DT Generator Commissioning SNO-STR-97-049

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Abstract

On the afternoon shift of December 8 1997, an equipment check and radiation survey of the SNO DT generator and ^{16}N pit was carried out. No significant (or measurable) radiation fields above background were found. Details of the equipment check and radiation survey are given in this report. Based on this commissioning survey, there are *no* exclusion zones required for safe operation of the SNO DT generator.

1 Introduction

This document summarizes the results of tests done for the commissioning of the SNO DT generator facility. These tests were performed in accordance with the Commissioning Plan document, SNO-STR-97-016 [1]. Section 2 gives details of the equipment check and activities prior to applying HV on the DT generator. Section 3 gives detailed results of the radiation survey. Section 4 gives some preliminary results from calibration of the DT neutron flux-monitoring equipment. Section 5 presents the conclusions and section 6 recommendations for additional work.

2 Equipment Check

2.1.1 All the cables for the DT generator, gas flow and monitoring equipment were connected and checked. All cable jackets have an FT rating (FT4 for power cables, and FT1 or FT4 equivalent for all other cables). All electronics boxes are CSA, UL, or Ontario Hydro approved.

2.2.1 The DT generator assembly was taken out of the ^{16}N pit. All electrical and gas flow connections were checked and confirmed O.K.

2.2.2 The functioning of the Fast Neutron Flux Monitor (FNFM) was checked. High Voltage (+875 V) was applied to the FNFM, and signals were observed from ^{60}Co and ^{137}Cs sources placed nearby.

2.2.3 A confirmatory leak check was performed. The entire gas flow system had previously been leak checked in detail. For the present test, the entire gas flow loop, including the target and dummy decay chambers and gas flow lines was pressurized to 51.2 psiA with Helium, and isolated (from valves VD1 to VA5 on the gas-board). The pressure was monitored (via pressure gauge P1, read through the gas flow control computer) for 700 sec. The observed pressure drop was 0.05 psiA. This is considered negligible compared to the accuracy of the pressure gauge itself. The entire gas flow system is therefore leak-tight.

2.2.4 The functioning of the target chamber positioning mechanism was verified. The ^{16}N target chamber position was recorded (reproducibly) to be "36.2" on the position indicator.

2.2.5 The distance from the source to the irradiation position of the pneumatic capsule was measured to be 9.75 ± 0.25 cm.

2.3.1 The DT generator was re-inserted into the ^{16}N pit. The interlock connector to the top of the assembly was connected. All lines were checked to be clear. The shielding blocks on top of the pit were re-installed. The interlock connections to each of these two blocks were established. The water-detector sensor was installed in its SS tube (to access the bottom of the pit).

3 Radiation Survey

3.1.1 The functioning of the radiation survey instruments was verified. Survey instruments and sources used are given below,

Instruments	Sensitivity
Texas Nuclear Model 9146	0.02 mR/hr neutrons
Scintrex Model 189A	1 mR/hr γ
AEP 5302A	1 μR/hr β-γ
Scintrex Model 80040	1 cps β-γ

Sources	Activities at time of commissioning
^{22}Na	1.3×10^4 Bq (γ source)
^{137}Cs	2.22×10^5 Bq (γ source)
^{60}Co	1.72×10^4 Bq (γ source)
^{252}Cf	$\approx 5.9 \times 10^4$ Bq (n, γ, source)

Table 1: Dose meter check with source containers on contact with the various detectors. The ^{252}Cf container is such that the distance between source and detector is ≈ 2 inches.

	^{22}Na	^{60}Co	^{137}Cs	^{252}Cf
AEP 5302A (mrem/h)	0.3	0.4	1.1	-
Scintrex 80040 (counts/sec)	150	200	920	-
Scintrex 189A (mrem/h)	1.5-2.0	2-3	3-5	-
Texas Nuclear (mrem/h)	-	-	-	0.2

Table 2: Cross calibration with ^{22}Na, ^{60}Co, and ^{137}Cs together at two different distances.

	7.5 cm	25 cm
AEP 5302A (mrem/h)	0.3	0.04
Scintrex 80040 (counts/sec)	150	20
Scintrex 189A (mrem/h)	1.5-2.0	-

3.1.2 Results of the instrument verification and cross-calibration are shown in Table 1 and Table 2. Table 1 gives the dose rate with the source containers on contact with the meter detectors, and Table 2 with sources placed at two distances from the detectors. These results indicate that the Scintrex 80040 β-γ instrument is linearly correlated to dose. A γ-dose rate of 1 mR/hr corresponds to ≈ 500 cps on this instrument.

3.2.1 The functioning of the interlock system was checked. A functional diagram of the interlock system as built is shown in Figure 1. No neutrons were generated at this stage. When the interlock was switched on via the front panel key in the DT generator console, the interlock indicator light on the front-panel was activated. The "DT Generator ON" warning light on the wall was activated. Each of the switches/connectors in the interlock loop was manually opened in turn. Both lights (front-panel and wall) were observed to de-activate indicating correct functioning of the interlock loop.

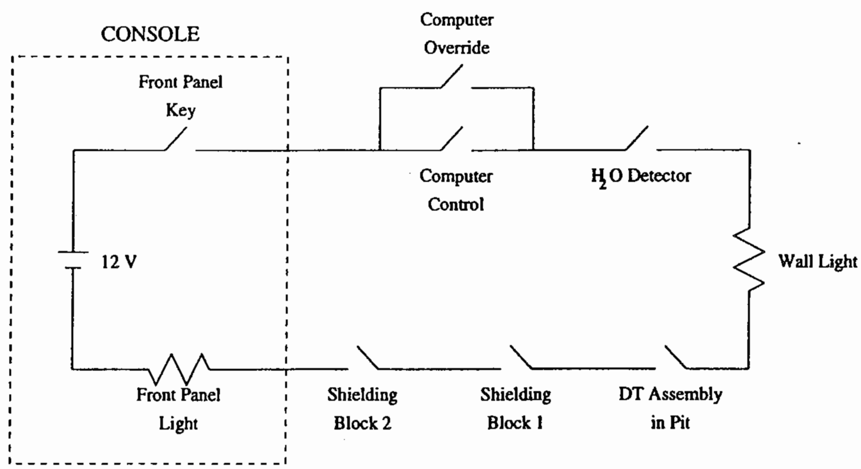

Figure 1: Schematic of Interlock System.

3.3.1 Radiation survey points were established and are shown in Figure 2. In practice, it was found that there was insufficient space to monitor point 1. The point marked 7 ,8 was originally meant to be two measurement points on top of the blocks (closest to any passing personnel): but were collapsed into a single measurement due to lack of space for accommodating all the survey instruments. Note that point 6 is directly in front of the $\approx$ 4" by 4" conduit for cables and gas flow lines that penetrate the shielding enclosure.

3.4.1 A background survey was performed. Results are shown in Table 3.

3.5.1 The entire Junction area of the SNO UG lab was cleared and guarded so that no personnel could approach within 10 m of the generator. The survey instruments were placed in position 2. The

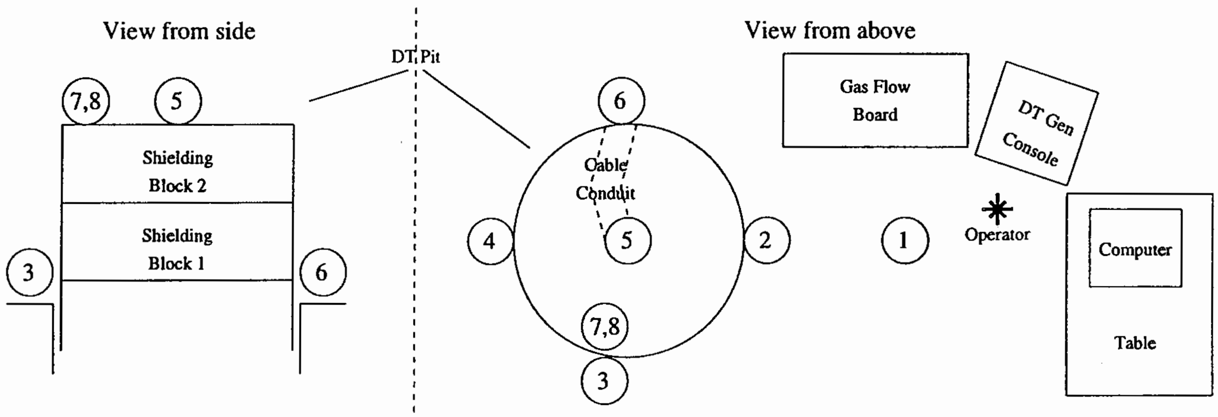

Figure 2: Radiation Survey Measurement Points.

Table 3: Background Survey Results.

Position	Texas Nuclear	Scintrex 189A	AEP 5202A	Scintrex 80040
2	0	≤ 1	0-4 μR/h	0-3 cps
3	0	≤ 1	0-4 μR/h	0-3 cps
4	0	≤ 1	0-4 μR/h	0-3 cps
5	0	≤ 1	0-4 μR/h	0-3 cps
6	0	≤ 1	0-5 μR/h	0-2 cps

Table 4: Radiation Survey Results.

Position	Texas Nuclear	Scintrex 189A	AEP 5302A	Scintrex 80040
2	$\leq$ 0.02 mR/h	$\leq$ 1	5 μR/h	0-3 cps
3	$\leq$ 0.02 mR/h	$\leq$ 1	4-6 μR/h	3-6 cps
4	$\leq$ 0.02 mR/h	$\leq$ 1	3-7 μR/h	1-3 cps
5	$\leq$ 0.01 mR/h	$\leq$ 1	1-6 μR/h	1-4 cps
6	$\leq$ 0.01 mR/h	$\leq$ 1	10-11 μR/h	3-6 cps
7,8	$\leq$ 0.02 mR/h	$\leq$ 1	0-4 μR/h	1-4 cps

trained DT operator, B. Sur applied HV to the generator, with the neutron output control on the lowest setting. Fast neutron output was confirmed via the FNFM. Since no discernible radiation field could be measured, the neutron output was raised to the highest level. A complete radiation survey was carried out and is recorded in Table 4. For all survey points, the resulting activities were well below the calculated maximum field of $\approx$ 0.1 mRh^{-1}, and therefore the as built shielding exceeds the original design goal [2]. The reasons for the lower than calculated fields may be a) the addition of 10 inches of polyethylene shielding placed directly above the DT target, and b) the larger size of shielding block used in the construction. Both a) and b) were added simply because the space was made available during the construction.

3.6.1 Normal gas flow conditions (200 cc /sec of CO_2) were established. The DT generator was turned on. The entire length of the gas transport capillary and return tubing, and the dummy decay chamber were surveyed using the AEP5302A and the Scintrex 80040. No discernible radiation levels above background could be measured.

3.6.2 It should be noted that CO_2 gas will be used as both target and carrier gas for future SNO ^{16}N calibrations, and not pure O_2 as described in the Construction Report [3]. CO_2 was chosen over pure O_2 to address INCO fire safety concerns.

4 Preliminary calibrations of FNFM and DT generator output

4.1.1 The pulse height spectrum from the FNFM was recorded. This spectrum is different than that observed with no shielding around the generator, because scattered neutrons and γ-rays are now detected by the FNFM. Consequently the sharp cut-off in the energy spectrum due to recoil protons with maximum energy 7 MeV is no longer evident. After some investigation, it was decided to retain the original window of pulse-heights as the indicator of the FN flux. Note that the readings have now changed as follows:

Neutron Output Control	Original FNFM rate	Present FNFM rate
0 (nominally 5×10^7 n/s)	5.8×10^2 s^{-1}	1.4×10^3 s^{-1}
10(nominally 1×10^8 n/s)	2.8×10^3 s^{-1}	3.9×10^3 s^{-1}

4.2.1 A preliminary effort was made to measure the output of fast neutrons by an activation method. A pneumatic "rabbit" system is available for inserting a ≈ 0.5 inch OD capsule into an irradiation position close to the DT generator neutron source. For this exercise a 5 g Teflon (C_2F_4) capsule was used. ^{18}F ($t_{1/2}$=109.7 min) was produced via the ^{19}F(n,2n) reaction ($\sigma(E_n$=14 MeV)= 42.9 mb, Q=-11.6 MeV). 511-keV γ's from e^+e^- annihilation were detected in a 2"x2" shielded NaI detector. The efficiency of the NaI detector for 511-keV γ's was determined by counting a calibrated ^{22}Na source. A 10-minute irradiation was followed by a 10-min count. A preliminary estimate of the maximum fast neutron output from the DT generator, obtained by this method, gives 4×10^7 n/sec. There is, however, at least a factor of two systematic uncertainty in this measurement.

5 Conclusions

5.1.1 Based on the above survey, the additional dose to persons working in the vicinity of the DT generator during operation is comparable to background.

5.1.2 No exclusion zones, based on radiation protection, are necessary during operation of the DT generator.

5.2.1 The DT generator and gas flow equipment has been verified to work as intended.

6 Recommendations

6.1.1 It is recommended that trainees acquire additional instructions from A. Hamer prior to operating the gas calibration system by themselves.

6.2.1 More careful measurements of the fast and thermal neutron fluxes inside the ^{16}N pit should be carried out. These should be used to (a) confirm DT generator output (b) calibrate FNFM output, and (c) determine whether a thermal neutron shielding jacket is required to prevent activation of materials inside the pit.

6.3.1 The pulse height spectrum of the FNFM could be studied further to establish a window within which the count rate is stable and linearly proportional to the FN flux.

7 Addendum

Persons who have been trained by B. Sur to operate the DT generator:

A. Hamer

G. Jonkmans

H. Seifert

References

[1] G. Jonkmans and B.Sur, *Commissioning Plan*, SNO Scientific and Technical Report, SNO-STR-96-053, July 1996.

[2] G.B. Wilkin, AECL report RTB-TN-057.

[3] G. Jonkmans and D. Earle, *Construction Report*, SNO Scientific and Technical Report, SNO-STR-97-015, February 1997.