Tech Guide #4

Welcome To LN2

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What is nitrogen?

Nitrogen is the largest single constituent of the Earth's atmosphere (78.082% by volume of dry air, 75.3% by weight in dry air). It is created by fusion processes in stars, and is estimated to be the 7th most abundant chemical element by mass in the universe.

Nitrogen is a pure element, just as oxygen, gold and mercury are all pure elements. Because it boils at -196° Celsius, pure nitrogen occurs as a gas which makes up 78% of the atmosphere

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When was nitrogen discovered?

Nitrogen is formally considered to have been discovered by Daniel Rutherford in 1772, who called it *noxious air* or *fixed air*. That there was a fraction of air that did not support combustion was well known to the late 18th century chemist. Nitrogen was also studied at about the same time by Carl Wilhelm Scheele, Henry Cavendish, and Joseph Priestley, who referred to it as *burnt air* or *phlogisticated air*. Nitrogen gas was inert enough that Antoine Lavoisier referred to it as "mephetic air" or *azote*, from the Greek word *άζωτος* (*azotos*) meaning "lifeless". Animals died in it, and it was the principal component of air in which animals had suffocated and flames had burned to extinction.

How is nitrogen classified?

The nitrogen shall conform to the following types, grades, and classes:

Type. The type of technical nitrogen shall be as specified.
Type I - gaseous
Type II - liquid

Grade. The grade of technical nitrogen shall be as specified.
Grade A - 99.95 percent pure nitrogen
Grade B - 99.50 percent pure nitrogen

The amount of nitrogen in the material shall be a minimum of 99.95 percent by volume (v/v) for grade A nitrogen or 99.50 percent v/v for grade B nitrogen. This includes trace amounts of neon, argon and helium. The purity shall be determined by one of the methods described in Compressed Gas Association (CGA) G-10.1, "Commodity Specification for Nitrogen".

ULTRA High Pure Nitrogen Gas, UHP Nitrogen in gaseous form that are widely used for gas chromatography(GC), industrial purposes by the fractional distillation of liquid air, or by mechanical means using gaseous air (i.e. pressurized reverse osmosis membrane or pressure swing adsorption). Serving as an inert replacement for air where oxidation is undesirable; they are also used in production of electronic parts such as transistors, diodes, and integrated circuits.

How is liquid nitrogen made?

Liquid nitrogen is made by cooling and compressing air straight from the atmosphere. When you compress air, air molecules are forced closer together. If you also cool it down the molecules can slow down enough to make weak bonds. When enough molecules start bonding together like this, droplets of liquid form. This process is called condensation.

Liquid nitrogen is a liquefied atmospheric gas produced industrially in large quantities by fractional distillation of liquid air.

Fractional distillation is the separation of a mixture into its component parts, or fractions, such as in separating chemical compounds by their boiling point by heating them to a temperature at which several fractions of the compound will evaporate. It is a special type of distillation. Generally the component parts boil at less than 25°C from each other under a pressure of one atmosphere (atm). If the difference in boiling points is greater than 25°C, a simple distillation is used.

Is there an alternative to liquid nitrogen?

Liquid helium is colder than liquid nitrogen. However, liquid nitrogen is a lot less expensive than helium. Even though Helium is the second most common element in the universe there is only a fixed amount available on the earth, so we don't waste any of it. Liquid nitrogen is very inexpensive because we can get it from air. Liquid oxygen is also extracted from air, but for each gallon of liquid oxygen you get three of liquid nitrogen. There are many industrial uses of oxygen, like in the manufacturing of steel, so there is usually a surplus of liquid nitrogen.

Fluid	**Boiling temperature**	**Boiling temperature**
	Celsius	**Fahrenheit**
Oxygen	-183°	-297°
Nitrogen	-196°	-320°
Neon	-253°	-411°
Hydrogen	-253°	-423°
Helium	-270°	-452°

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Is LN2 considered a hazardous material?

Be sure you review the MSDS information before using liquid nitrogen. This is a potential very hazardous material, yet often times it is not given the respect it deserves.

Risk is greatly reduced and minimized if the following safety measures are followed when handling liquid nitrogen.

- Liquid nitrogen can cause terrible burns. Hand protection and goggles (not safety glasses) are to be worn when dispensing and handling liquid nitrogen.
- When handling large quantities, a full length apron will minimize the chance of a spill going into your shoes.
- Persons using a tipper to dispense LN2 should wear a full face shield, cryo-gloves, full length cuff less trousers which completely cover the tops of the shoes (or a full length apron), and shoes which will not permit liquefied gas to enter them in case of a spill, and which are also quickly removable in case they do (allow liquid to enter).
- Liquid nitrogen expands more than 700 times when it goes from a liquid to a room temperature gas. If confined it can produce pressures that can burst nearly any container. Pressures of over 40,000 pounds per square inch are possible.
- Use only vessels designed for extreme cold. Not all Dewars are rated for liquid nitrogen. Always follow manufacturers' guidelines for use of cryogen vessels of any size.
- Do not use rubber or plastic tubing for liquid nitrogen transfer. Liquid nitrogen may freeze rubber or plastic tubing such that the tubing will fracture from a small movement.

How do I distribute LN2 from my supply cylinders or bulk storage tank to my equipment?

LN2 can be distributed in several ways. You can use flexible stainless steel transfer hose, insulated pipe, flexible vacuum-jacketed hose, rigid vacuum-jacketed pipe, or a combination of these means. Stainless steel flexible transfer hose is usually used in short lengths of less than 10 feet (3 meters). Its ribbed inner surface creates turbulence in the LN2 as it flows through the hose. This turbulence can cause spontaneous vaporization of the liquid creating gas bubbles in the LN2. These gas bubbles cause "slugging" or irregular effects when the nitrogen is used. This in-line gas can be removed by using a phase separator.

Rigid vacuum-jacketed pipe and vacuum-jacketed hose are the most efficient means of distributing LN2. Large, permanent installations frequently use vacuum-jacketed pipe for their main LN2 distribution system.

How are vacuum jacket pipe lines beneficial?

Liquid nitrogen piping must have some insulation to effectively transfer the liquid nitrogen with minimal vaporization or loss. There are two types of liquid nitrogen piping, vacuum jacketed and non-vacuum jacketed. Vacuum-jacketed lines are more efficient than unjacketed lines and operate frost-free. A vacuum jacket is an annulus positioned around the inner liquid nitrogen pipe.

Jacketed lines can be either rigid or flexible pipes. Rigid pipes must be accurately dimensioned for proper installation into a facility, whereas flexible lines are easier to install and allow more versatile routing. By contrast, unjacketed lines typically are foam insulated and have a heat loss as much as 20 times greater than that of a jacketed line. They also have a larger outside diameter than jacketed lines. Foam-insulated lines typically lose their insulating qualities as the foam degrades over time.

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Vacuum insulated LN2 supply line

- Outer Pipe
- Vacuum Space
- Inner Pipe

Vacuum insulated pipe, also referred to as vacuum jacketed pipe, is constructed of an inner and outer pipe. The inner pipe, which carries the cryogenic liquid, is wrapped with multiple layers of super-insulation consisting of alternating layers of a radiant heat barrier material and a non-conductive spacer material. The air in the space between the two lines is pumped out, creating a static vacuum shield. The vacuum space contains getter materials to collect out-gassed molecules to further improve the vacuum.

The thermal barrier between the inner and outer lines is so effective that even with -452 F liquid helium flowing through the pipe, the outer surface remains safe to touch with bare hands.

Flexible vacuum insulated LN2 supply lines

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What type of customers are likely to use a vacuum insulated LN2 supply line?

Large facilities such as blood banks, fertility and biomedical clinics with a large number of freezers that require a regular and consistent supply of liquid nitrogen are likely to use a vacuum insulated supply line.

Examples of theses facilities may include:

- MERCK
- Rutgers University
- New York Blood
- Lockheed Martin
- Bristol Myers Squibb
- Glaxo Smith Kline
- Schering Plough
- Amgen
- Ortho-PCC

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Why use a liquid nitrogen freezer rather than a mechanical -80°C freezer?

Cryopreservation is a process where cells or whole tissues are preserved by cooling to low sub-zero temperatures, such as (typically) 77 K or -196°C (the boiling point of liquid nitrogen). At these low temperatures, any biological activity, including the biochemical reactions that would lead to cell death, is effectively stopped. However, when vitrification solutions are not used, the cells being preserved are often damaged due to freezing during the approach to low temperatures or warming to room temperature.

The storage of cells at temperatures below -130ºC is essential in order to preserve the material unaltered. Many workers achieve this by the use of liquid nitrogen (at -196ºC), which is a dangerous medium to work in. We therefore recommend that samples be stored in the vapor phase of liquid nitrogen at temperatures as close to -196°C as possible to be absolutely safe. In this state the temperature is well below the level required to keep the material in good condition.

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Do my samples require preparation prior to storage at liquid nitrogen temperatures?

Controlled-Rate and Slow Freezing in Cryopreservation is a well established technique pioneered in the early 1970s which enabled the first human embryo frozen birth in 1984. Since then machines that freeze biological samples using programmable steps, or controlled rates, have been used all over the world for human, animal and cell biology - 'freezing down' a sample to better preserve it for eventual thawing, before it is deep frozen, or cryopreserved, in liquid nitrogen. Such machines are used for freezing oocyte, skin, blood products, embryo, sperm, stem cells and general tissue preservation in hospitals, veterinary practices and research labs around the world.

Is there anything else liquid nitrogen can be used for?

Manufacturing and Construction:

- Nitrogen is used to treat the melt in the manufacture of steel and other metals and as a shield gas in the heat treatment of iron, steel and other metals.
- Materials become hard and brittle when cooled by to very low temperatures. This property permits the removal of "flash" or "fins" on cast plastics and rubber. The castings are cooled by liquid nitrogen and the flash broken off by mechanical action.
- Shrink fitting is an interesting alternative to traditional expansion fitting. Instead of heating the outer metal part, the inner part is cooled by liquid nitrogen so that the metal shrinks and can be inserted. When the metal returns to its normal temperature, it expands to its original size, giving a very tight fit.
- Liquid nitrogen is used to cool concrete, which leads to better cured properties.
- When construction operations must be done in soft, water-soaked ground such as tunnel construction underneath waterways, the ground can be frozen effectively with liquid nitrogen. Pipes are driven into the ground, liquid nitrogen is pumped through the pipes under the earth's surface. When the nitrogen exits into the soil, it vaporizes, removing heat from the soil and freezing it.
- Liquid nitrogen is used as a method of freezing water pipes in order to work on them in situations where a valve is not available to block water flow to the work area.

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More uses for LN2

Chemicals, Pharmaceuticals and Petroleum Uses:

- Refineries, petrochemical plants and marine tankers use nitrogen to purge equipment, tanks and pipelines of dangerous vapors and gases (for example, after completing a pipeline transfer operation or ending a production run) and to maintain an inert and protective atmosphere in tanks storing flammable liquids.

- Cold nitrogen gas is used to cool reactors filled with catalyst during maintenance work. The cooling time can be reduced substantially. Cooling reactors (and the materials inside) to low temperature allows better control of side-reactions in complex reactions in the pharmaceutical industry.

- Reactor cooling and temperature control systems usually employ a circulating low-temperature heat transfer fluid to transfer refrigeration produced by vaporizing liquid nitrogen to the shell of the reactor vessel. The liquid nitrogen is vaporized in specially-designed heat exchangers that transfer refrigeration to the circulating heat transfer fluid.

More uses for LN2

Food and Beverages:

- The intense cold in liquid nitrogen allows very rapid freezing of food items, resulting in minimal cell damage from ice crystals and improved appearance, taste and texture.

- When substances such as vegetable oil and wines are stored, the inert properties of nitrogen can be used to protect against loss of quality by oxidation by expelling any air entrained in the liquid ("sparging") and protecting liquids in storage tanks by filling the vapor space ("blanketing").

- Nitrogen (and nitrogen mixed with CO_2 and oxygen) is used in transport trucks and in Modified Atmosphere Packaging (MAP) to extend the shelf life of packaged foods by preventing oxidation, mold, insect infestation and moisture migration.

- Food such as olives, nuts, raisins, shrimp, pepperoni and much more can be frozen and then turned in to a powder to be used as flavoring.

More uses for LN2

Health Care Uses:

- Nitrogen is used as a shield gas in the packing of some medicines to prevent degradation by oxidation or moisture adsorption.

- Nitrogen is used to freeze blood, as well as viruses for vaccination. It is also used to freeze livestock semen, which can then be stored for years. The quick freezing resulting from the intense cold minimizes cell wall damage.

- Liquid nitrogen is also used in some MRI (Magnetic Resonance Imaging) devices to pre-cool the low temperature magnets prior to using much more expensive liquid helium for final cooling.

- Liquid nitrogen is used in cryo-surgery to destroy diseased tissue.

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More uses for LN2

Electronics:

- Liquid nitrogen is used to cool a CPU to achieve overclocking.

- Liquid nitrogen is used to increase the sensitivity of infrared homing seeker heads of missiles.

- Liquid nitrogen is used to cool high-temperature superconductors to temperatures sufficient to achieve superconductivity.

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