How long will a tank of Nitrogen Gas Last?

Joule Thomson refrigerators operate using high pressure gas to cool a sample stage with high temperature precision and very low noise. The most commonly used gas is nitrogen gas. In order to ensure maximum performance of the Joule Thomson refrigerator, with minimum operational problems, the type of nitrogen gas used is very important.

For more information on the types of nitrogen gas required for operation with Joule Thomson refrigerators, please refer to the Technical Support Bulletin entitled "What are the Specifications for the Nitrogen Gas used in Joule Thomson Refrigerators?"

MMR Technologies Cryocooler Operating Time as a Function of Storage Tank Size and Pressure

Another important consideration when deciding which nitrogen gas tank to use with your cooling system is the length of time the experiments are expected to take, and how long the tank of nitrogen gas will last. There are several variables that are important in this:

- Tank Size
- Tank Pressure
- The usage rate of the refrigerator

While the first two variables are intuitive, the usage rate of the refrigerator can vary from system to system, and from experiment to experiment, depending on the types of samples being cooled, the experimental conditions, the cooling requirements on the system, and the vacuum pressure within the chamber housing the Joule Thomson refrigerator. There are also slight variations from refrigerator to refrigerator.

With that in mind, Table 1 will suggest some typical usage times that can be expected.

If you are interested in the details of the calculations, please "Gas Tank Lifetime Calculations" on page 1-3.

TABLE 1: OPERATING TIME FOR A TANK OF NITROGEN GAS AS A FUNCTION OF THE SIZE AND PRESSURE OF THE SUPPLY TANK

TANK ID	EQUIVALENT STP VOLUME OF NITROGEN IN THE TANK AT DELIVERY PRESSURE	STP VOLUME AVAILABLE FOR REFRIGERATOR USE	USAGE RATE OF REFRIGERATOR	OPERATING TIME AS A FUNCTION OF TANK
1L	211.0 cu. ft.	98.5 cu. ft.	2 cu. ft. / hr.	49 hours
			3 cu. ft. / hr.	33 hours
			4 cu. ft. / hr.	25 hours
			5 cu. ft. / hr.	20 hours
1A	189.0cu ft.	72.5 cu. ft.	2 cu. ft. / hr.	36 hours
			3 cu. ft. / hr.	24 hours
			4 cu. ft. / hr.	18 hours
			5 cu. ft. / hr.	15 hours
1H	189.0 cu. ft.	178.5 cu. ft.	2 cu. ft. / hr.	89 hours
			3 cu. ft. / hr.	60 hours
			4 cu. ft. / hr.	45 hours
			5 cu. ft. / hr.	36 hours
1U	183.0 cu. ft.	426.8 cu. ft.	2 cu. ft. / hr.	213 hours
			3 cu. ft. / hr.	142 hours
			4 cu. ft. / hr.	107 hours
			5 cu. ft. / hr.	85 hours
2	72.0 cu. ft.	8 cu. ft.	2 cu. ft. / hr.	4 hours
			3 cu. ft. / hr.	2.7 hours
			4 cu. ft. / hr.	2.0 hours
			5 cu. ft. / hr.	1.6 hours

GAS TANK LIFETIME CALCULATIONS

To calculate how long as gas tank can be used with the MMR Technologies' Joule Thomson (J-T) refrigerators, one must know the following:

- Tank Storage Volume in Cubic Feet (Vo)

  1 cubic foot = 2.832 x 10^{-2} cubic meters (m^3)
  = 28.32 Liters (L)
  = 2.832 x 10^4 cubic centimeters (cm^3)

- Tank Delivery Pressure in psi (Po)

  1 psi = 6.895 x 103 Newtons per meters squared (NT/m^2)
  = 6.9 x 10^{-2} bar
  = 6.805 x 10^{-2} atmosphere

- Gas Consumption Rate in Standard Cubic Feet per Hour (Ro)

  1 STCFH = 4.72 x 10^{-1} liter/min. (L/min.)

Since gas consumption is measured at standard temperature (300 K) and pressure (1 atm.) conditions (STP), it is best to do all calculations under those same conditions.

STEP 1: CALCULATE THE AMOUNT OF GAS (AT STP) STORED IN THE GAS TANK AT THE TIME OF DELIVERY.

To do this, you must assume that the tank has a storage volume of Vo and a delivery pressure of Po..

$$\text{GasVolume} = Vo \times \frac{Po}{14.76}$$

▶ **NOTE:**

Vo must be in cubic feet and Po must be in psi.

STEP 2: CALCULATE THE AMOUNT OF GAS (AT STP) LEFT IN THE GAS TANK AT THE TIME THE PRESSURE IN THE TANK REACHES 1800 PSI.

$$\text{GasVolume} = Vo \times \frac{1800}{14.76} = Vo \times 121.95$$

▶ **NOTE**

1800 psi is usually the lowest pressure for gas to be delivered to the refrigerator.

STEP 3: CALCULATE THE AMOUNT OF GAS AVAILABLE FOR USE WITH THE REFRIGERATOR.

Subtract the result of Step 2 from the result of Step 1.

$$V = \frac{Vo}{14.76} \times (Po - 1800)$$

STEP 4: CALCULATE THE TIME IT WILL TAKE FOR THE VOLUME OF GAS (CALCULATED IN STEP 3) TO FLOW THROUGH THE REFRIGERATOR.

Assume the refrigerator has a gas consumption of Ro.

$$\text{Time(hours)} = To = \frac{V}{Ro} = \frac{Vo}{Ro}\left(\frac{1}{14.76}\right)(Po - 1800)$$

Example Calculations on Expected Operating Time on a Tank of Nitrogen

Example 1:

How long will a gas tank with a storage volume of 5 cubic feet of nitrogen gas, delivered at 2640 psi last when used by a refrigerator that consumes gas at a rate of 4.5 standard cubic feet per hour?

Known Information:

Vo = 5 cu. ft.

Po = 2640 psi

Ro = 4.5 cu. ft./hr.

Put the information into the equation:

$$To = \frac{Vo}{Ro}\left(\frac{1}{14.76}\right)(Po - 1800) = \frac{5}{4.5}\left(\frac{1}{14.76}\right)(2640 - 1800) = 63.23\text{hours}$$

Example 2:

Suppose you can normally purchase gas at a maximum tank pressure of 2000 psi. You discover a new gas supplier who can deliver gas at a maximum tank pressure of 2100 psi. Does the increase in tank lifetime justify switching to the new vendor?

Defining the Times for the Two Tanks

$$\mathrm{To}(2000) = \frac{\mathrm{Vo}}{\mathrm{Ro}}\left(\frac{1}{14.76}\right)(2000 - 1800)$$

$$\mathrm{To}(2100) = \frac{\mathrm{Vo}}{\mathrm{Ro}}\left(\frac{1}{14.76}\right)(2100 - 1800)$$

The Difference in Time for the 2100 psi tank:

$$\Delta T = \mathrm{To}(2100) - \mathrm{To}(2000)$$

$$\frac{\Delta T}{\mathrm{To}(2000)} = \frac{\mathrm{To}(2100) - \mathrm{To}(2000)}{\mathrm{To}(2000)} = \frac{(2100 - 1800) - (2000 - 1800)}{(2000 - 1800)}$$

$$= \frac{(300 - 200)}{200} = \frac{100}{200} = 0.5$$

Conclusions:

By increasing the tank pressure from 2000 psi to 2100 psi, you increase the usable tank life by 50%! That definitely makes it worthwhile to change vendors.

Example 3:

Support you are operating the refrigerator at 85K and determine the cooling capacity needed at that temperature was only 100 mWatt, whereas the refrigerator is producing a cooling capacity of 250 mWatt. How can you conserve gas and lengthen the usable tank life?

Answer:

- Cool the system to 85K.
- Verify the cooling capacity is 250mWatt.
- Reduce the gas delivery pressure from 1800 psi to 1700 psi and wait 5 minutes. Measure the cooling capacity.

- If the cooling capacity is still greater than 100mWatt, reduce the gas delivery pressure to 1600 psi. Wait 5 minutes and remeasure the cooling capacity.
- Repeat the stepwise reduction of gas delivery until the cooling capacity is about 100 mWatt. Make note of this pressure, P, for the future.
- In the future, you will simply need to cool down to 85K at 1800 psi, and then reduce the pressure to the noted pressure, P, to conserve gas.

Example 4:
How much increase (approximately) in tank lifetime does one obtain if, in Example 3, you determine you can operate your refrigerator at 1600 psi. Assume the tank delivery pressure is 2000 psi.

$$To\left(\frac{2000}{1800}\right) = \frac{Vo}{Ro}\left(\frac{1}{14.76}\right)(2000-1800)$$

$$To\left(\frac{2000}{1600(1800)}\right) = \frac{Vo}{Ro}\left(\frac{1}{14.76}\right)(2000-1600)$$

$$\frac{\Delta T}{To(2000-1800)} = \frac{To\left(\frac{2000}{1600}\right) - To\left(\frac{2000}{1800}\right)}{To(2000-1800)} = \frac{400-200}{200} = 1.0$$

Conclusion:

By decreasing the normal low temperature operation tank delivery to 1600 psi from 1800 psi, one could almost double (100% increase) the useful tank lifetime of the gas.

Example 5:
Is it worthwhile to consider using a smaller size, higher pressure gas tank instead of the larger, lower pressure gas tank? Assume Ro = 5 cu ft / hr

Tank 1:

Delivery Pressure = 10,000 psi

Tank Size: 1 cu ft

Tank 2:

Delivery Pressure = 2500 psi

Tank Size: 5 cu ft

The Calculations:

$$\text{To(Tank1)} = \frac{1}{5}\left(\frac{1}{14.67}\right)(10000 - 1800) = 111.11\text{hr}$$

$$\text{To(Tank2)} = \frac{5(1)}{5}\left(\frac{1}{14.67}\right)(2500 - 1800) = 47.43\text{hr}$$

The Conclusions:

The higher pressure, smaller volume tank in this example provides an additional 63.68 hours of refrigerator operation - almost 2.5 times that of the lower pressure, higher volume tank.

FURTHER QUESTIONS

If you have further questions, please do not hesitate to contact MMR Technologies, Inc:

Phone: +1 (650) 962-9620
Fax: +1 (650) 962-9647
Email: Sales@mmr-tech.com
Web: www.mmr-tech.com