Chain Temperature Monitoring

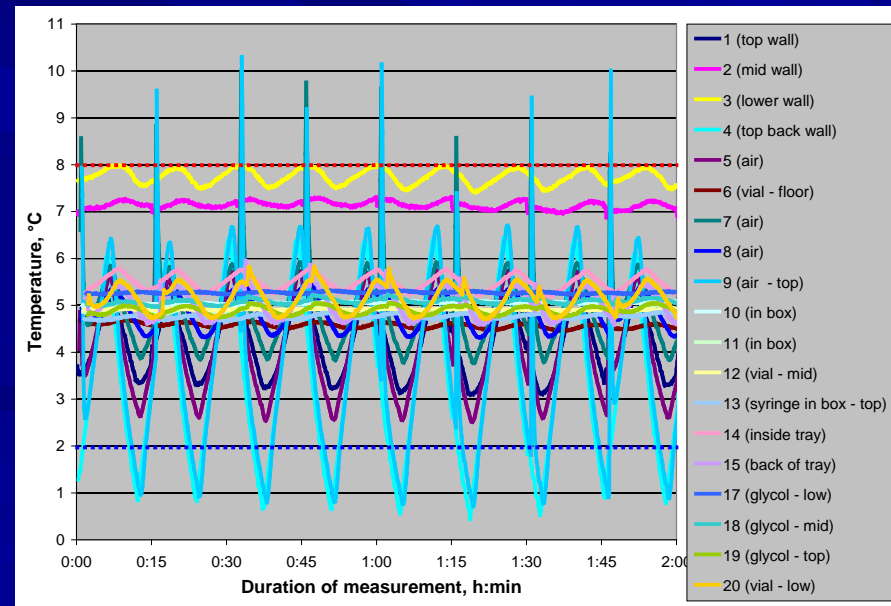
- **How do you know if stored vaccines are safe and effective?**
 - Track temperature history
- **Refrigerator temperature is NOT a single point measurement**
 - Refrigeration cycle – compressor timing
 - Air circulation patterns – spatial temperature variations
 - Use patterns – door opening, loading density, temperature set point
 - Environmental conditions – room temperature variation, power failures
 - Defrost cycle
 - Thermometer location – what are you measuring?

A refrigerator is ONLY as good as the temperature monitoring system inside

High-tech, pharmaceutical-grade units still affected by variable conditions



Accurate temperature history that reflects actual vial temperatures is **imperative** to effective vaccine management



Cold Chain Temperature Monitoring

Why doesn't the current VFC system work?



F° Check Both Temperatures Twice A Day

Month: _____

Days 1-15 (16-31 continued on other side)

Refrigerator		1		2		3		4		5		6		7		8		9		10		11		12		13		14		15			
Staff Initials																																	
Day of Month		1		2		3		4		5		6		7		8		9		10		11		12		13		14		15			
Time																																	
		am		pm		am		pm		am		pm		am		pm		am		pm		am		pm		am		pm		am			
Too high*	≥ 49°F	Take immediate action* if temperature is in the shaded area.																															
	48°F	If temperature is above 49°F F, write in the current temperature.																															
	47°F																																
	46°F																																
	45°F																																
Aim for	44°F																																
	43°F																																
	42°F																																
	41°F																																
	40°F																																
	39°F																																
	38°F																																
	37°F																																
	36°F																																
	35°F																																
Too low*	34°F	If temperature is below 32°F F, write in the current temperature.																															
	33°F	Take immediate action* if temperature is in the shaded area.																															
	32°F																																
	≤ 32°F																																
Freezer																																	
Too high*	≥ 8°F	Take immediate action* if temperature is in the shaded area.																															
	7°F	If temperature is above 8° F, write in the current temperature.																															
	6°F																																
	5°F																																
	4°F																																
	3°F																																
	≤ 3°F																																

Instructions for Temperature Log:

Check both temperatures twice a day, each working day of the month. Place an "X" in the boxes that show the temperatures you read in the morning and afternoon; enter your initials and the time in the boxes at the top of the day's column. If your entry is in a shaded area, take immediate action! Use a new form each month and save in a file or month's end for one year.

MM-652 Fahrenheit (F°) Temperature Log (1/06)

*TAKE IMMEDIATE ACTION if the temperature is too high or too low:

1. Store the vaccine under proper conditions as quickly as possible.
2. Call your VFC Representative.
3. If he/she is not available, call VFC Customer Service at 1-877-2GET-VFC (1-877-243-8632)

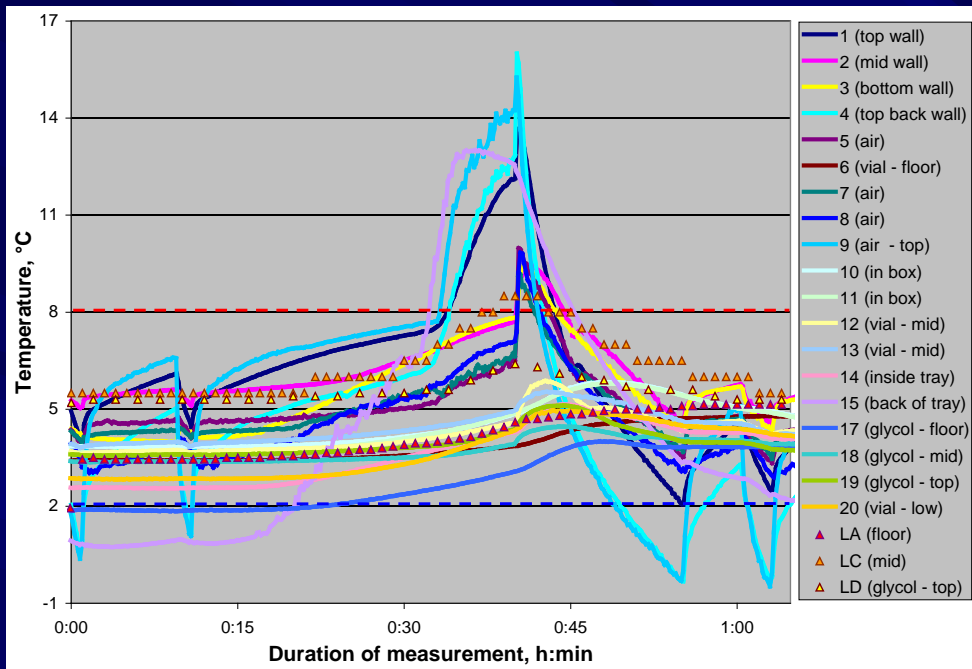
VFC Field Representative LHD Immunization Program

() ()

Vaccines for Children Program
California Department of Health Services
850 Marine Bay Parkway
Richmond, CA 94804



Continuous Temperature Monitoring

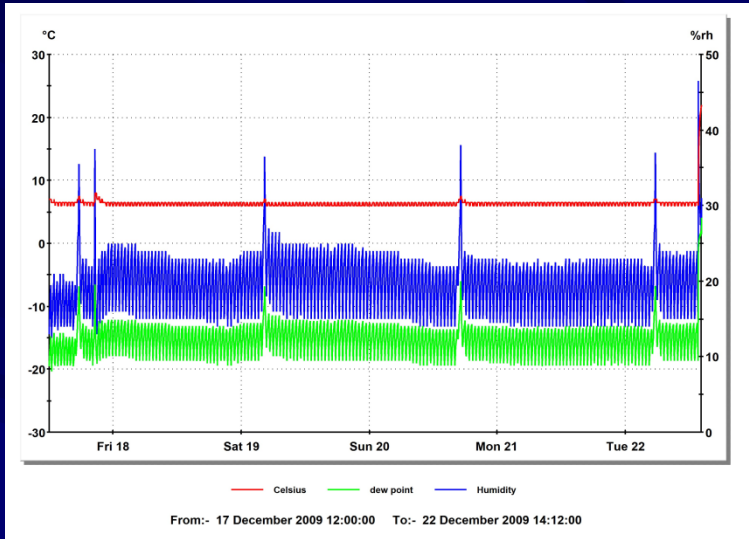


- Vital to proper vaccine storage
- Current “manual check” system:
 - Possible false alarm if checked during defrost cycle
 - Failure to recognize existence of defrost cycle and take any necessary protective measures
- Freezerless fridge example
 - Cumulative effect of time above 8 °C during multiple defrost cycles?
 - Must evaluate on case-by-case basis
- Monitor placement is very important!

WITHOUT a continuous temperature monitoring system in place..

- Likelihood of undiscovered thermal excursions occurring is **VERY HIGH**
Examples: overnight power outage, excessive refrigerator cooling following long or frequent periods of door opening, defrost cycle patterns
- Likelihood of administering spoiled, ineffective vaccines to patients is **VERY HIGH**
- By the time temperature deviations are found, may be too late for corrective action
- No way to tell when a problem started, how long it lasted,
...or whether the vaccine is safe!

Continuous Monitoring Solution: Electronic Data Loggers



ADVANTAGES

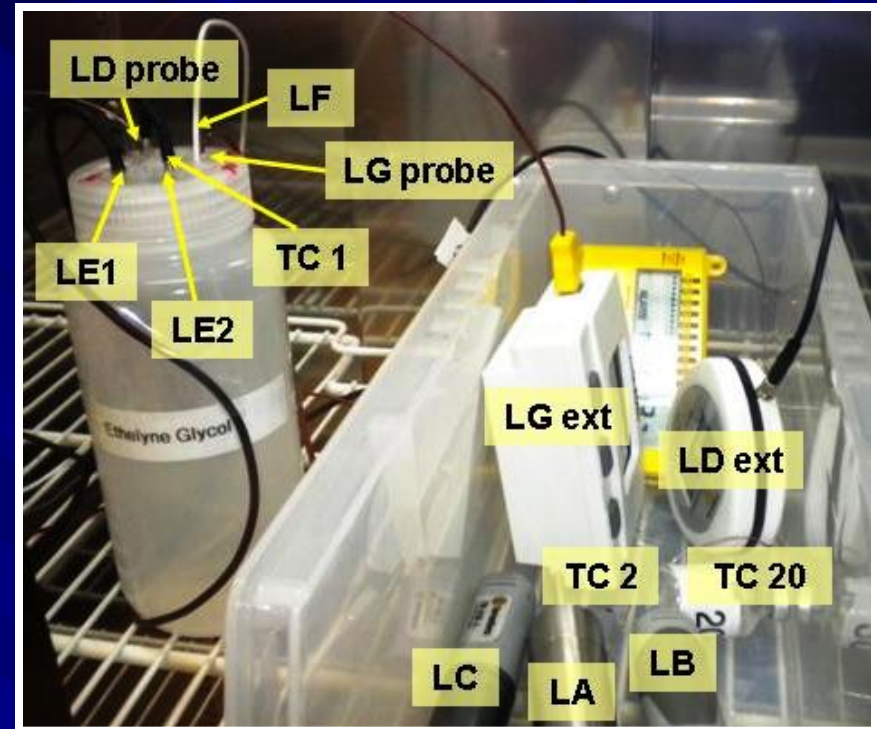
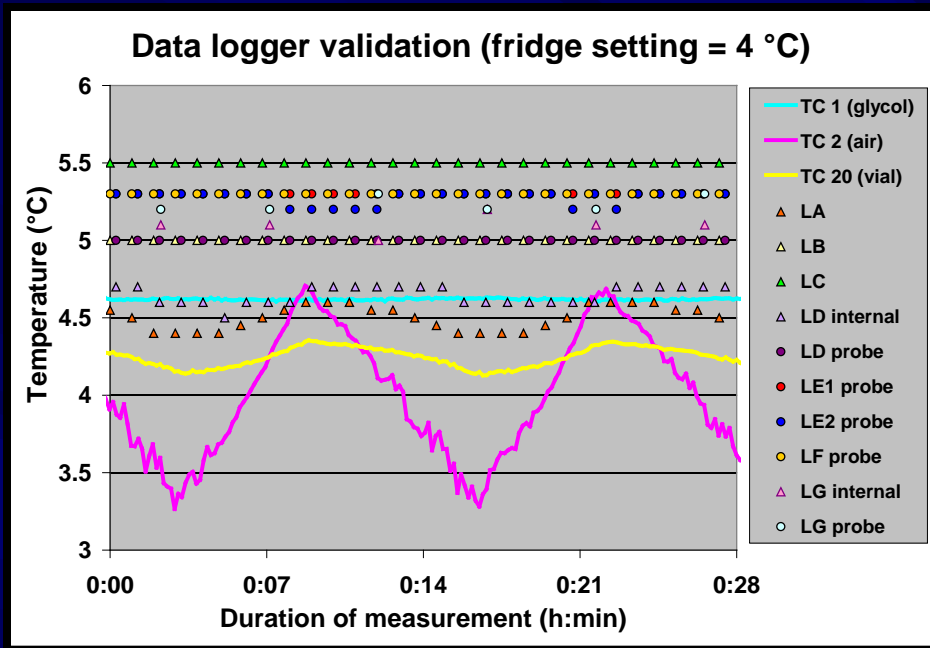
- **Continuous monitoring** - ensures that all thermal excursions are captured, improving confidence in vaccine supply efficacy
- Easy to use
- Quickly analyze results, eliminating time-consuming paperwork
- Archival data stored electronically
- Alarm capabilities, some with email notification mean that problems are revealed (and can be dealt with) immediately
- Wireless models allow for real-time monitoring
- Can be calibrated by end-users at the ice point

DISADVANTAGES

- Data logger use requires computer capability and some training



Evaluating Electronic Data Logging Thermometers



Measurement objectives

In-depth testing of seven data logger models

- 3 self-contained units, sensor measures air temperature: LA, LB, LC
- 2 units with external temperature probes, kept in glycol-filled bottle: LE1 and LE2, LF
- 2 units with a self-contained air temperature sensor (labeled ext) and a separate probe: LD, LG

Evaluate out-of-box performance and manufacturer-specified accuracy from 0 °C to 10 °C

- Shown above: comparison to reference thermocouple (TC 1) at 2 °C, 4 °C, 6 °C, 8 °C, 10 °C
 - **Note pink line (air temp. TC)** - refrigerator set point is most likely determined by a similar air temp probe ($T_{avg} = 4\text{ °C}$), we can see that air temp measurements don't quite correspond to the temperatures of items stored in the refrigerator!
- Ice melting point (0 °C)

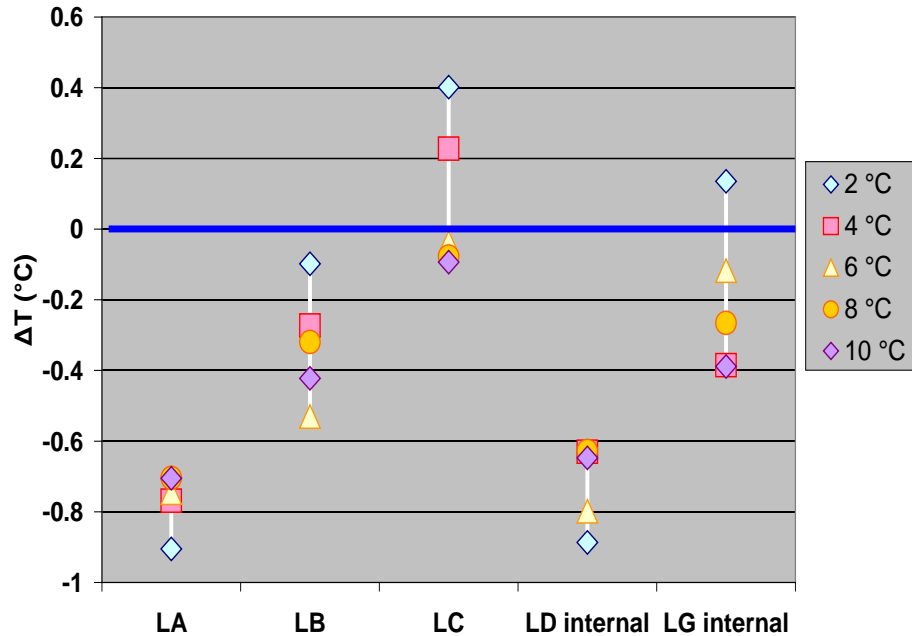
Track stability over 6 month period

Determine proper use so that measurements reflect actual vaccine vial temperatures

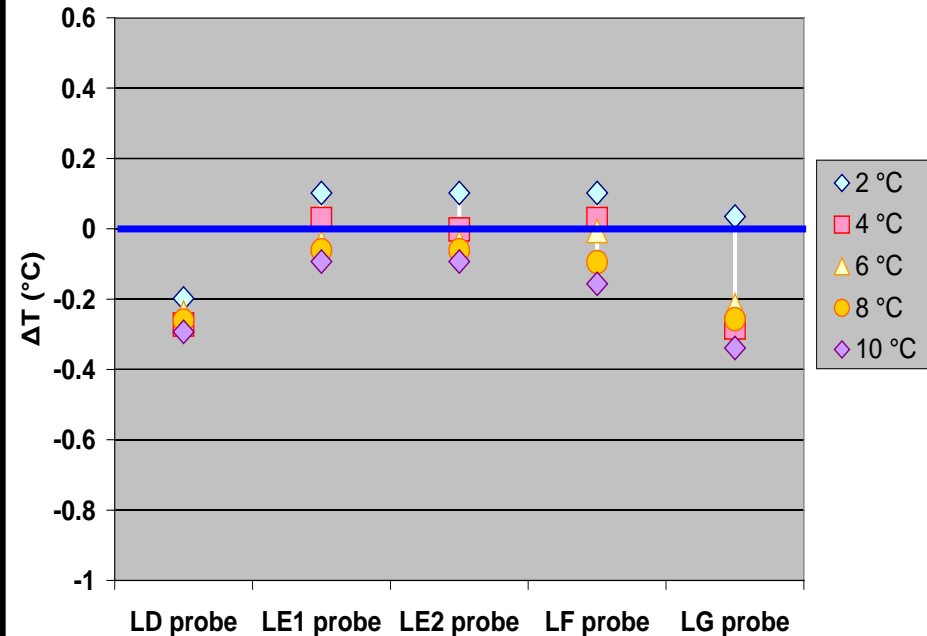
Evaluating Electronic Data Logging Thermometers

Deviation from reference thermocouple (blue line, TC 1 in glycol) over range of 2 °C to 10 °C

Data loggers recording air temperature



Data loggers with probes in glycol



Reference thermocouple in glycol-filled bottle

- Glycol approximates thermal mass and properties of liquid vaccine

Average temperatures recorded by data loggers with probes in glycol matched ref TC measurements more closely than loggers recording air temperature

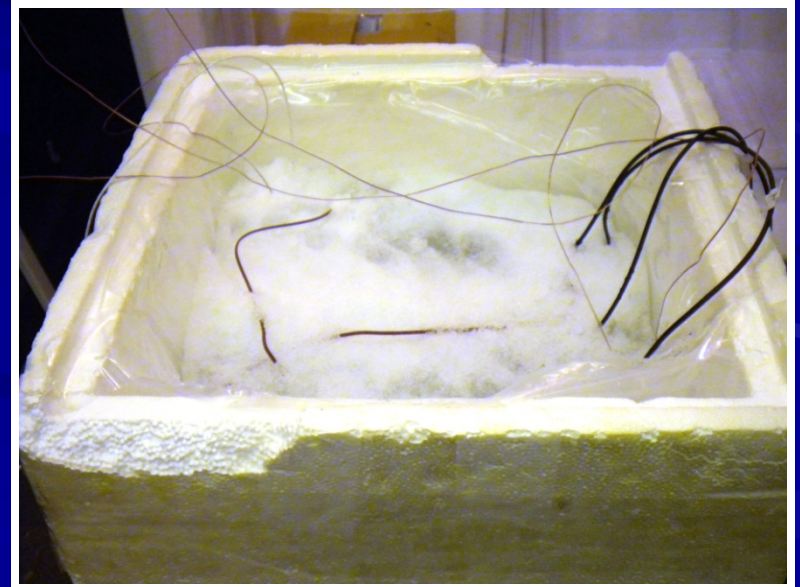
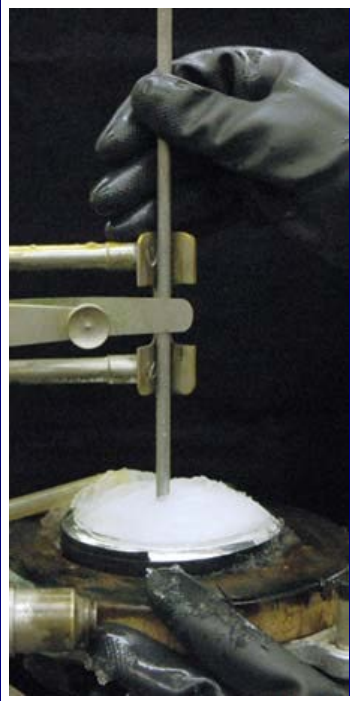
- Air temperature sensors: less thermal mass \rightarrow more susceptible to small temperature fluctuations, less representative of vaccine temperatures

Validation at 0 °C Using an Ice Melting Point Check



Ice Melting Point Temperature Readings (°C)			
Sensor Name	12/8/09	3/7/2011	3/15/2011
TC1	0.0	0.0	0.0
TC2	-	0.0	0.0
TC20	-	0.0	0.0
LA	-0.1	-0.1	-0.1
LB	-	0.0	0.0
LC	0.5	0.5	0.5
LD internal	-	-	-0.2
LD probe	-0.2	-	-0.2
LE1 probe	-0.1	-0.1	-0.1
LE2 probe	-0.1	-0.1	-0.1
LF probe	-	0.0	0.0
LG internal	-	-0.1	-0.1
LG probe	-	0.4	0.4

...no measurement drift after 15 months of use!



Data Logger Performance: Manufacturer Specified Accuracy

Loggers with External Probes in Glycol (\pm °C)			
Sensor Name	Mfc. Specified Accuracy	Ice Point (T = 0 °C)	Ref. TC Comparison (2 °C to 10 °C)
LD probe	0.5	0.2	0.3
LE1 probe	0.5	0.1	0.1
LE2 probe	0.5	0.1	0.1
LF probe	0.3	0.0	0.2
LG probe	0.4	0.4	0.4

Loggers with Air Temperature Sensors (\pm °C)			
Sensor Name	Mfc. Specified Accuracy	Ice Point (T = 0 °C)	Ref. TC Comparison (2 °C to 10 °C)
LA	0.5	0.1	0.9
LB	0.5	0.0	0.5
LC	0.3	0.5	0.5
LD internal	0.5	0.2	0.9
LG internal	0.4	0.1	0.4

■ Loggers with probes in glycol

- 5 of 5 are within or better than manufacturer specifications
- Glycol-filled bottle approximates the thermal mass and properties of liquid vaccine, producing measurements representative of actual vaccine temperatures
- Easily validate logger performance over the full 0 °C to 10 °C range using a simple ice point check

■ Loggers with air temperature sensors

- 3 of 5 are LESS accurate than manufacturer specifications
- Measuring the wrong thing - air temperature is not representative of liquid vaccine temperatures
- Ice point check not sufficient to determine validity of logger readings over entire 0 °C to 10 °C range

An ice point check is an easy and effective method for validating thermometer performance, but it only works if the thermometer is used correctly!

Choosing the “Right” Thermometer

Past and present CDC thermometer purchasing guidelines

- No accuracy or uncertainty requirements listed
- Trick question: what is a “Certified Calibrated Thermometer”?
- Cannot endorse specific manufacturers, which leads to provider/ program manager confusion about which thermometer to buy

Working toward a standardized solution

- NIST-CDC collaboration to determine required specifications and features based on temperature logger study results
- NSF has agreed to include NIST-developed vaccine thermometer specifications as an appendix to ANSI 7
- Manufacturers submit products to NSF for ANSI 7 compliance testing to receive NSF certified seal
- VFC providers can then purchase NSF certified thermometers, certain that they will meet their vaccine temperature monitoring requirements



Measurement Assurance: Calibration and Validation

■ Maintaining thermometer calibration

“Each device is to be covered by a Certificate of Traceability and Calibration. The traceability declaration is to confirm that the measurement standards and instruments used during calibration of the product are traceable to an ISO/IEC 17025 accredited testing laboratory, to NIST, or to another internationally recognized standards agency.” - VFC Operations Guide (Jan. 2011)

■ Determining calibration intervals

- Consult manufacturer guidelines
- Compare thermometer readings to another, recently calibrated thermometer
- Providers or on-site assessors may validate thermometers by performing regular ice point checks

■ NIST-developed, simplified ice point method

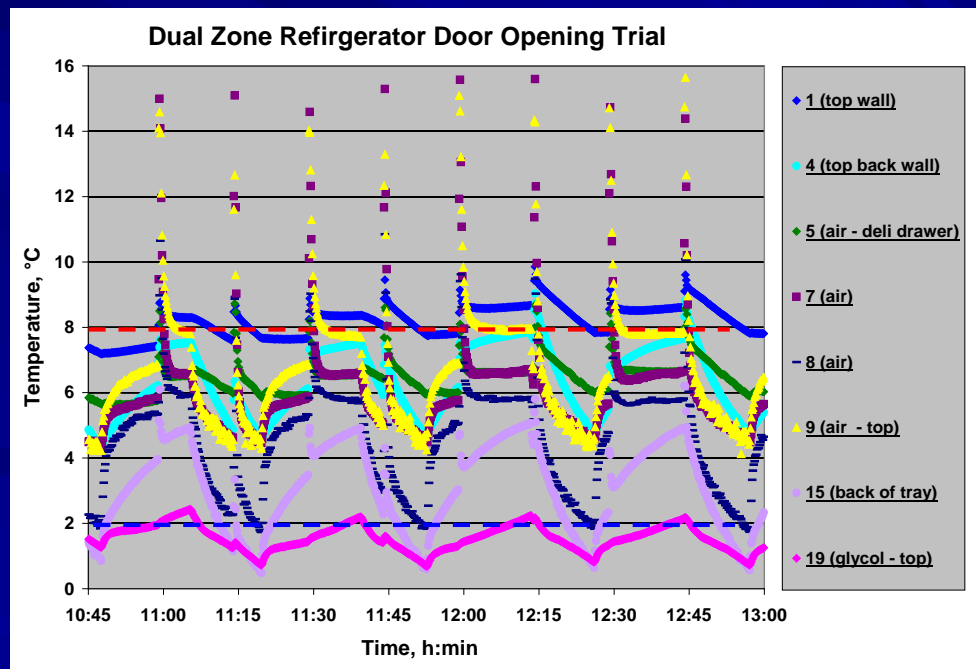
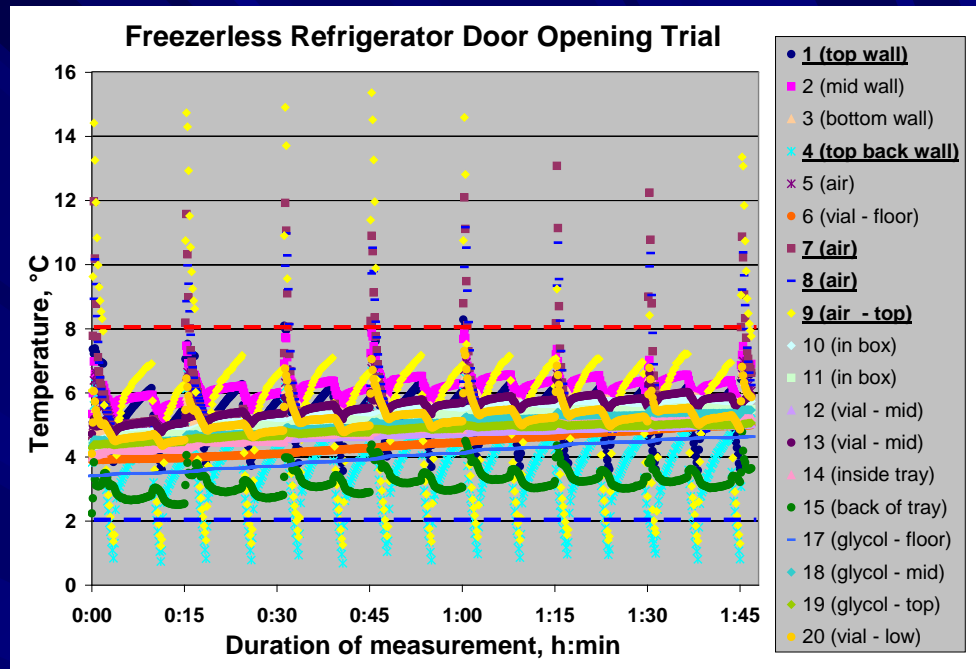
- Materials readily available at grocery or large discount stores (distilled water, small ice cube tray, container)
- Measurement uncertainty = ± 0.01 °C
- [Video tutorial](#)
- Non-waterproof data loggers may be sealed in plastic bag prior to placing in ice point, allow extra time for temperature equilibration
- If the recorded ice point temperature differs from 0 °C by an amount greater than the manufacturer's stated accuracy, the device should be re-calibrated or replaced

False Alarm Alert: Thermometer Placement Matters!

Sensors in air, attached to walls, or near cooling vents show temperature spikes $> 8\text{ }^{\circ}\text{C}$ in all refrigerator types

TC #19 (magenta) shows temperature $< 2\text{ }^{\circ}\text{C}$

- Inside glycol-filled bottle, directly on glass shelf under cooling vent
- Repeated door opening results in driving temp down
- Monitor placed in this location NOT a good indicator of stored vaccine temperature!



Next Steps

- **Continue tracking data logger stability over a period of 6 months**
- **Transform temperature monitoring practices across other segments of the cold chain**
 - VFC on-site provider assessments
 - Validate out-of-box performance of IR thermometers
 - Develop protocol for accurate use
 - Develop simple thermometer verification methods
 - VFC product distribution from warehouse to provider office
 - Quantify performance of data loggers and chemically activated sensors for use during shipping
 - Produce guidelines for use
- **Test all new storage and handling guidelines for practicality, user friendliness**
 - Evaluation by CDC, AIM, WHO, VFC program coordinators and selected VFC clinics

Thank You!

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