SNO-STR-93-049

SNO Cover Gas

An Alternate Design Concept

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D. Sinclair, K. McFarlane

1. Introduction

A description of a proposed cover gas system for SNO has been circulated as TS-17-633-01 with drawings 17-702-A-6471-001 and 17-702-A-6471-002. The proposal requires over 50 very low pressure (few inch water gauge) regulating valves together with a few hundred shut-off valves. The regulating valves are probably very expensive and will require an R&D programme to evaluate for compatibility with SNO. The shut-off valves will contain over 1000 o-rings which constitutes a major radon source.

We propose a much simpler cover gas system which avoids these difficulties, and which is more transparently fail-safe. The concept calls for each protected volume to be connected through a single line to a manifold through which a gas flow is maintained which is adequate to ensure that there is no back flow of gas. The concept requires that the volumes with the most stringent radon criteria be located closest to the nitrogen supply.

In this document we do not address the system for the initial gas purge which would remain as in the above documents or the bubbler gas system for which a separate gas supply would be required.

2. Design Concept

A schematic of the proposed design is shown in Figure 1.

The source of cover gas is boil off from a dewar of liquid nitrogen. A heater is placed in the dewar to control the flow although for all normal operations it is expected that there will be adequate flow due to the heat flow through the dewar. The gas would be provided at very close to atmospheric pressure and at room temperature. Separate supply systems would be provided for the light and heavy water systems although for most of the time the light water system could be fed from the exhaust of the heavy water system. The only time when this might not be acceptable is when additional D_2O or brine is being introduced into the system.

The gas travels down a manifold and exits through a flow meter. The flow can be regulated by feeding the flow meter signal back to the heater through the process computer. For normal operation the flow might be set to 20 l/min, giving a ~~2 week~~ life for a 450 L dewar. A thermal mass flow type of flow meter might be used. As the manifold is open to the air at one end it is not possible to build up a significant over pressure. If the manifold is made of 50 mm pipe then the flow speed would be 16 cm/sec. It is simple to show that the diffusion of radon against this flow would be totally negligible providing the ports on the manifold are spaced more than a few cm apart.

Each volume is connected to the manifold through a single pipe except that the large volumes (the acrylic vessel and the cavity) are connected directly to their respective level control tanks. Thus each region is essentially stagnant except when the water levels are changing or there is a change in atmospheric pressure. It is important to ensure that the lines to the manifold have adequate conductance to deal with level changes and pressure changes. The most demanding changes are likely to occur during the start up and shut down of the circulation system to the vessel and cavity. Although the control system is designed to maintain a constant water level throughout these periods, there may be a brief period of hunting. The maximum flow velocity is 200 l/min. If the pipe length from the gas manifold to the cavity or vessel is 400 feet, then 2" pipe would be required to limit the over/under pressure to 0.8" water gauge. A pressure drop Calculation is attached. This worst case upset condition would be short lived except during filling of the light water part of the cavity. During the filling operation it might be acceptable to remove the oil from the H_2O over-pressure protection device and let the gas vent directly to cavity deck. As the other pipe lengths are much shorter, there are no other areas where conductance is an issue.

There does not appear to be a problem in sequencing the heavy water tanks. The heavy water collection drain tank, TK11 is likely to be contaminated with mine air and should be the last tank in the chain or removed from the cover gas system. TK06 and TK03 should be near the end to allow for the heavy water addition and salt addition. All other operations require clean water in all tanks and there is no concern about cross contamination.

For the light water systems we must make a minor change in the operation of the radon decay tanks. One of these will always receive water from the initial purification system and, after an initial decay period, pass it on to the second tank for the balance of the decay period. When required, the water is pumped from the second tank into the recirculation loop. This change does not appear to introduce any operational difficulties and ensures that the bulk movements of water are always in one direction. The gas flows in the opposite direction and is always going from the clean to the dirty containers.

3. Fail-safe Concept

Because the cover gas manifold is open at one end to the atmosphere and all gas volumes are connected together through large bore pipe, it is not possible to generate significant differential pressures. As an added safety check, over/under pressure protection in the cavity and in the vessel using an hydraulic system comprised of a pipe in an oil bath open to the air. By locating this bath at the end of a few metres of stagnant gas the diffusion of radon through the device will be negligible. The concept has no moving parts and no operating controls which could lead to damage to the water containment systems.

4. D_2O Vapour Trap

It is proposed to use two vapour traps without inline valves to trap the heavy water vapour. The nitrogen passing through these traps is expected to be low in water vapour since the gas does not pass directly over any of the liquid water surface. The details of the traps and the refrigeration/heating cycles have yet to be examined.

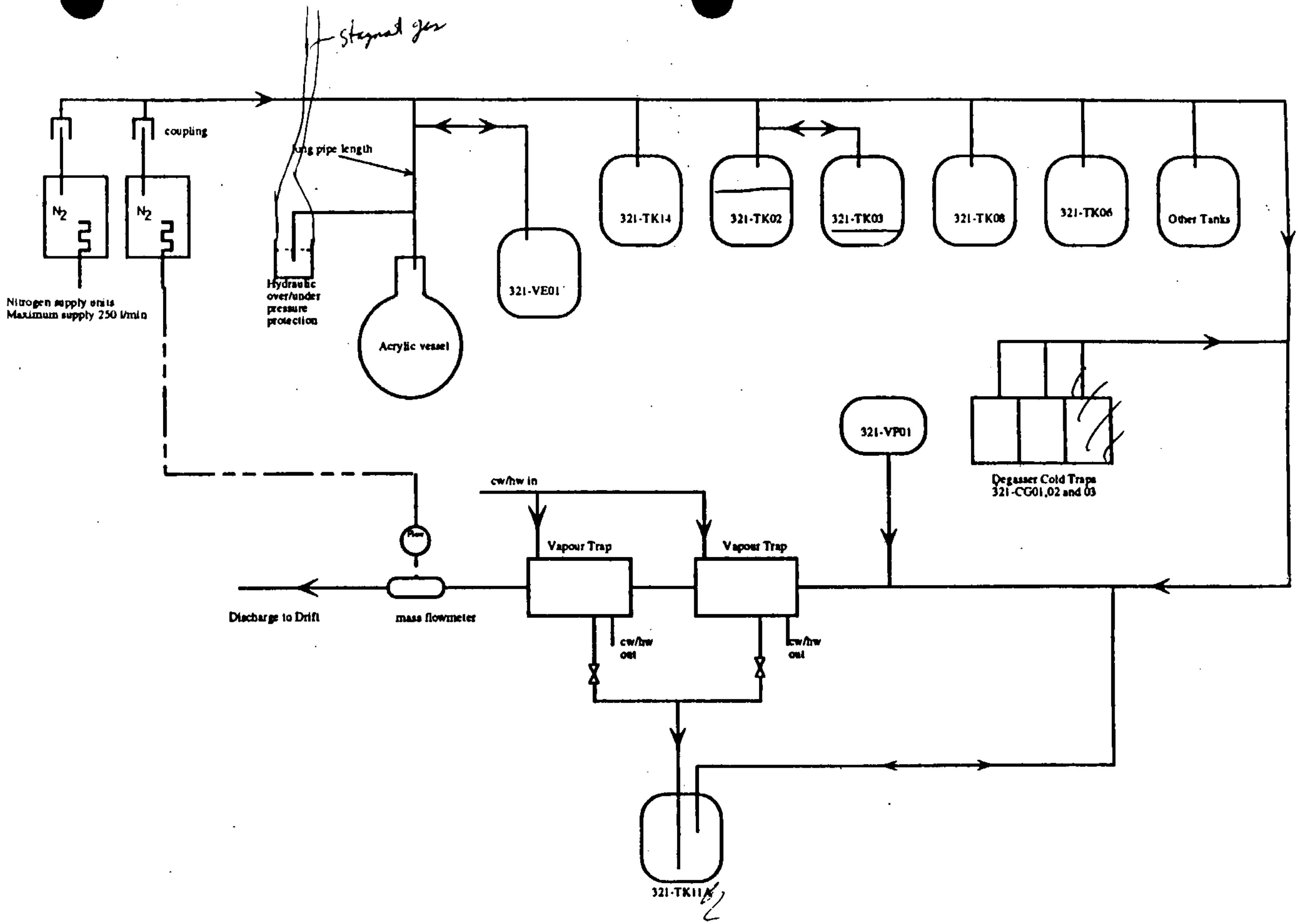

Figure 1 Sheet 1 of 2 D2O Cover Gas Conceptual Schematic

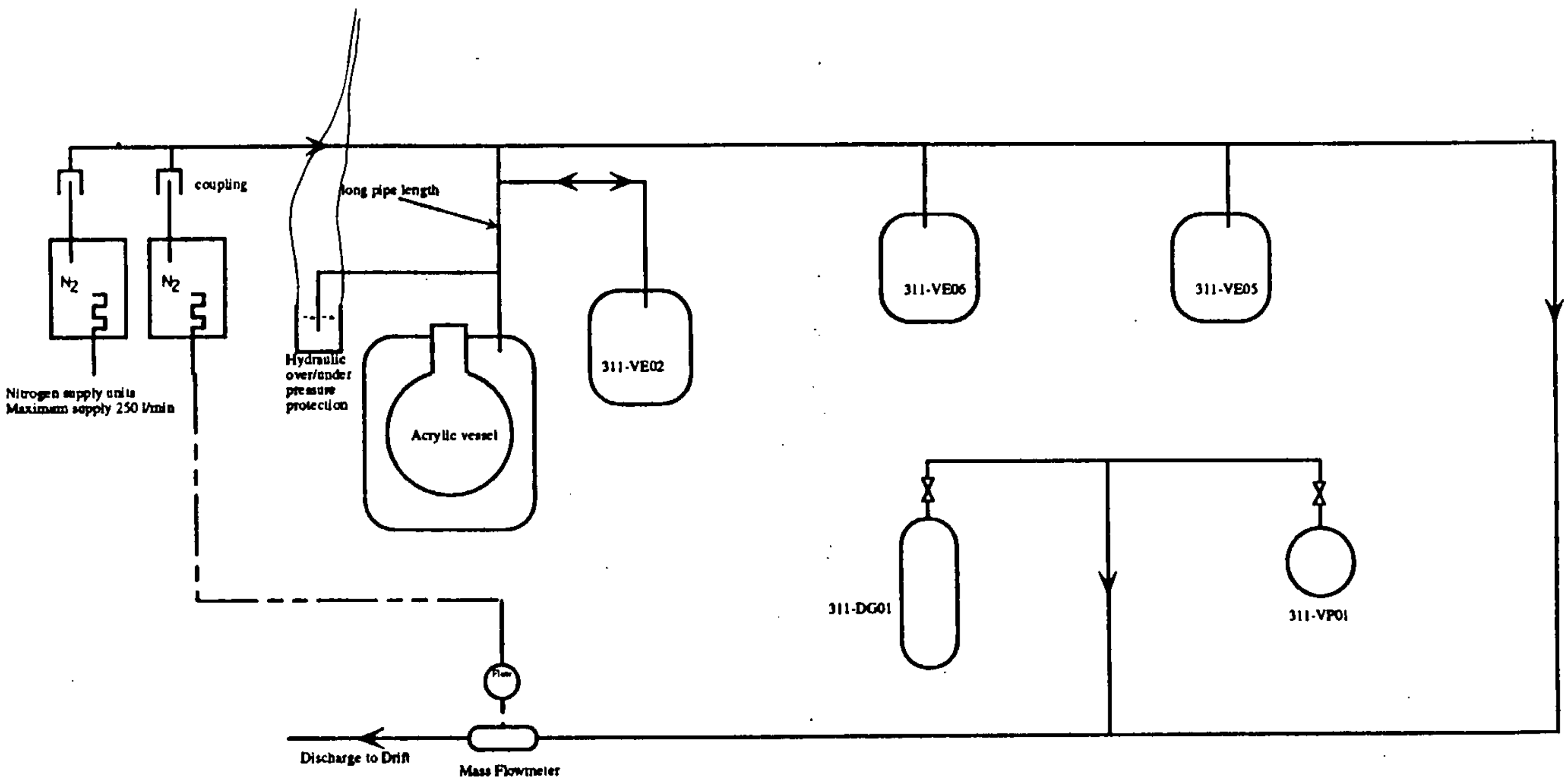

Figure 1 Sheet 2 of 2

H2O Cover Gas Conceptual Schematic

$A = \frac{1}{4}\pi(2.06)^2$
$= 3.$

Pressure Drop Calculation
Nitrogen Gas in long pipe length

Flow rate	W=		lb/sec	**Pipe area Calc**		
	g=	32.200	ft/sec2	inside Diameter=	$\boxed{2.0670}$	inches ← 2" sch 40 pipe I.D.
Cross Section	A=	0.023	ft2	inside area=	3.3556	in2
Upsteam Pressure	P1'=	$\boxed{18.200}$		inside area=	0.0233	ft2
Downstream Pressure	P2'=	$\boxed{18.173}$		cross section		
Friction Factor	f=	$\boxed{0.036}$				
Pipe Length	L=	$\boxed{500.000}$	Feet			
Internal Diameter	D=	0.172	Feet			
Specific Volume	V=	$\boxed{11.104}$	Ft3/lb	density=	0.0901	lb/ft3

Note: check that friction factor is acceptable using Re calculated at end of program. Iterate f until in agreement.

CALCULATED FLOW w= 0.0108 lb/sec or 7.21 Ft3/min or 201.86 l/min 53.33 USGPM

viscosity	$\boxed{0.018}$	centipoise
velocity	5.16	ft/sec
Reynolds Number	Re=	6,607

P1'-P2'= 0.027 psi, or 0.7477 inches of H2O

Note: bordered numbers are input numbers, all others are calculated

Formula Used $w = \sqrt{\left(\frac{144 g A^2}{V_1 f \frac{L}{D}}\right)\left(\frac{(P_1')^2 - (P_2')^2}{P_1}\right)}$ ← page 3-2 CRANE "Flow of Fluids through valves, fittings & pipe" # 410-C

where w = flow in (lb/sec)
g = 32.2 (ft/sec²)
A = pipe cross section in (ft²)
V_1 = specific volume (ft³/lb)
L = pipe length (ft)
D = internal dia (ft)
(P_1') = psia upstream
(P_2') = psia downstream
f = friction factor