Liquid Nitrogen System
National Electrostatics Corp.

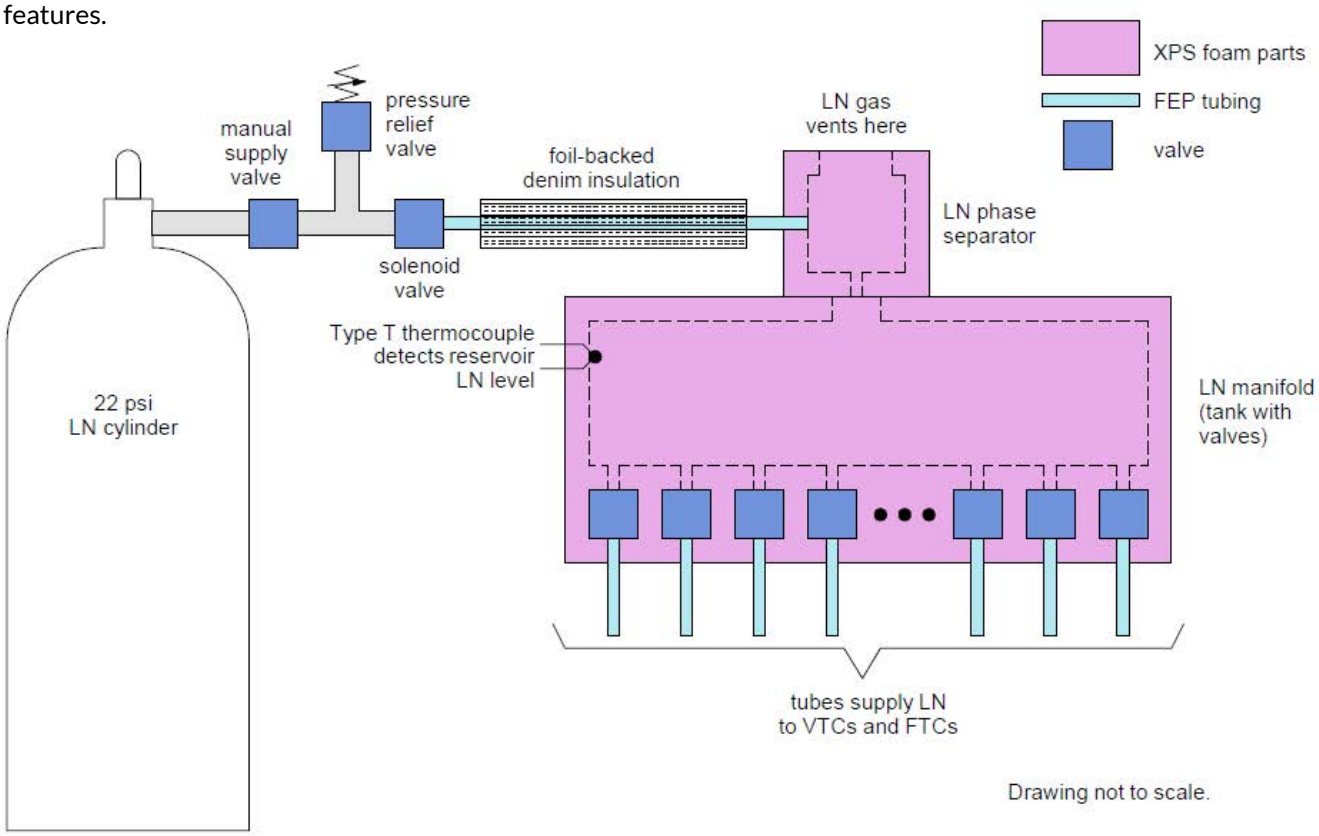
Liquid Nitrogen System

General Description

Vacuum-based gas-sample processing systems, like the NEC-Aeon CEGS, often must cool parts, typically called "coldfingers", to cryogenic temperatures. Liquid nitrogen (LN) offers a convenient and relatively inexpensive means to produce temperatures as low as -196 °C, but its benefits come with some unique challenges.

LN is usually delivered to the lab in a vacuum-insulated cryogenic cylinder, which dispenses it at 22 psi. Because LN boils at -196 °C, moving it into room-temperature plumbing or containers rapidly and violently flashes a large amount of the liquid into a gas, which then occupies a volume 700 times that of the liquid. The turbulence and increased pressure caused by this phase change continues until the contacted materials have cooled to LN's boiling point. In addition to these unstable conditions, cryogenic temperatures cause significant and diverse changes to the mechanical properties of most materials. All of this must be addressed by the automated LN-handling system, so that devices can be operated in a safe, reliable, and controlled manner.

The automated LN system manages delivery of LN from the cylinder to the coldfinger. Here is a brief description of the key features.



Liquid Nitrogen System

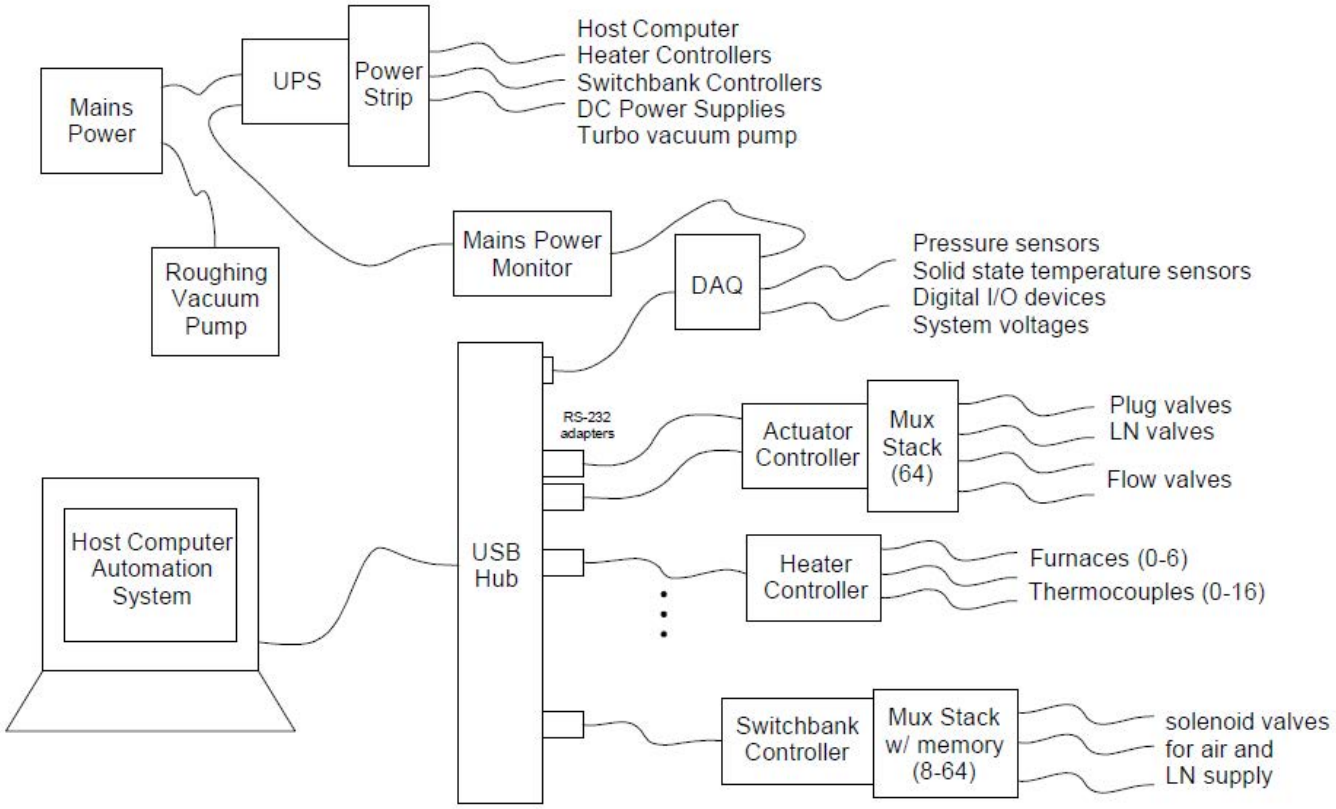
Materials

A key aspect is material selection. Everywhere possible, components are constructed of materials with the low thermal effusivity. Vessels are machined from single blocks of closed-cell extruded polystyrene foam (XPS). Tubing is fluorinated ethylene propylene (FEP). Where flexible bends in FEP tubing are desirable, two pieces of FEP are joined by a short length of slightly larger silicone tubing. Coldfingers are fused quartz or borosilicate glass. Direct contact with metals is specifically avoided except where thermal conductivity is required for function, and in such cases the parts are kept as small as possible and the metal is thermally insulated from ambient temperatures.

In general, low effusivity materials and nonmetal connections cannot withstand significant pressure. Additionally, contact between different materials destabilizes as temperatures change from ambient to cryogenic. To address these challenges, as soon as the LN has been elevated above the delivery points, we immediately reduce the liquid pressure to atmospheric. Remaining transport is accomplished by the force of gravity, with a minor assist from expanding gas as the LN makes its way through the FEP tubing to the destination.

Control

The LN supply solenoid valve is powered by switched mains voltage (120 VAC). The valve actuators on the LN manifold are operated by a standard RC proportional servo control scheme. In the NEC-Aeon CEGS, the solenoid valve is operated by a Switchbank, and the LN valve actuators connect to an Actuator Controller's multiplexer stack. VTC and FTC thermocouples, and the VTC heater power go to one of our 6-channel Heater Controllers. All three controllers are managed by our host software.



Liquid Nitrogen System

Cryongenic Pressure Relief Valve

At the cylinder plumbing, an automatic mechanical valve protects against the potentially dangerous overpressure that can be caused by rapidly expanding trapped gas.

Supply Solenoid Valve

The solenoid valve that delivers pressurized LN from the cylinder to the phase separator is the last element in the system to present a significant heat load to the liquid.

Phase Separator

The phase separator de-pressurizes liquid nitrogen and routes it down into the LN manifold, while venting the large volume of expanding gas up and out of the system. A flexible "snorkel" directs the cold gas flow away from temperature sensitive areas.

LN Manifold

This device contains a 200 mL reservoir and a set of special valves, each of which can release a tiny trickle of LN at atmospheric pressure to a single destination by gravity. The manifold is machined from a single block of XPS. The valve stems are one-piece, machined from solid FEP rod. The stems are driven by simple RC servo based actuators mounted to the stainless steel frame on which the manifold rests.

Freeze-Thaw Coldfinger (FTC)

This simple device contains a reservoir for a few milliliters of LN and a thermocouple to monitor the level. The FTC attaches to a vacuum system coldfinger, providing one of two temperature settings: Freeze or Thaw. When set to Freeze, the reservoir is filled with LN, cooling the coldfinger. When set to Thaw, the LN is ejected from the reservoir by compressed air, and the coldfinger warms to ambient.

Variable Temperature Coldfinger (VTC)

A VTC attaches to a vacuum line coldfinger, to control its temperature to a precise setpoint anywhere in the range from -196 to +50 °C. It contains a small reservoir for LN, a resistance-wire heater, and a thermal conduit. The conduit transfers energy between the heater and the LN at a controlled rate so the bottom tip of the coldfinger can be maintained at a precise temperature by modulating the heating element power using feedback from a thermocouple. Additional thermocouples monitor the LN level, the element wire temperature, and a secondary temperature at the top of coldfinger.

Contact NEC

www.pelletron.com +1 (608) 831-7600 nec@pelletron.com

7540 Graber Rd, Middleton, WI 53562-0310 USA