Custom Liquid Nitrogen Freezer Monitoring System

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BACKGROUND:

The Centers for Disease Control and Prevention's (CDC) Biorepository has over 250 cryogenic storage vats and mechanical freezers that provide accommodation for approximately six million samples, representing over 500 collections from a wide variety of scientific studies. Many of the collections contain irreplaceable samples, including some from the beginning of the Human Immunodeficiency virus (HIV) epidemic. Liquid nitrogen (LN2) is used to maintain temperatures as low as -196° C, which is ideal for long-term preservation to suspend sample degradation. However, liquid nitrogen poses a suffocation hazard, can damage equipment and facilities, and could threaten sample integrity if not properly handled or monitored.

METHODS

Correct LN2 levels and appropriate temperatures are maintained in the cryogenic vats using a continuous electronic monitoring system developed by a software engineer in the CDC Division of Laboratory Systems. The system consists of several components (Web interface, window service, etc) written using Microsoft's .NET Framework 4.5 and Microsoft's SQL Server database as the backend. The Freezer Monitoring System (FMS) collects temperature and liquid nitrogen level data for each cryogenic vat and compares it against performance thresholds. In addition, the system is being configured to monitor temperatures of mechanical freezers

CONCLUSIONS

The web-based and mobile friendly FMS system provides a number of features including graphical layout of the freezer locations and a dashboard to display current freezer events, such as filling with LN2 and alarms. The FMS is unique because it allows users to interact and control all systems remotely. The FMS is a critical tool to protect employee safety, ensure sample integrity, and prevent facility and equipment damage.

The use of trade names is for identification only and does not imply endorsement by the Department of Health and Human Services or the Centers for Disease Control and Prevention.

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RESULTS:

1. Rapid Response

The FMS sends alert emails (Figure 1) and text messages to on-call staff for events such as a temperature reading outside established thresholds, or an LN2 overflow, enabling them to respond.

Figure 1 - Example of an alert email automatically sent by FMS

Freezer Monitor System (FMS)			
00001	High TempA Alarm (AH)	Chart Industries - TEC2000 MVE XLC 1841	
Temperatures	Level	Settings	
TempA Sensor: -134.7	Level: 5.4	TempA High/Low: -135/-199	
TempB: 14.3	Filling: No	Fill Point High/Low: +005.5/+004.4	
Cooling (Vario): 0		Level Alarm High/Low: +007.5/+003.3	
Inlet (Vario): 0			
Comments: (Comments)			

2. Troubleshooting

The freezer-troubleshooting feature allows staff to send queries and commands remotely to investigate the cause of an alarm and determine corrective action. This feature allows users to identify the cause of an alarm (Figure 3), to reset and mute alarms remotely (Figure 4), and check freezer status (Figures 5, 6).

Figure 3 - Query to identify cause of alarm

Figure 5 - Freezer status

This FMS display shows the temperature and LN2 level of each freezer and whether it is filling with LN2 (blue outline) or in alarm (yellow outline). Information about freezer type is also displayed.

The freezer overview display shows the location and identification number of each freezer in the room, and indicates whether the freezer is in alarm (red or yellow shading) or is filling with LN2 (blue shading). Brown shading indicates the fraction of freezer capacity that is filled with samples. The location of low O2 sensors are indicated by small green dots.

3. Configuration

FMS System and freezer configuration tools allow users to adjust freezer thresholds (Figure 7) and modify the system settings (Figure 8).

Figure 7 - View of freezer settings

This display allows users to view the current settings of each freezer unit.

Figure 8 - Settings in FMS can be configured in many ways

Location	Events	Data	Activity	Testing
Do Events:	Yes			
Do Events Time Out:	1000	ms (1s = 1000)		
Read Line Time Out:	100	ms (1s = 1000)		
Do Event Wait:	800	ms (1s = 1000)	Est: 2.7m	
Reset Command Wait:	5000	ms (1s = 1000)		
Setting Refresh Time:	10000	ms (1s = 1000)		

Warning: Any modifications to the settings can severely affect the application.

Do Events: This is the main functionality of the application. This constantly cycles through the laboratory's units and obtain the current status of each including events (alarms). This setting will turn off this process for entire laboratory. Turning off is usually used for maintenance and the Data Activity is still being monitored.

Do Events Time Out: Occasionally a command is sent a Unit but for some reason a response is not received. This sets the time in milliseconds to move on the next Unit and log no response. Moreover, a counter is incremented for each consecutive 'No Responses' for each Unit.

This display allows users to adjust how often data is collected from each freezer.

B. Data Activity Tab

Location	Events	Data	Activity	Testing
Data Activity Check:	Yes			
Data Activity Minutes:	30	Minutes		
Data Activity Delay:	30	Minutes		
Data Activity Location:	20	CASPIR-A		

Warning: Any modifications to the settings can severely affect the application.

Data Activity: This is used to turn off data monitoring for each laboratory. However, if there an issue with the laboratory's computer, the data monitoring will stop as well. To solve this problem each location will monitor a different location.

Data Activity Minutes: This determines how many minutes without data collection a notification will be sent.

Data Activity Delay: This sets delay minutes for any subsequent 'No Activity' notifications.

Data Activity Location: This is the other location the laboratory will monitor. The Location ID must be used instead of the location name.

This display is used to determine when and how often notifications are sent to indicate a non-responsive freezer. This can be used to detect issues with the sensors and the monitoring system.

4. Scheduler

The scheduler is used to control when a freezer starts to fill with LN2, and can be used to perform other tasks. This unique feature can be used remotely to start or stop the flow of LN2, avoiding spills.

Figure 9 - FMS can be used to schedule LN2 fills

5. Analysis

The FMS analysis tools can generate reports and charts that display historical data to evaluate freezer performance over time.

Figure 10 - Example: Freezer MF002 temperature over several days.

Figure 11 - Display of collections housed in each freezer

Clicking on an individual freezer (0054) displays current temperatures, total number of stored samples, % freezer capacity used, as well as a list of each collection and number of samples.