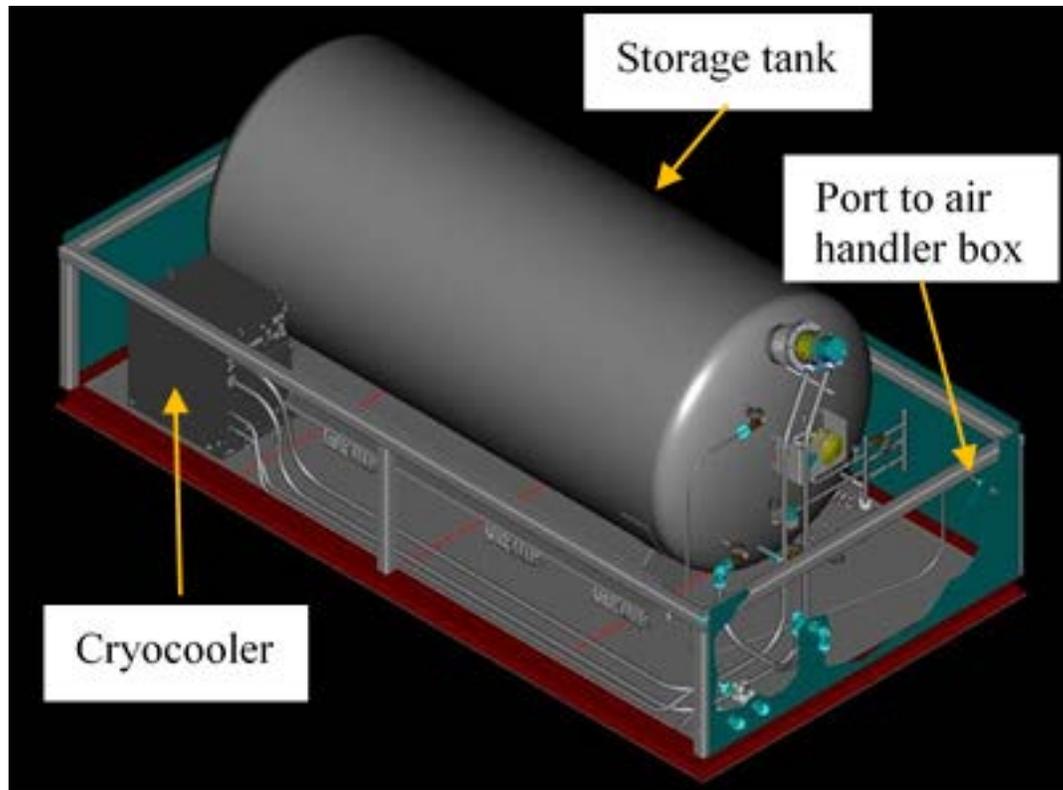


NIOSH evaluated the cooling capability of a cryogenic air supply using its BIP RA in the Experimental Mine



The cryogenic air supply does not require electrical power to deliver cool air after a disaster

- Includes a 2,000-liter dewar connected to an air-handler (heat exchanger) with a vacuum-jacketed hose
- Keeps liquid air at -195°C (-318°F) using a cryocooler



storage tank and cryocooler



air-handler box (heat exchanger)

A liquid air cart is used to transfer liquid air to the cryogenic air supply's dewar via a vacuum-jacketed hose

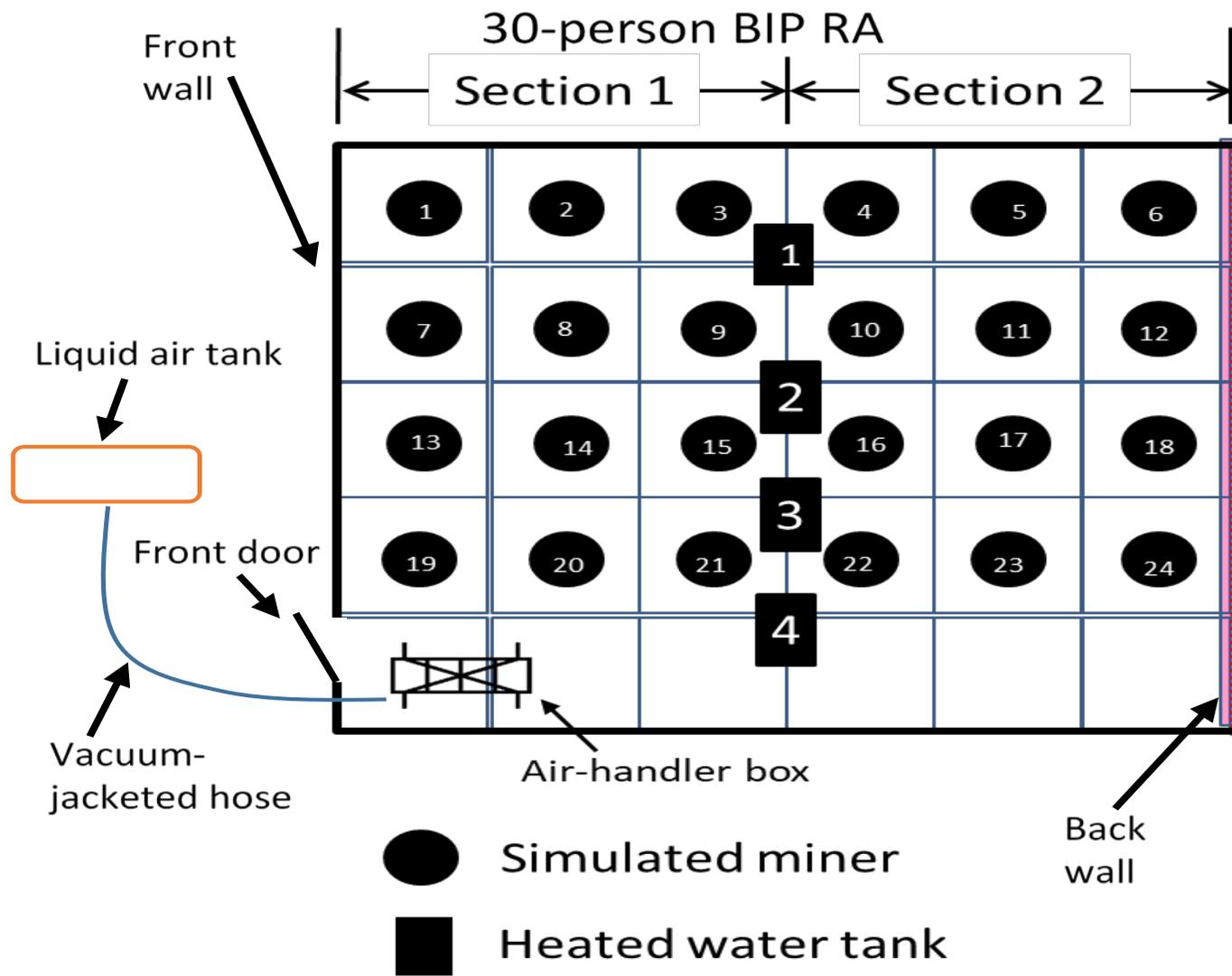


NIOSH has been mixing liquid air and transporting it into the Experimental Mine using the liquid air cart



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To evaluate the cooling ability of the cryogenic air supply, NIOSH performed heat/humidity testing on a 30-person BIP RA with its air temperature elevated to 85 °F



- Tests conducted to determine *derated capacity* of the BIP RA
- Number of simulated miners varied
- Apparent temperature monitored with max of 95 °F

To supply the representative heat and humidity of actual miners and the carbon dioxide scrubbing system, NIOSH used second-generation simulated miners and heated water tanks connected to programmable VARIACs



A stable 85 °F thermal environment was created in the BIP RA using VARIAC-controlled baseboard heaters to achieve energy balance using **fixed heat input** (i.e. no thermostats)



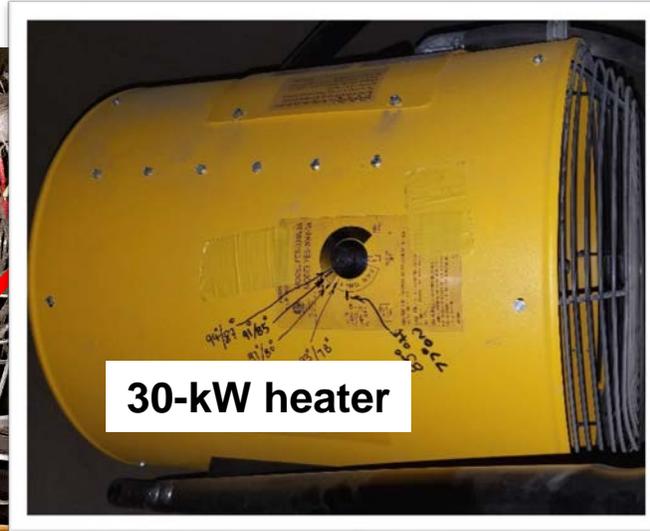
Setup and Testing of VARIAC & Baseboard Heaters



**VARIAC
(variable autotransformer)**

VARIAC Positioned Outside BIP RA

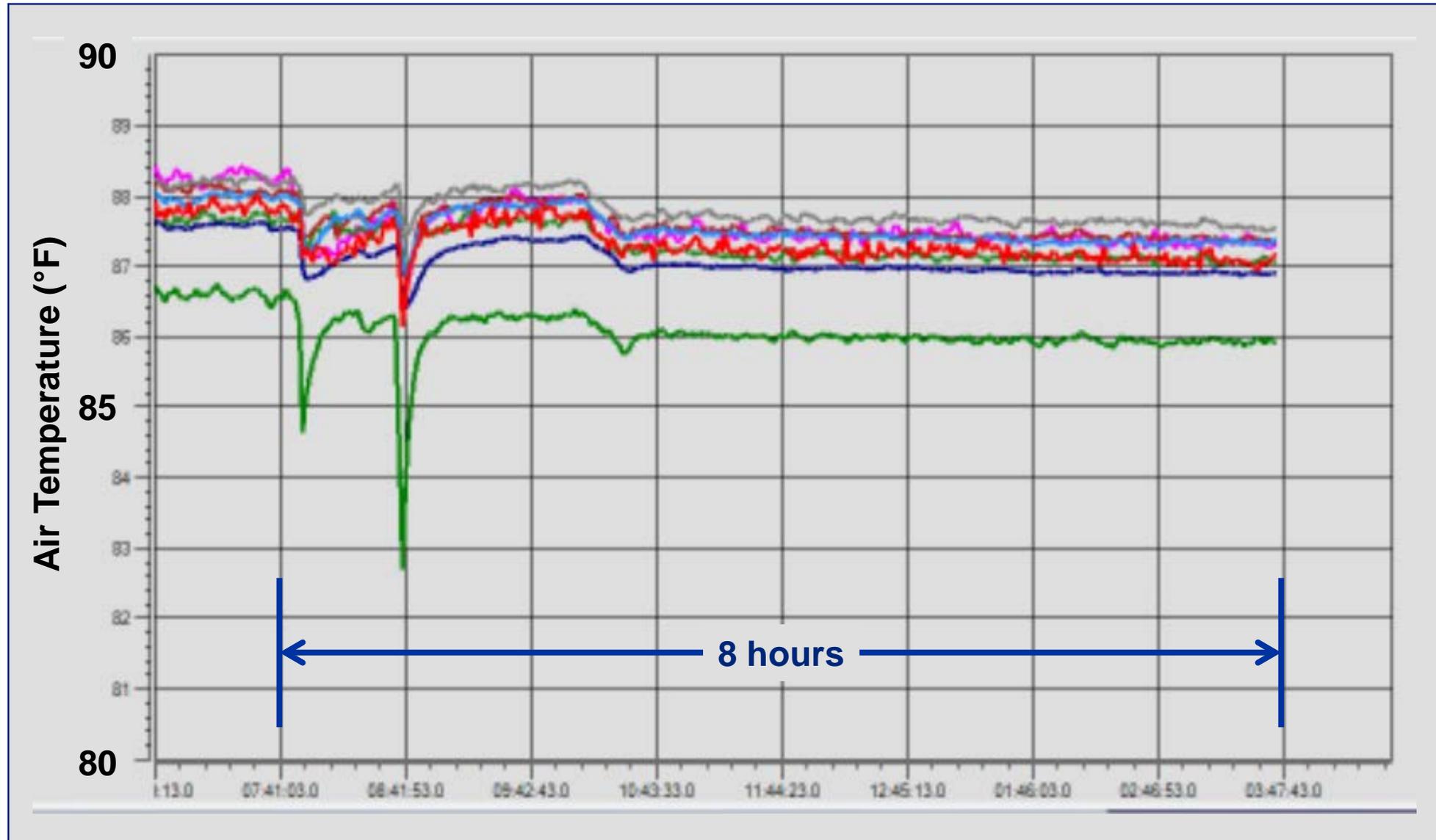
A 30-kW heater and six VARIAC-controlled heaters were used to raise the initial air and strata temperatures in the BIP RA



2 of 6
VARIAC-controlled
baseboard heaters

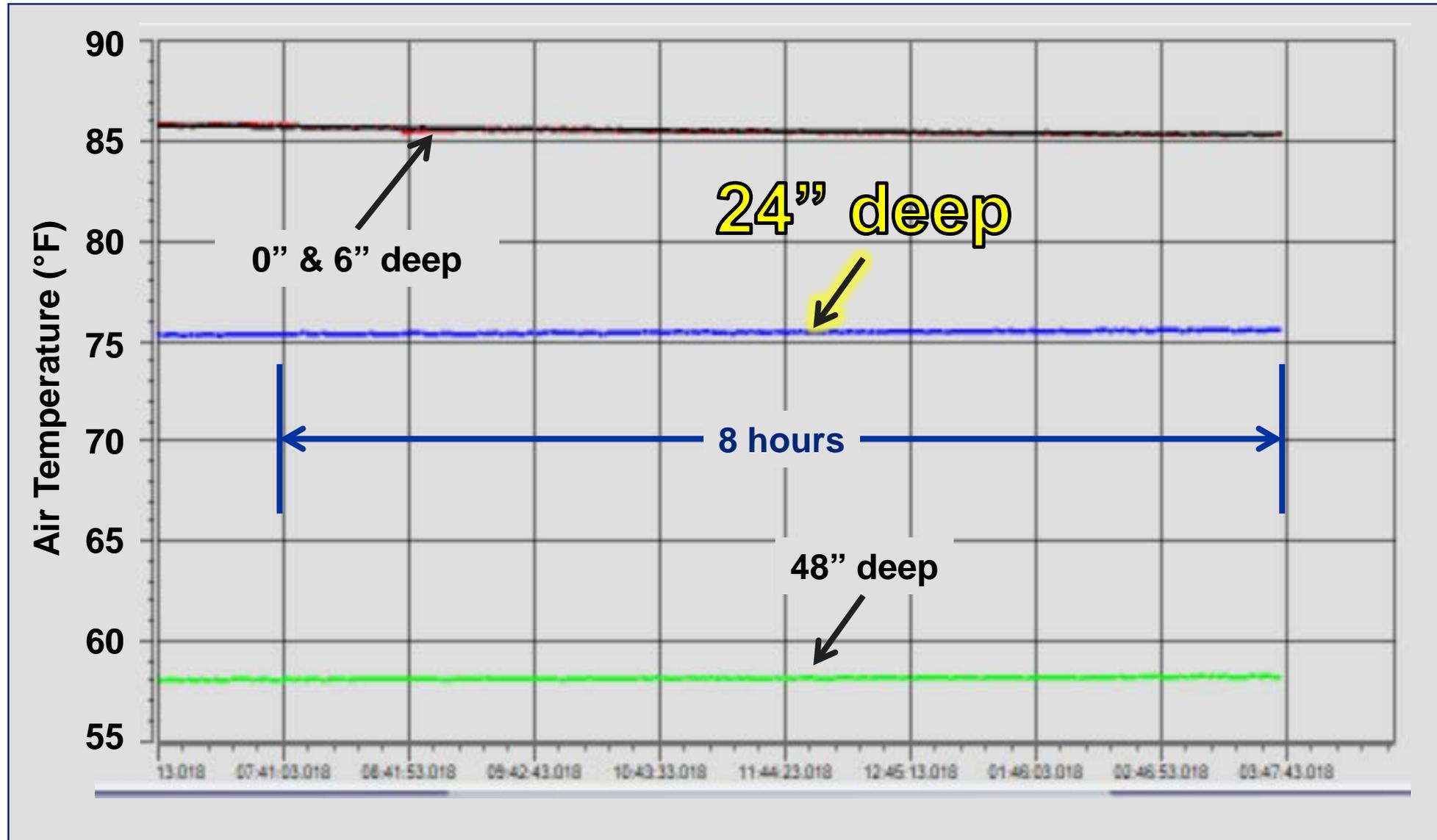
30-kW heater

The air temperature inside the BIP RA was stabilized at ~85°F before beginning each 96-hour test



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The BIP RA strata temperatures were raised to ~75 °F at a depth of 24", the same value measured in an Alabama coal mine



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Heat/humidity tests were conducted using a consistent test procedure

Before testing

- The liquid air tank was filled with about 1,800 liters of liquid air
- The BIP RA was preheated so that the BIP interior air temperature was 85 °F and the mine strata temperature at 24" depth was 75 °F
- The power delivered to the heaters was then kept constant during the test

During testing

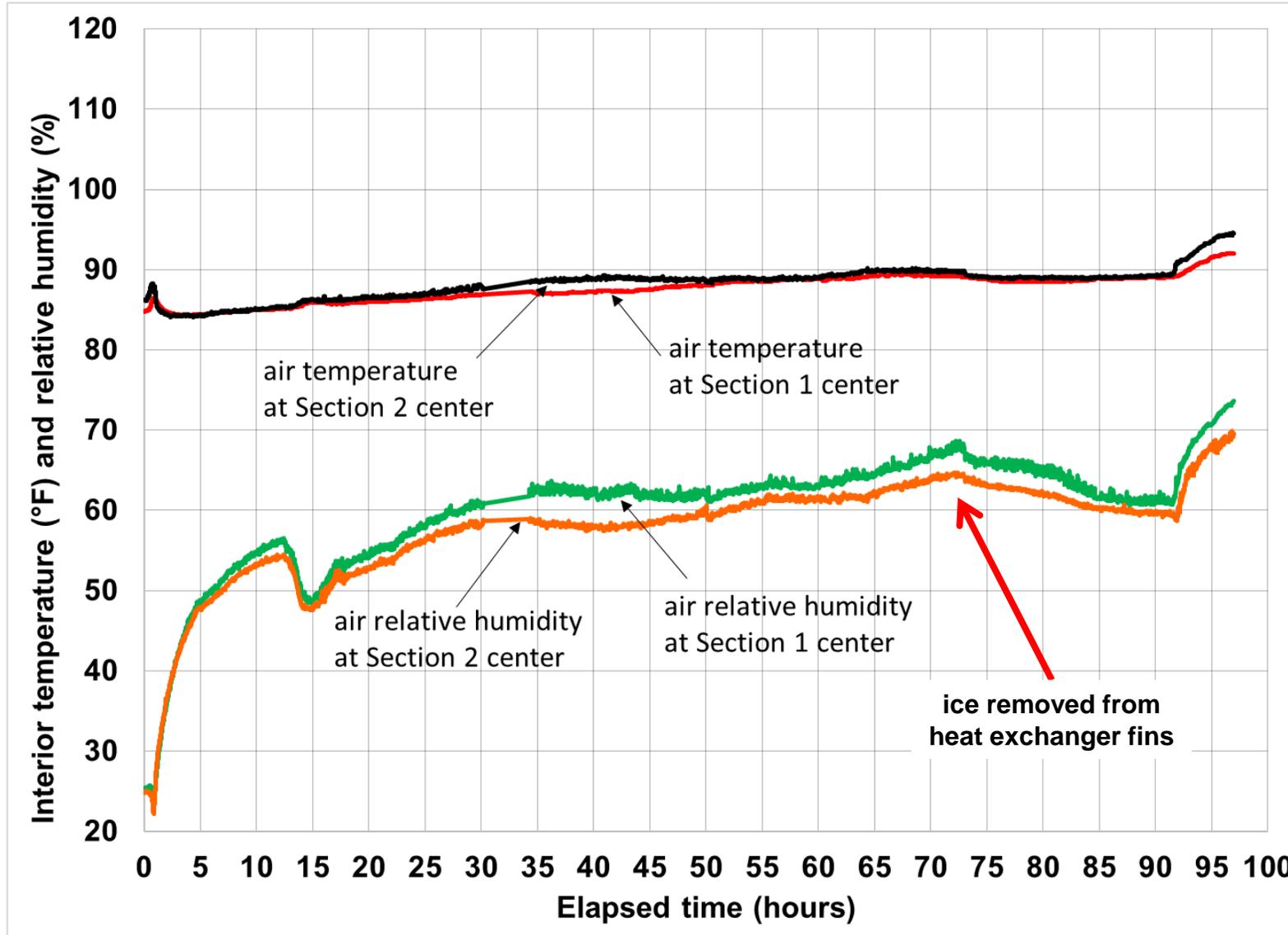
- Each simulated miner (SM) delivered 117 W of heat and ~1.3 to ~1.5 L of moisture per day
- Heated water tanks used to deliver an additional 27.5 W of heat per SM to represent carbon dioxide scrubbing system heat
- The cryogenic air supply flow rate measured at the air handler was set to ~200 - 220 LPM

Heat/humidity tests were conducted with 24, 16, and 12 simulated miners

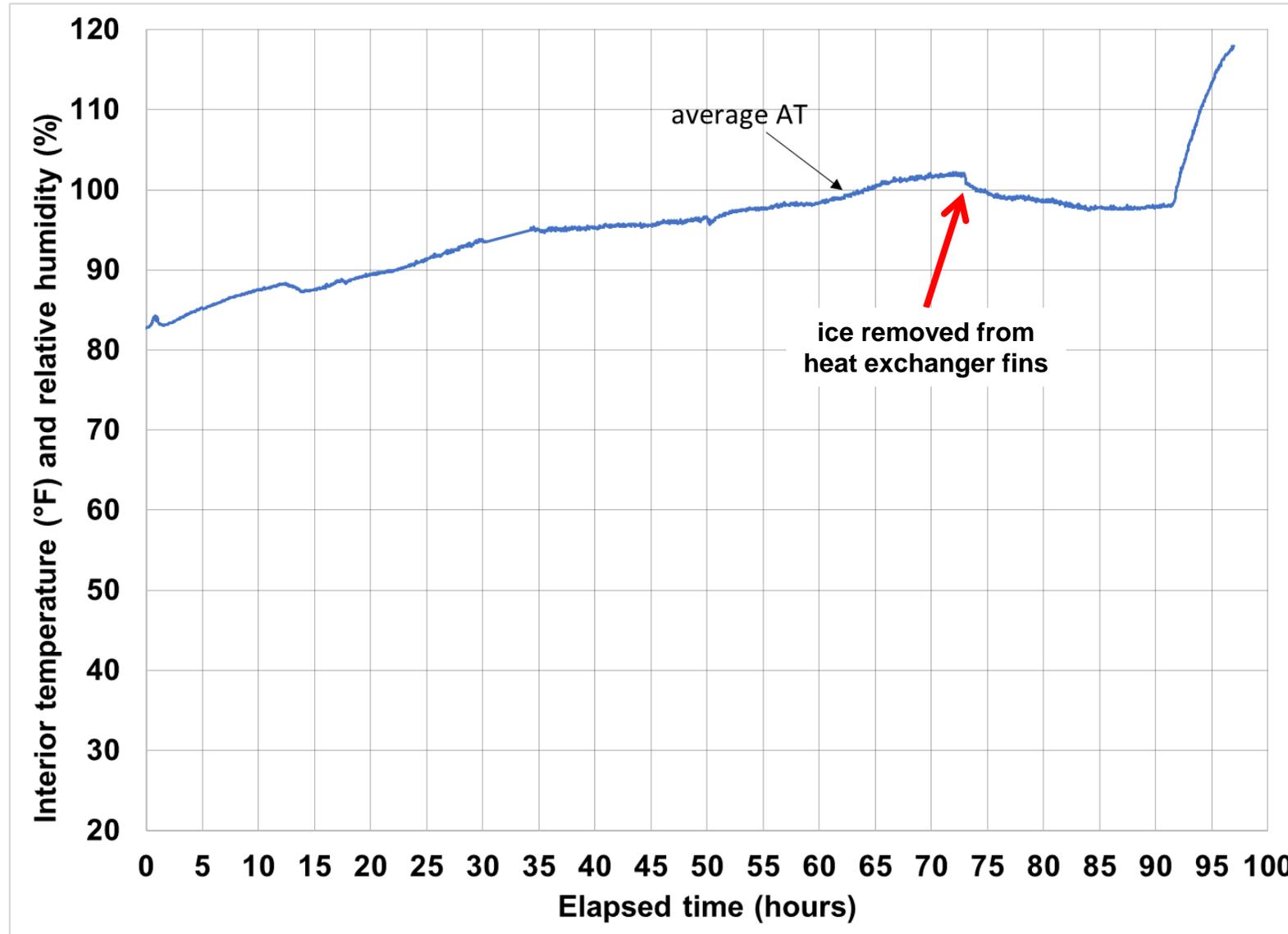
	Test #1	Test #2	Test #3	Test #4
# of SMs	24	16	12	12
Cryo used	yes	yes	yes	no
Testing hours	96	96	96	8



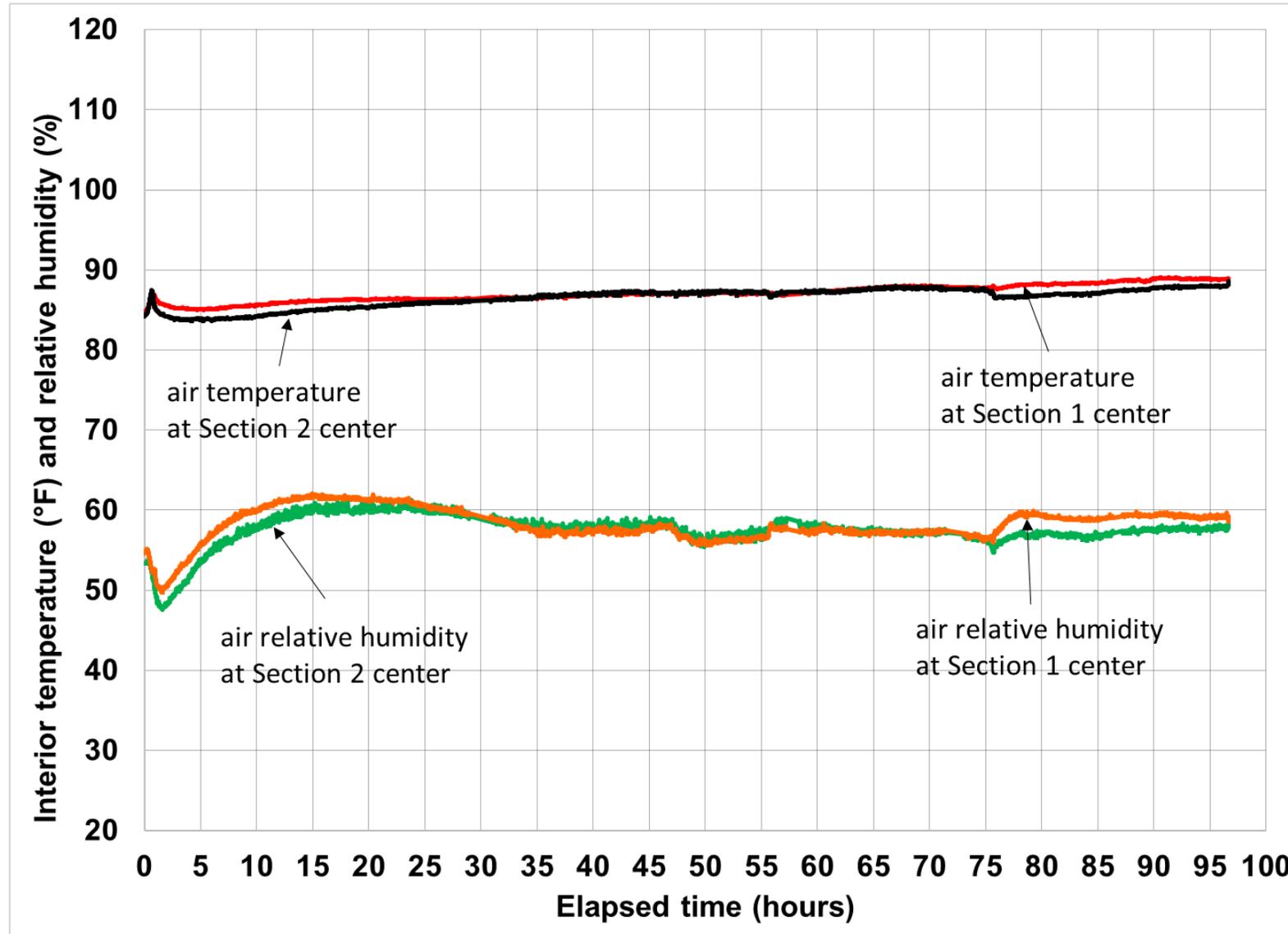
During Test #1 with 24 SMs, the air temperature exceeded 90°F and the %RH reached ~67%



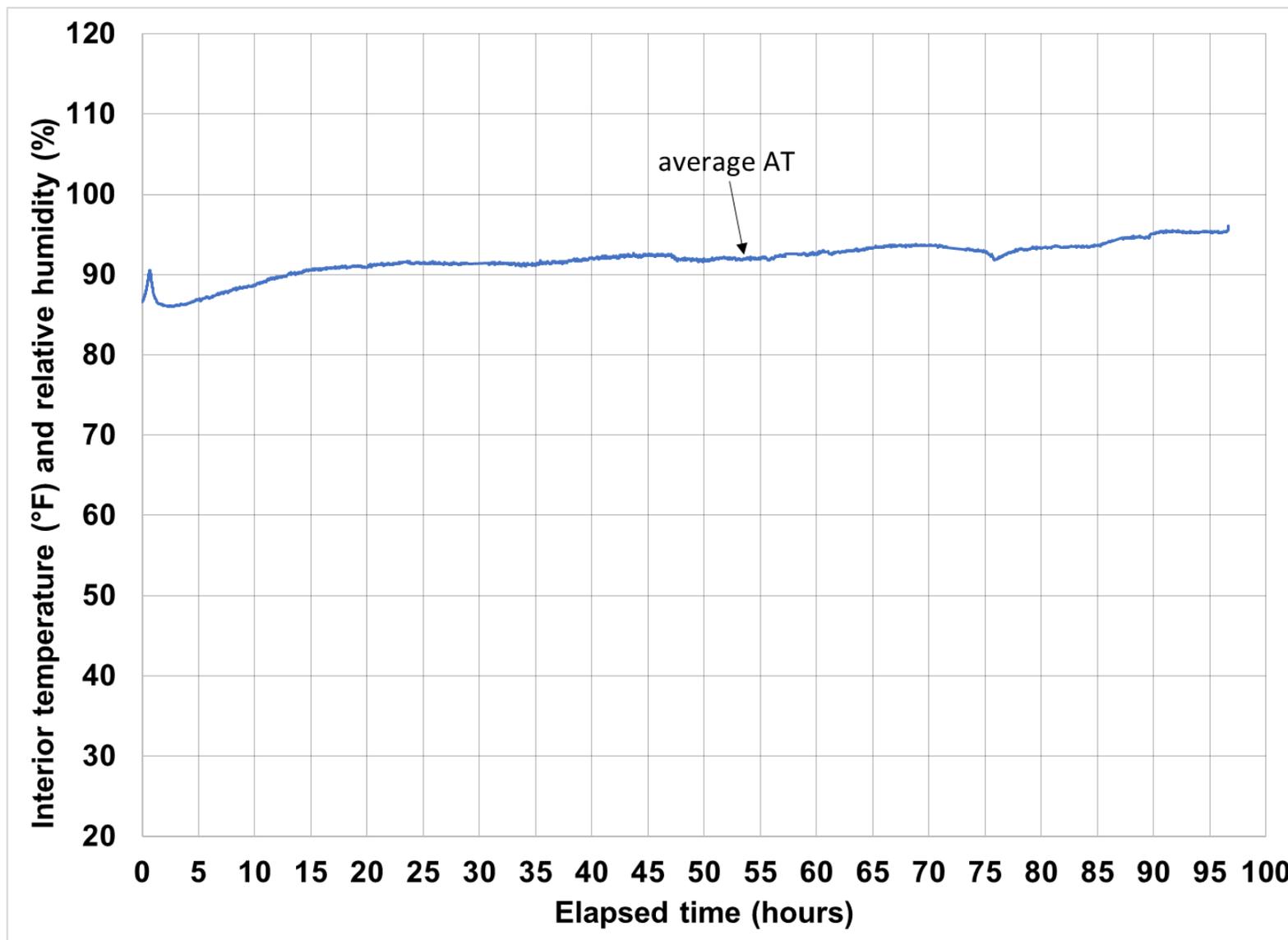
During Test #1 with 24 SMs, the apparent temperature reached 99°F when the liquid air ran out at 91 hrs, and 119°F at the end of the test



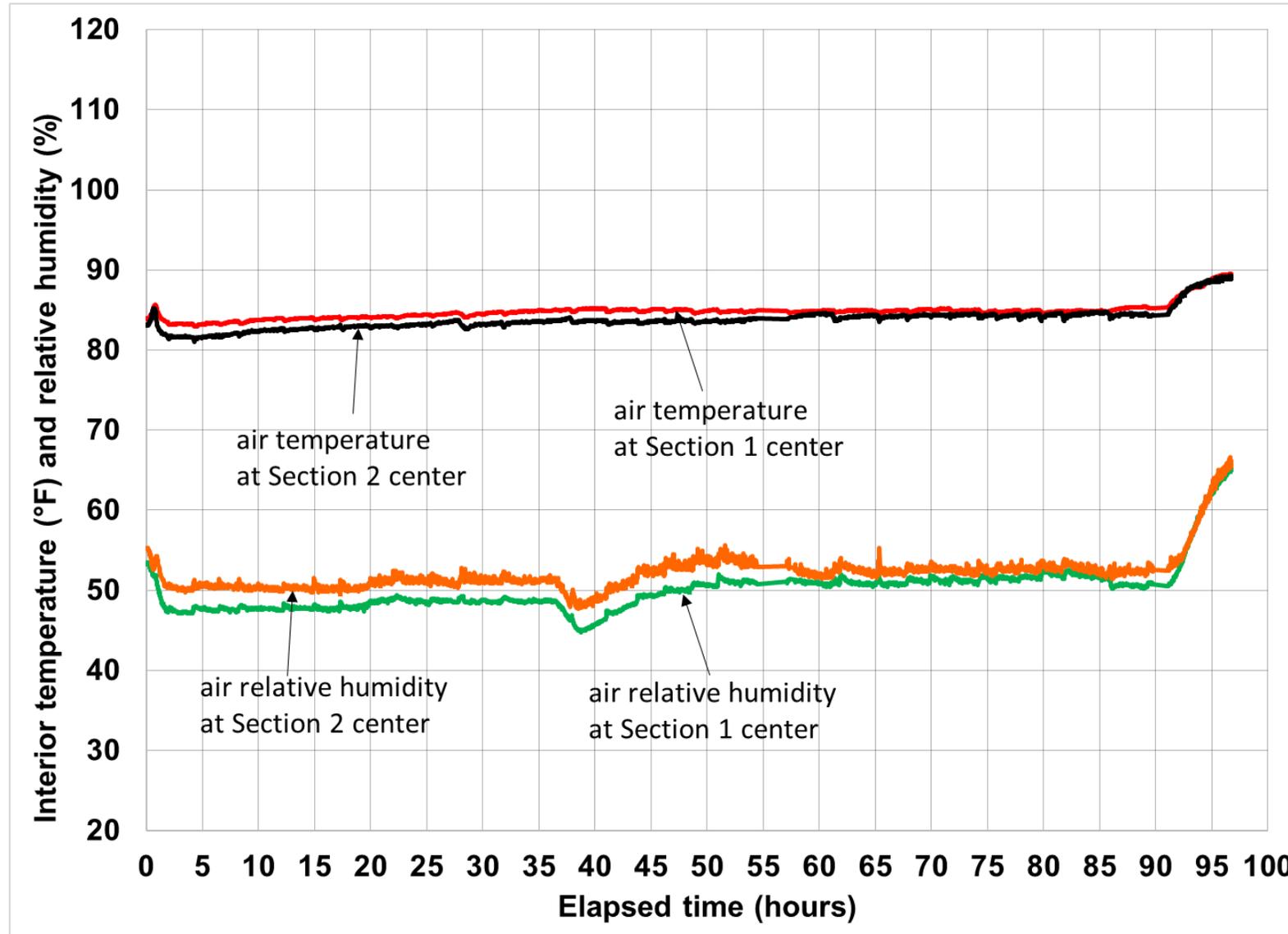
During Test #2 with 16 SMs, the air temperature was just under 90°F and the %RH reached ~60%



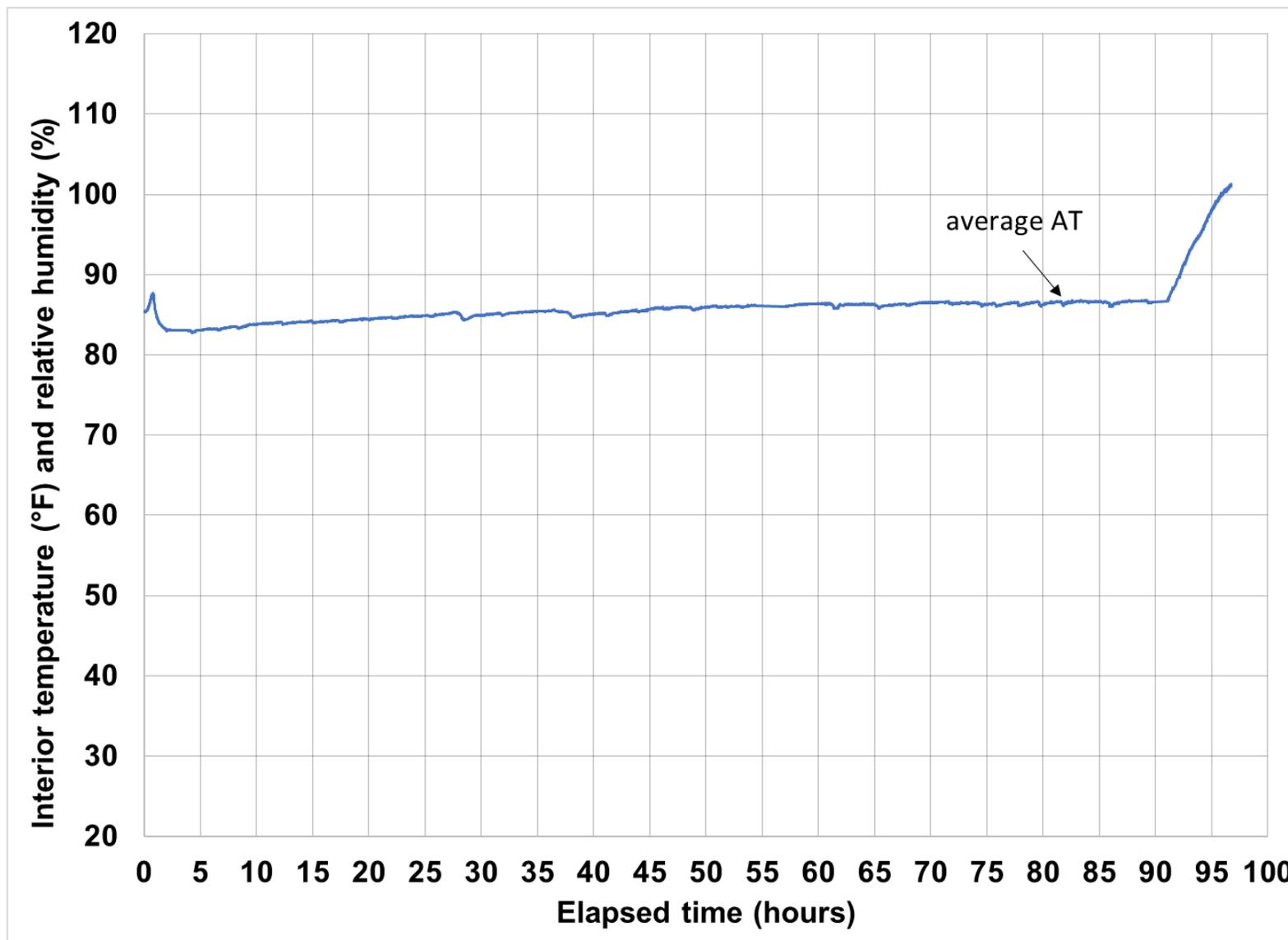
During Test #2 with 16 SMs, the cryogenic air lasted for 96 hours, but the apparent temperature reached 95.3°F at the end of the test



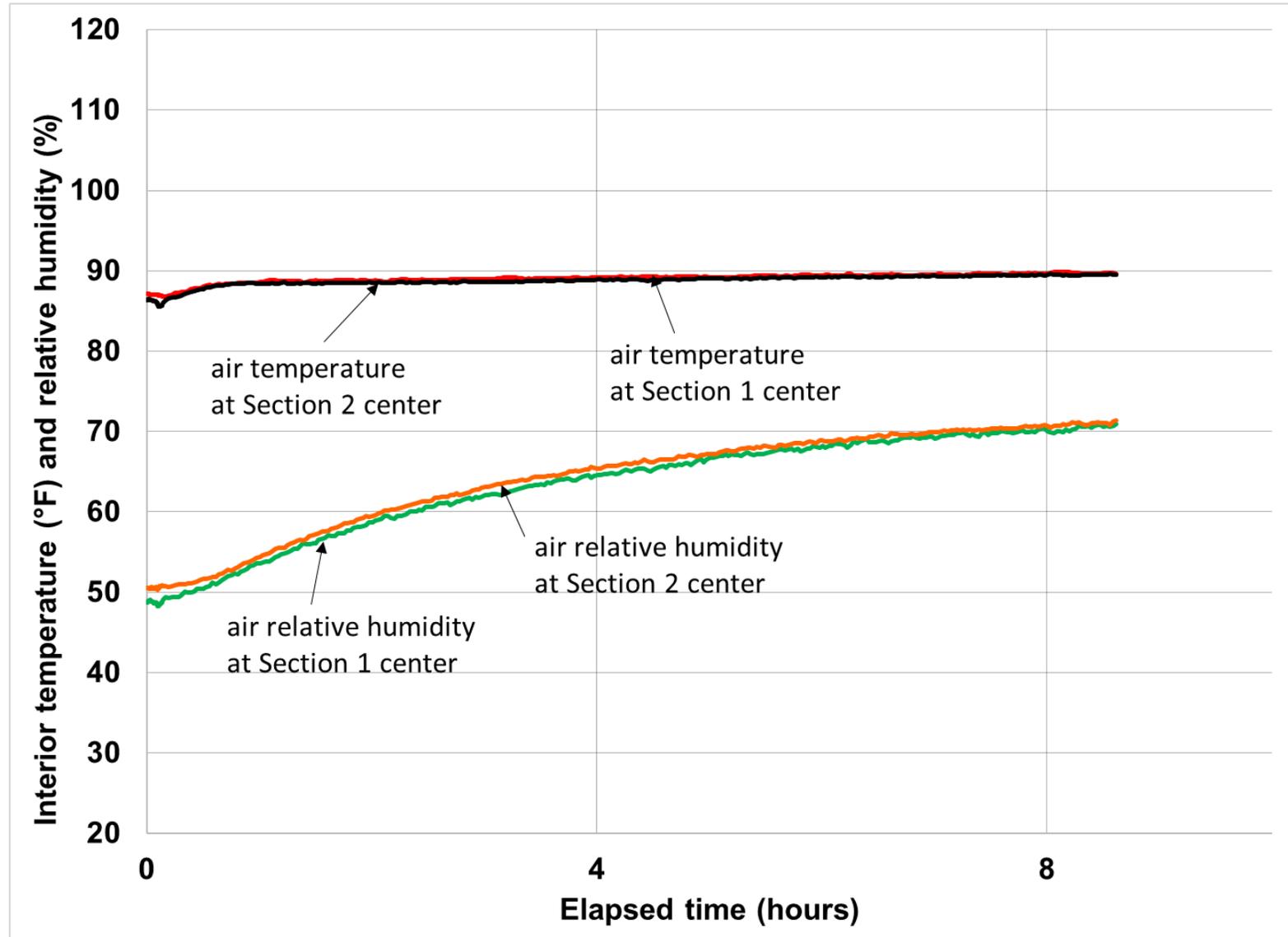
During Test #3 with 12 SMs, the air temperature was kept at ~85°F and the %RH was kept at ~52% until liquid air ran out at 91 hours



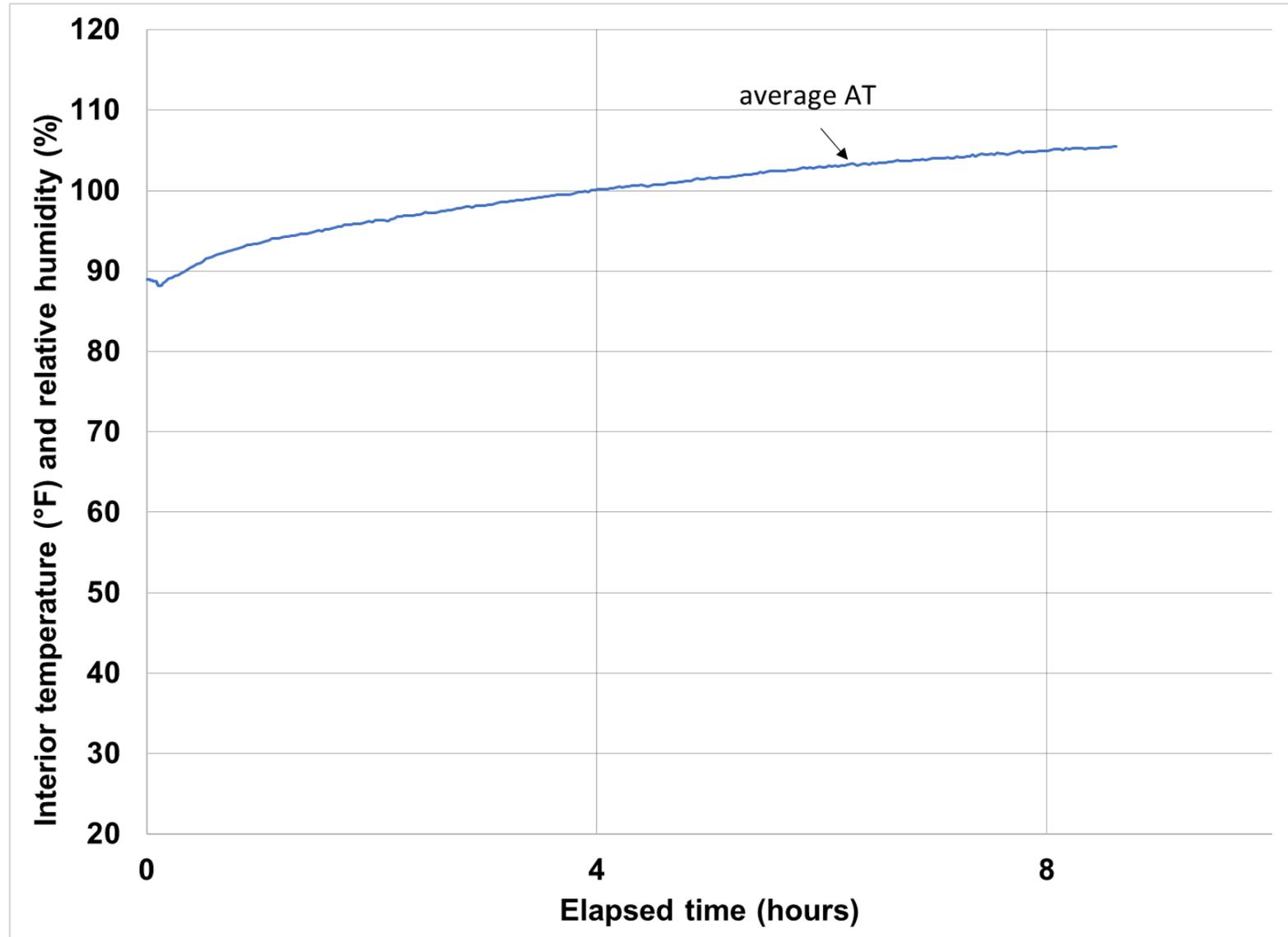
During Test #3 with 12 SMs, the apparent temperature was ~87°F when liquid air ran out at 91 hours and it reached ~100°F by the end of the test



During Test #4 with 12 SMs and without the cryogenic air supply, the air temperature reached 90 °F and the %RH reached 70% in 8 hours



During Test #4 with 12 SMs and without the cryogenic air supply, the apparent temperature reached 105°F in 8 hours



The results show the cryogenic air supply has potential for use as an RA cooling system

	Test #1	Test #2	Test #3	Test #4
# of SMs	24	16	12	12
Testing hours	96	96	96	8
Cryo used	yes	yes	yes	no
When cryo air supply was depleted (hours)	91	96	91	--
Interior AT when cryo air was depleted (°F)	99.4	--	86.6	--
Interior AT end of the test (°F)	118.6	95.3	100.3	105.2

Summary

- The cryogenic system was effective in controlling the air temperature inside the BIP RA, with limitations
- A larger volume of liquid air could allow for improved cooling and a longer duration
- The cryogenic system needs to have improvements made to address several areas
 - Liquid air volume measurement
 - Flow control
 - Flow measurement
 - Heat exchanger design
- Tests on the cryogenic air supply must be conducted to investigate
 - Breathable air
 - Carbon dioxide scrubbing requirements
 - Purging requirements



Questions ?

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NIOSH Mining Program
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