Hall B Torus' 325 K Cernox Error

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The Cernox temperature sensors of the Hall B Torus sometimes jump to, and stay at, a temperature reading of 325 K. It was determined the best solution that allows an automatic recovery of a Cernox from an incorrect 325 K reading is to target a fixed voltage for the Cernox excitations rather than fixed power.

For the Torus, six Low Voltage Excitation Chassis (LV Chassis) read data from Cernox and PT100 temperature sensors, load cells, strain gauges, and Hall sensors. All LV Chassis connect to two NI-9870 RS232 modules in an NI cRIO-9030 (LV cRIO), which uses LabVIEW.

Sometimes, a Cernox temperature reading jumps to and stays at 325 K (Fig. 1), for an unknown reason. This issue has been present since the beginning of the Torus project and only occurs when the Torus is at 4 K. Many empirical solutions were tested, Table I. Since January 1, 2017, the error has occurred 22 times, Table II.

To determine when the 325 K error occurs, indicators were added to the program to monitor hexadecimal currents sent to Cernoxes, hexadecimal voltages read from Cernoxes, and

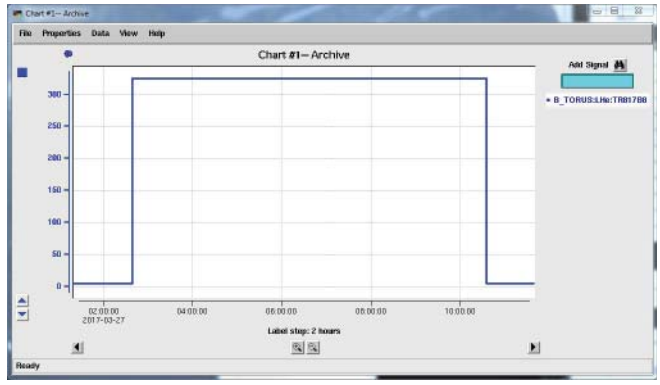

FIG. 1. MyaViewer EPICS plot showing TR817B9 jumping to 325 K and staying there until cRIO program was manually restarted.

Date	HBTORUS log entry #	Description	Result
2/2/17	3454964	Developed procedure for connecting computer to cRIO and manually restarting cRIO program, which fixed error.	Manual procedure used to clear error until automatic recovery solution found.
2/10/17	3457453	Added subVI that looks for any Cernox temperature ≥ 325 K and runs initialization algorithm for just that sensor. Algorithm attempts to force voltage read from Cernox to be between 0.028 mV and 0.032 mV by varying next iteration's excitation current. After five iterations, Cernox continued in normal operation.	Did not allow Cernox to automatically recover. Program indicated that reinitialization algorithm was running in every DAQ loop iteration when Cernox was at 325 K, but Cernox reading was not affected by algorithm.
2/20/17	3460573	Swapped LV cRIO module 1, NI-9870, with spare. At this point, all errors had been in LV Chassis read by module 1 so attempted to eliminate bad module as cause of error.	Additional errors after swapping module indicated that module was not cause of error.
2/28/17	3463259	Added indicators and latching indicators for raw hexadecimal voltages read from LV Chassis, raw hexadecimal currents written to LV Chassis, and resistance as calculated in program, providing more information when error occurs. All indicators were also network-shared variables to allow monitoring without connecting to cRIO. Latching indicators latched when Cernox jumped to 325 K.	For all cases of error, raw hexadecimal voltages read from LV Chassis were equal, which caused calculated resistance to be 0.0 Ω and interpolated temperature to be 325 K. Exact cause of identical voltages is unknown.
4/11/17	3469806	To replicate what happens when program is manually restarted, ~4 s delay was added after start-up algorithm runs (see 2/10/17). During this delay, all VISA communication buffers between LV cRIO and LV Chassis were also cleared.	Delay and VISA clear had no effect on error. On 4/17/17, delay and VISA clear were removed (HBTORUS log entry 3470177).
4/21/17	3470593	Added subVI for Fixed Voltage Solution to LV cRIO program.	Three cases were observed of Cernox jumping to 325 K and then returning to normal temperature one second later. After third case, Fixed Voltage Solution was determined to be successful.
6/14/17	3475869	LV cRIO program with Fixed Voltage Solution was set as LV cRIO's start-up application. This allows cRIO to automatically deploy program with Fixed Voltage Solution if cRIO is rebooted.	Issue considered solved.

TABLE I. List of tasks performed to solve error.

the calculated resistance. The error was found to occur when the two voltages read during a single DAQ loop from a single Cernox were equal. This caused the calculated resistance to be 0.0 Ω and the interpolated temperature to be 325 K. See steps 2–8 in Fig. 2.

The error occurred in the version of the LV cRIO program in which the algorithm used to determine Cernox excitation currents targeted a fixed power. The program was modified so that the algorithm targets a voltage of 15 mV ("Fixed Voltage Solution", Fig. 2). This new algorithm (deployed April 21, 2017) replicates how Cernoxes are calibrated at the manufacturer and how they are initialized when the LV cRIO starts.

After the Fixed Voltage Solution was deployed for testing, three instances of a Cernox jumping to 325 K and resuming normal operation after a second were observed. On April 29, 2017, Cernox TR817F9 jumped to 325 K, but then resumed normal operation after a second. On May 31, 2017, LV cRIO's program indicated TR817D3HB1 jumped to 325 K and then resumed normal operation. However, this error and recovery were not recorded in EPICS, and therefore it was not decisive that the Fixed Voltage Solution was successful. On June 13, 2017, Cernox TR817D3HB1 jumped to 325 K and resumed normal operation after a second (Fig. 3), confirming that the Fixed Voltage Solution prevents Cernoxes from getting stuck at 325 K.

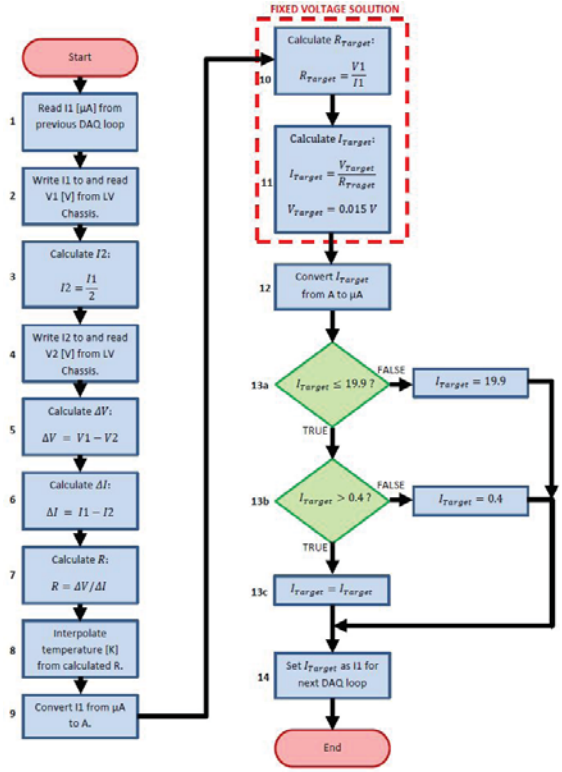

FIG. 2. Flowchart of Cernox excitations using Fixed Voltage Solution.

Cernox	Date of error	# of 325 K errors	LV Chassis #	LV Chassis connector	cRIO module #	cRIO module channel #
TR817B8	1/24/2017	5	4	J6-A	1	3
	2/9/2017					
	2/23/2017					
	3/27/2017					
	4/12/2017					
TR817BR	1/26/2017	2	4	J1-A	1	3
	2/11/2017					
TR817F2	2/17/2017	2	2	J3-B	1	1
	2/20/2017					
TR817F9	3/30/2017	2	2	J6-B	1	1
	4/29/2017 *					
TR817A2	4/6/2017	2	3	J3-B	1	2
	4/19/2017					
TR817D3HB1	5/31/2017 *	2	3	J7-B	1	2
	6/13/2017 *					
TR8122A	2/2/2017	1	1	J7-A	1	0
TR8122B	1/30/2017	1	1	J7-B	1	0
TR817B7	1/6/2017	1	4	J5-B	1	3
TR817B2	2/10/2017	1	4	J3-B	1	3
TR817B1	3/31/2017	1	4	J3-A	1	3
TR817FS	4/10/2017	1	2	J1-B	1	3
TR817U5HB2	4/16/2017	1	5	J7-B	2	0
TOTAL		22				

TABLE II. All instances of a Cernox jumping to 325 K since January 1, 2017. Table is sorted based on number of errors for each Cernox. * denotes 325 K Errors where the sensor automatically recovered with the Fixed Voltage Solution deployed.

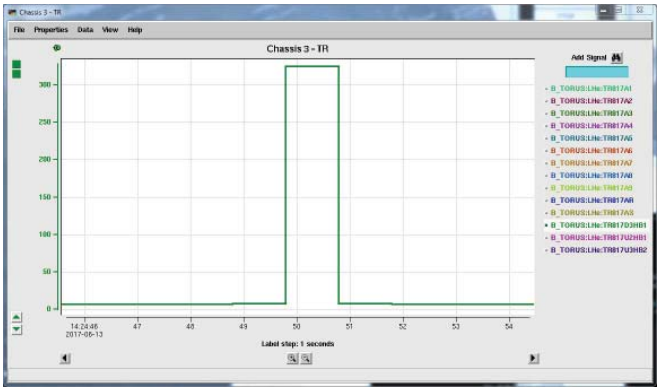

Fig. 3. MyaViewer data from EPICS on June 13, 2017, showing TR817D3HB1 jumping to 325 K and returning to a normal temperature 1 s later, indicating that the Fixed Voltage Solution allows a sensor to automatically recover from jumping to 325 K.

On the basis of the results, the LabVIEW program containing the Fixed Voltage Solution has been deployed to the Torus LV cRIO as its start-up application and the program will deploy automatically any time the cRIO is restarted.

In conclusion, though the exact cause of the 325 K Error for Hall B Torus Cernoxes is unknown, a solution of targeting a voltage of 15 mV for the Cernox excitations allows Cernoxes to recover automatically and has been deployed.