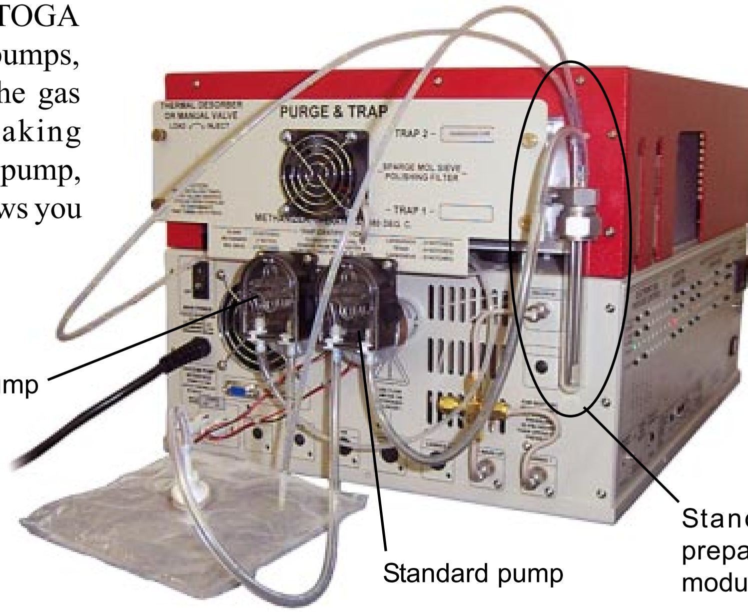
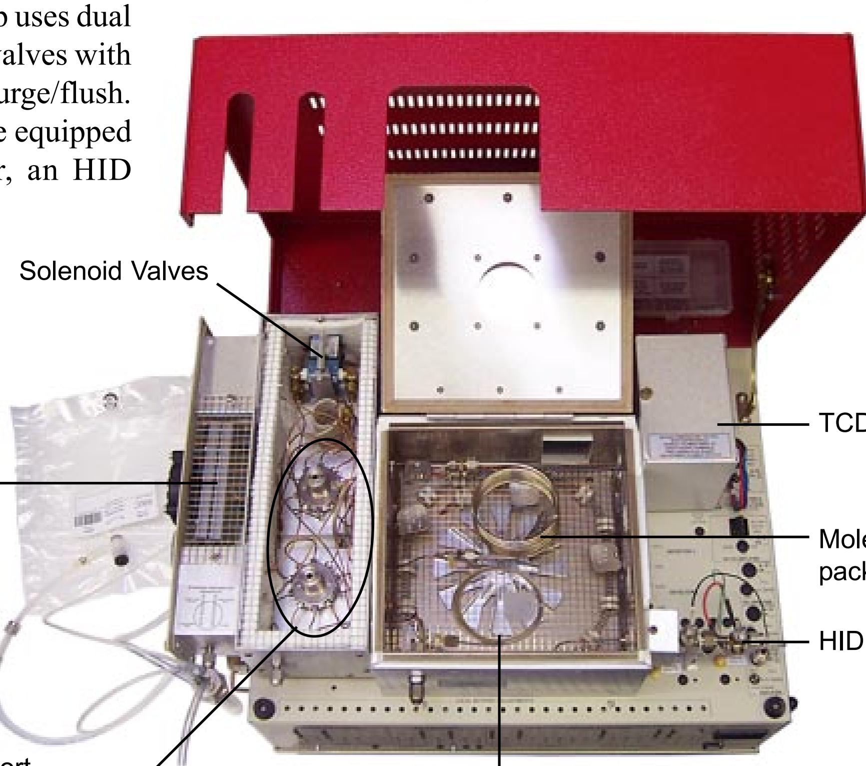
System Overview

Use the SRI TOGA GC to determine the type and quantity of gases dissolved in transformer oil, and to create dissolved gas standards. The TOGA GC is equipped with two peristaltic pumps, one to convey the sample oil into the gas extraction loop, and one for making standards. Along with the standard pump, the standards preparation module allows you to prepare dissolved gas standards.



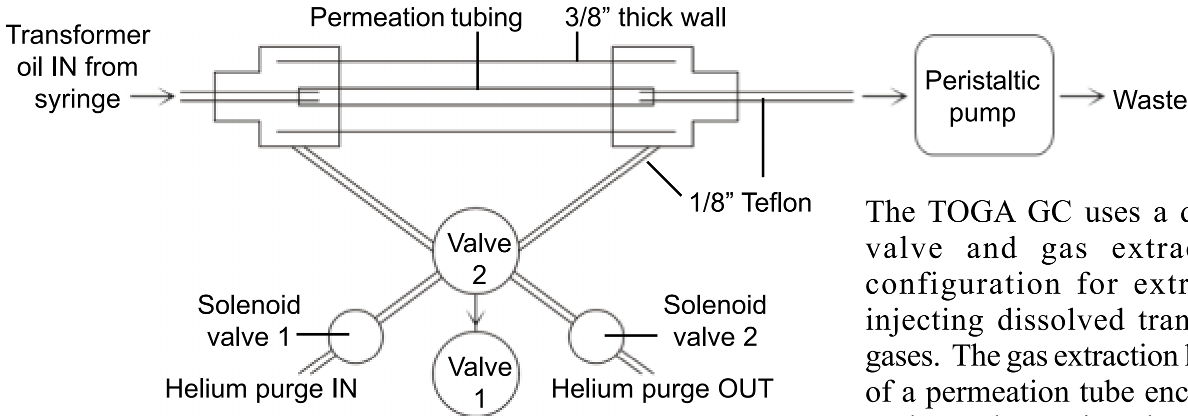
The gas extraction loop uses dual 10-port gas sampling valves with solenoids for helium purge/flush. The TOGA GC may be equipped with a TCD detector, an HID detector, or both.



The TOGA GC may also be used to perform more general dissolved gas analyses (DGA) with sample liquids like water and soft drinks.

POPULAR CONFIGURATION GCs
Transformer Oil Gas Analyzer (TOGA) GC

Theory of Operation



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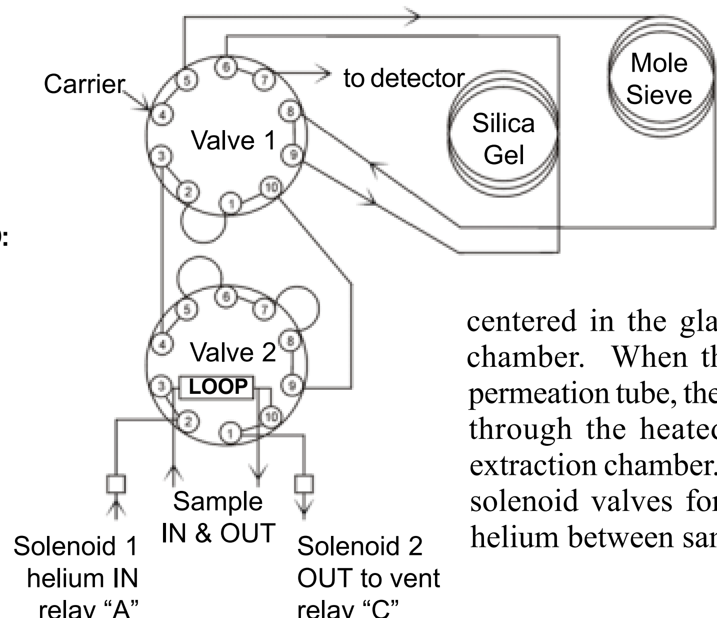
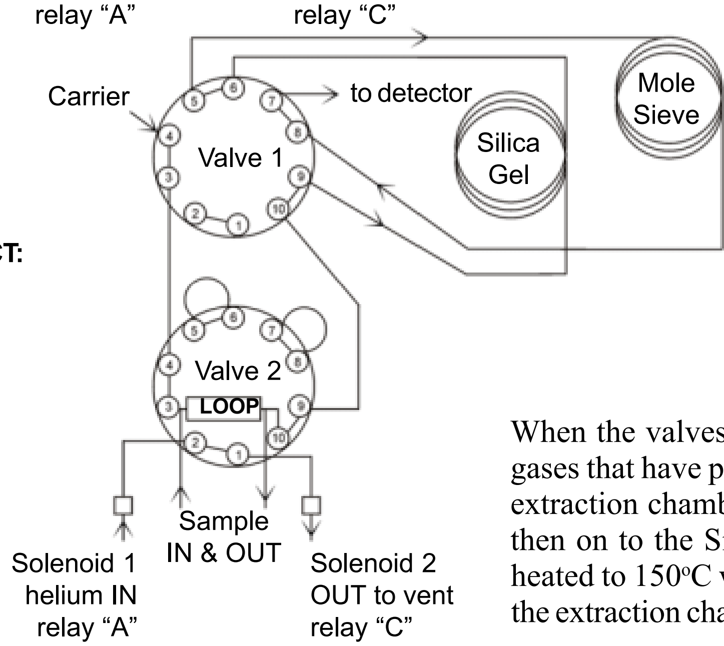


INJECT:



The TOGA GC uses a dual 10-port valve and gas extraction loop configuration for extracting and injecting dissolved transformer oil gases. The gas extraction loop consists of a permeation tube encapsulated in a glass tube equipped with a heated trap, and replaces the sample loop in the valve circuit. Teflon tubing is used to convey the sample oil from the syringe to the permeation tube, and from the permeation tube out to waste. The Teflon tubing and the permeation tube are secured in the gas extraction loop, with the permeation tube centered in the glass tube which functions as the extraction chamber. When the transformer oil is pumped through the permeation tube, the dissolved gases therein selectively permeate through the heated (70^{o}C) membrane into the surrounding extraction chamber. Plumbed to the dual 10-port valves are two solenoid valves for purging the gas extraction chamber with helium between sample injections, to prevent carryover.

Valve 1 is plumbed to the Molecular Sieve 13X column, then to the Silica Gel column. Valve 2 is plumbed to the gas extraction loop. While the transformer oil is being pumped through the gas extraction loop, both valves are in the LOAD position. During this time, the gases dissolved in the transformer oil are extracted by selective permeation through the membrane.

When the valves are rotated into the INJECT position, the gases that have permeated the membrane are swept from the extraction chamber onto the Molecular Sieve 13X column, then on to the Silica Gel column. The permeation tube is heated to 150^{o}C while the solenoids are turned ON to sweep the extraction chamber clean with helium for the next sample.

Expected Performance

These two chromatograms show a 100ppm DGA standard as separated by the TOGA GC. The permeation chamber was baked out at 150°C between runs.

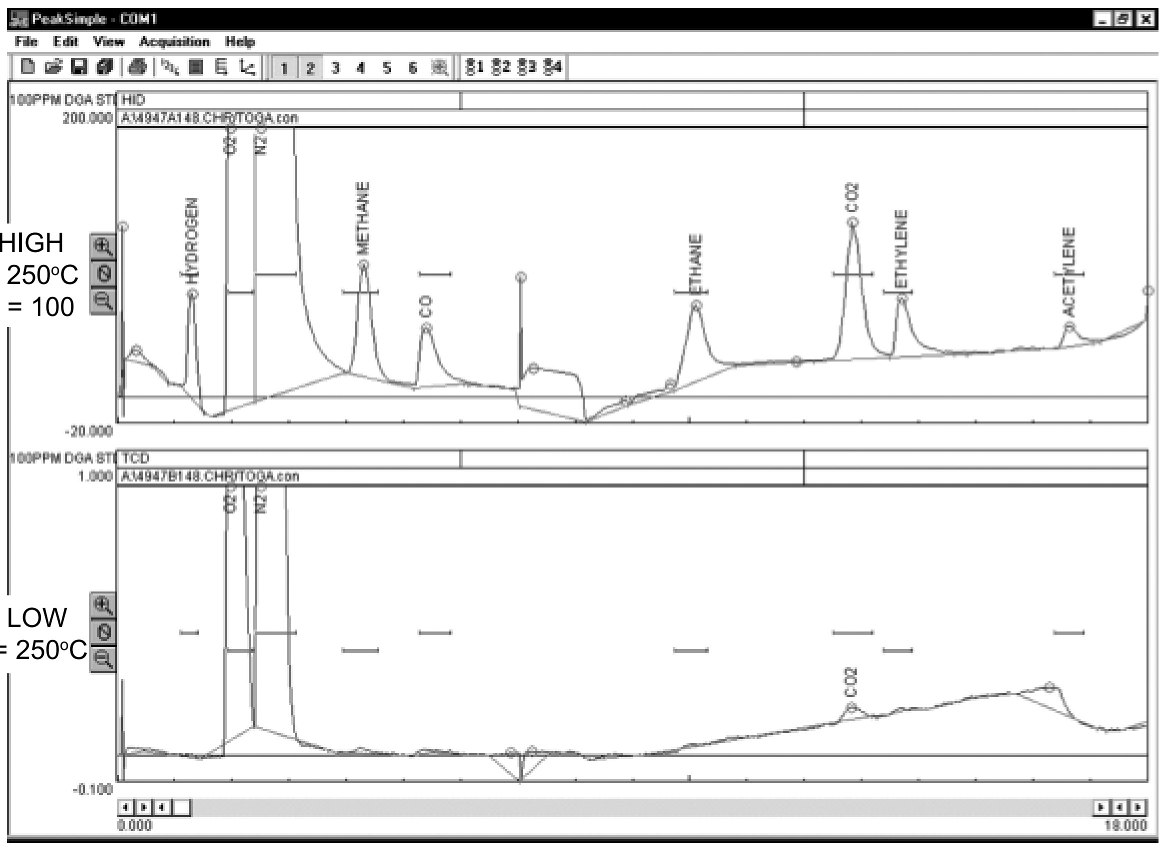
Sample: 10mL 100ppm DGA standard
Columns: 1-meter Molecular Sieve, 2-meter Silica Gel
Carrier: Helium @ 20mL/minute
Pump rate = 2.0mL/minute
Valve oven temp = 90°C
Permeation tube temp = 70°C

Temperature program:

Initial	Hold	Ramp	Final
40.00	7.000	10.000	100.00
100.00	0.000	20.000	250.00
250.00	5.000	0.000	250.00

HID gain = HIGH
HID temp = 250°C
HID current = 100

TCD gain = LOW
TCD temp = 250°C



Events:

Time	Event
0.000	C ON (OUTLET SOLENOID)
0.050	A ON (INLET SOLENOID)
1.000	A OFF
1.050	C OFF
1.100	E ON (SAMPLE PUMP)
7.100	E OFF
7.150	ZERO
7.200	G ON (VALVE 1 INJECT)
7.250	H ON (VALVE 2 INJECT)
7.750	H OFF
7.850	C ON (OUTLET SOLENOID)
7.900	A ON (INLET SOLENOID)
7.950	F ON (TRAP HEAT)
16.500	F OFF
17.500	A OFF
17.700	C OFF

Results:

Component	Retention	Area
Hydrogen	1.283	732.8160
O2	1.950	76505.4300
N2	2.483	118654.2520
Methane	4.283	1388.4300
CO	5.366	1083.2865
Ethane	10.083	1247.8820
CO2	12.816	1941.6180
Ethylene	13.683	798.1490
Acetylene	16.616	251.2315

POPULAR CONFIGURATION GCs
Transformer Oil Gas Analyzer (TOGA) GC

General Operating Procedure

1. Connect your helium source to the carrier and detector make-up gas inlets on the lower left-hand side of the GC. The pressures correlating with the proper flow rate for your instrument are printed on the right hand side of the GC, in a table under the heading GAS FLOW RATES. For best EPC performance, set the incoming helium pressure 15-20psi higher than the pressure listed in the table.

2. Turn the GC ON and let the system warm up and stabilize. Once you have ensured proper carrier gas flow, turn the TCD gain switch to LOW (this turns the current ON). The TCD temperature is factory set at 250°C. You may adjust this temperature if required. Turn ON the HID current. The HID temperature is also factory set at 250°C. Set the HID gain switch to HIGH. See each separate detector's manual section for more operating details.

3. Type in this column oven temperature program for channel 1:

Temperature program:

Initial	Hold	Ramp	Final
40.00	7.000	10.000	100.00
100.00	0.000	20.000	250.00
250.00	5.000	0.000	250.00

4. Type in the following event table for channel 1:

What this Event Table will do:
- -Pre-purge the gas extraction loop.
- -Turn ON the sample pump for 6 minutes (or until the waste line is full; your sample may take more or less time).
- -Zero the data system signal.
- -Actuate Valves 1 and 2 to the INJECT position.
- -Leave Valve 1 in INJECT and return Valve 2 to the LOAD position.
- -Turn ON the two solenoids.
- -Heat the gas extraction loop to 150°C for several minutes (again, your sample may take more or less time).
- -Turn OFF the two solenoids.

Events:

Time	Event
0.000	C ON (OUTLET SOLENOID)
0.050	A ON (INLET SOLENOID)
1.000	A OFF
1.050	C OFF
1.100	E ON (SAMPLE PUMP)
7.100	E OFF
7.150	ZERO
7.200	G ON (VALVE 1 INJECT)
7.250	H ON (VALVE 2 INJECT)
7.750	H OFF
7.850	C ON (OUTLET SOLENOID)
7.900	A ON (INLET SOLENOID)
7.950	F ON (TRAP HEAT)
16.500	F OFF
17.500	A OFF
17.700	C OFF

NOTE: Turning ON the two solenoids for 30 seconds before the run pre-purges the extraction chamber. As shown in this event table, open solenoid C first, then A. Close A first after 30 seconds, then close C. Maintain this order to avoid collapsing the permeation tubing under excessive gas pressure.

6. Connect the sample syringe outlet to the gas extraction loop inlet through the SAMPLE IN line.

7. Hit RUN on the front of the GC or hit the spacebar on your computer keyboard.

Changing the Permeation Tube

1. Remove the plate covering the gas extraction loop by unscrewing the four brass thumbscrews that hold it in place, and unplugging the fan power cord. Remove the two squares of white insulation to reveal the permeation tube assembly. Gently slide the assembly out of the valve oven ducts.

2. Loosen the glass tube's two stainless steel nuts and Teflon ferrules with a wrench to free the Teflon line. The fittings with the attached gas line are stationary.

3. Slide the Teflon tubing out of the glass tube until you can see the permeation tube.

4. Pull the old permeation tube off the Teflon tubing and discard. Wipe any oil off the Teflon tubing with a KimWipe or other lint-free wipe.

5. Slide the permeation tube over one end of the Teflon tubing. It is a tight squeeze to get the Teflon tubing into the permeation tube. To facilitate this, the Teflon tubing is cut at a 45^{o} angle or sharper. Slide it on about 3/4" on each side. The permeation tube should be 7 inches long. It will be stretched slightly inside the glass tube.

6. Slide the permeation tube and Teflon tubing back into the glass tube and center it.

7. Re-secure the two stainless steel nuts and Teflon ferrules onto the Teflon tubing. Make sure that the permeation tubing protrudes beyond the stainless steel nut, so that the nut and the ferrule are securing it to the Teflon tubing. You may have to stretch the permeation tubing a bit to fasten it with the nuts and ferrules. While you are tightening the nuts and ferrules, firmly grip the Teflon tubing where it protrudes about 2-3" from the end of the trap to avoid twisting or kinking the permeation tube. When you are finished, check the flow through the permeation tube to ensure there is no constriction (it should be the same as it was before you replaced the permeation tube). Once the transformer oil starts flowing through the permeation tube, it will stretch, resulting in a corkscrew appearance, which is normal for operating mode.

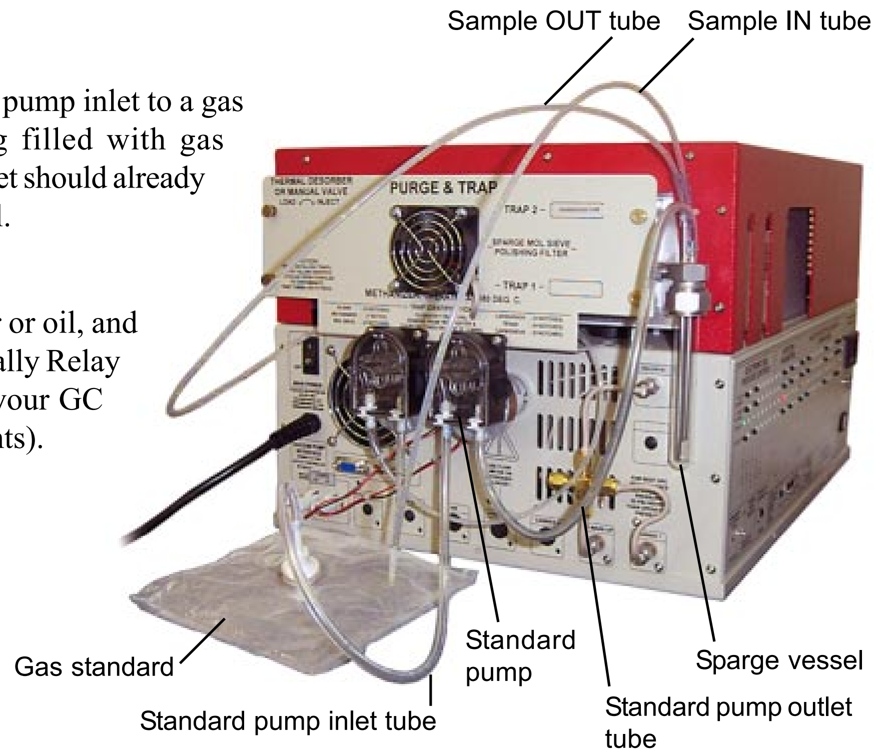
8. Slide the entire assembly back into the valve oven ducts. Replace the two squares of white insulation. Replace the cover plate and secure its four thumbscrews.

Standards Preparation with the TOGA GC

1. Attach the standard peristaltic pump inlet to a gas standard; we used a tedlar bag filled with gas standard. The standard pump outlet should already be connected to the sparge vessel.

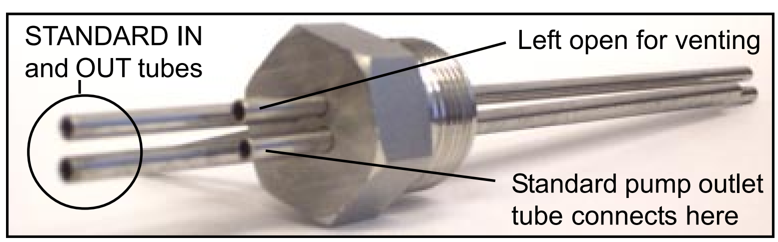
2. Fill the sparge tube with water or oil, and turn ON the standards pump (usually Relay D; check the right-hand side of your GC for your specific relay assignments).

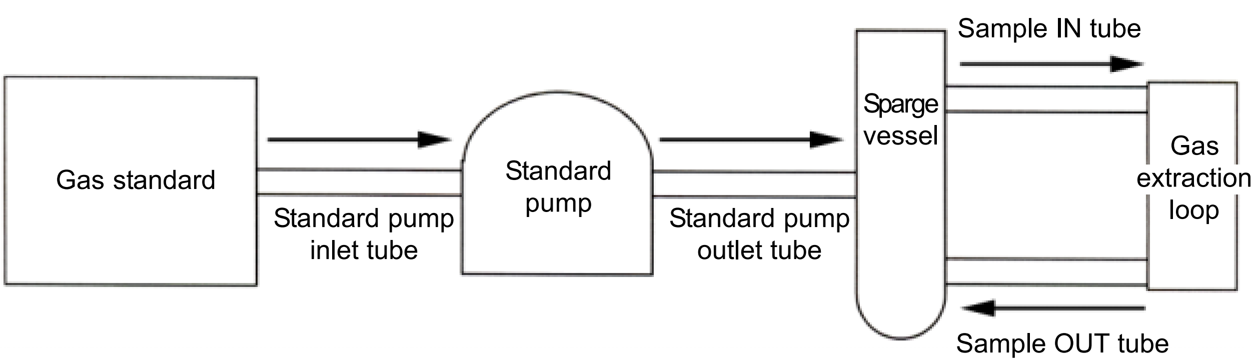
3. Continuously pump gas standard through the sparge tube. Over time, it will equilibrate; this could take up to two hours.



4. To sample the standard you've created with the tedlar bag and liquid-filled sparge tube: attach the SAMPLE IN and OUT tubes to the STANDARD IN and OUT tubes on the top of the sparge vessel.

SPARGE VESSEL TOP

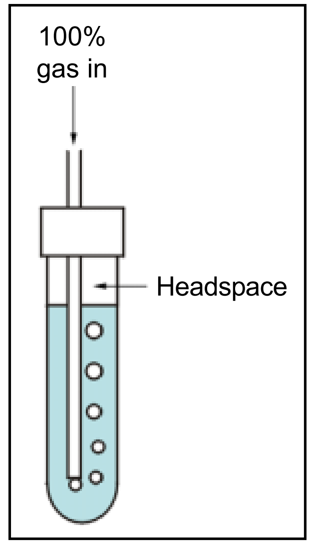




5. The extracted standard will return to the sparge tube to be regenerated for subsequent analysis.

6. Re-attach the SAMPLE OUT tube to the waste connection, and the SAMPLE IN tube to the next syringe.

General Information



Many factors determine the solubility of gases in a given liquid, such as temperature and pressure and type of liquid. The following tables were downloaded from the internet and are provided here for general information only. Table 1 lists the saturation solubilities for dissolved gases in transformer oil (percent by volume). The saturation solubility for a gas is the maximum amount of gas a liquid can hold when 100% of that gas is bubbled through the liquid and fills the headspace above the liquid.

Table 1 Solubility of Gases in Transformer Oil:

Gas	% by volume
Hydrogen	7
Nitrogen	8.6
Carbon monoxide	9
Oxygen	16
Methane	30
Carbon dioxide	120
Ethane	280
Ethylene	280
Acetylene	400

"The majority of gases that are indicative of faults are also those that are in general the more soluble in the oil."
—Table and quote from "Dissolved Gas Ananlysis of Mineral Oil Insulating Fluids," by Joseph B. DiGiorgio, Ph.D., for Northern Technology and Testing.
http://www.nttworldwide.com/tech2102.htm

The following equation can help you convert the percent by volume numbers to ppm by weight (within about 15%):

hydrogen (H2):

$$\frac{1\text{L oil}}{0.910\text{kg}} \text{ X } \frac{0.07\text{L H2}}{1\text{L oil}} \text{ X } \frac{1\text{ mole H2}}{24\text{L H2}} \text{ X } \frac{2\text{g H2}}{2\text{ moles H2}} = 0.0032\ \frac{\text{g}}{\text{kg}} = \frac{3.2\text{g}}{1000\text{kg}} = 3.2\text{ppm H2}$$

(24L is a constant representing the volumn occupied by 1 mole of an ideal gas at room temperature and pressure.)

Table 2 shows the solubility of gases in water (ppm by weight) for general DGA.
PPM by weight = the weight of the gas divided by the weight of one liter of water (2.205 pounds).

Table 2

Gas	Solubility (ppm by weight)
Acetylene	117ppm
Ammonia	5290ppm
Bromine	1490ppm
Carbon dioxide	169ppm
Carbon monoxide	28ppm
Chlorine	7290ppm
Ethane	62ppm
Ethylene	149ppm
Hydrogen	1.6ppm
Hydrogen sulfide	3850ppm
Methane	23ppm
Nitrogen	19ppm
Oxygen	43ppm
Sulfur dioxide	1128ppm

Table 2 is from The Wired Chemist:
http://wulfenite.fandm.edu/data%20/Table_16.html