# The Impact Of Exceeding Recommended Crucible Volumes In The Technegas Generator

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**Citation**

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**Abstract**

Introduction: While Technegas generators have been common place within departments for over a decade, misconceptions still exist concerning appropriate volumes used to fill the Technegas crucible. Anecdotal evidence suggests that it is common clinical practice to over fill the crucible as a means of increasing activity without the need for multiple simmer cycles.

Research Question: Is the convex bubble blown off by argon flow? If so, what is the extent of the lost activity? Is over-filling the crucible an effective means of increasing activity without performing multiple simmers?

Methodology: Various volumes of $^{99m}$Tc pertechnetate were assayed. Both volume and activity of $^{99m}$Tc pertechnetate delivered to the crucible were recorded before the simmer cycle. After completion of the simmer cycle the Technegas crucible was inspected to ensure complete evaporation, and then calibrated to allow calculation of the percentage difference between the expected activity and actual activity.

Results: No statistically significant difference was noted between mean loss for volumes within manufacturer specifications (2.0%) and the mean loss for volumes exceeding manufacturer specifications (2.4%) ($P = 0.62$). Visual inspection of the crucibles immediately following the completion of the simmer cycle demonstrated unevaporated liquid in the crucible 87.5% of assays with volumes greater than or equal to 0.19 ml and no assays within manufacturer specifications.

Conclusion: While the argon purge does not blow off the convex meniscus and there is negligible post simmer loss of activity from the over filled crucible, this practice is not an effective means of avoiding the need for multiple simmer cycles to increase crucible activity.

## INTRODUCTION

A Technegas generator is a microprocessor controlled device which produces an ultra fine micro-aerosol of a graphite coated Technetium atom used for ventilation lung scanning ($_1$). Recommended crucible loading activity ranges between 400 and 900 MBq of Sodium Pertechnetate in 0.14 ml ($_2$). High specific concentrations are not always available due to the decay of eluate and/or the generator bound parent. This decay results in significantly reduced available activity as the day and week progress. This is significant, as not only will the amount of $^{99m}$Tc available from the generator decrease throughout the week, but the eluted $^{99m}$Tc pertechnetate activity will also decrease throughout the day. Multiple simmer cycles of 6 minutes can be employed to obtain activity suitable for ventilation imaging.

Specific concentration has further ramifications on patient management since it is proportional to the efficiency with which an adequate count rate sufficient to complete the ventilation study is achieved. This may be compounded by the symptoms typical of a patient presenting for pulmonary embolism evaluation (i.e. dyspnea and chest pain) ($_1$). Anecdotally, patient compliance tends to decrease as the duration of the ventilation procedure increases, increasing the likelihood that the study will be performed with sub optimal count density and/or room contamination will occur. A high specific concentration should increase the likelihood of obtaining an adequate count rate with minimal inspiration and improved patient compliance.

A number of measures are employed to improve available specific concentrations of $^{99m}$Tc, such as, decreasing the

volume of saline used to elute the generator or performing additional elutions throughout the day. Nonetheless, specific concentration of $^{99m}$Tc eluate is of considerable concern, particularly on days of low activity due to generator decay. Contrary to manufacturer's guidelines ($_2$), anecdotal evidence suggests that it is a common practice to increase the $^{99m}$Tc pertechnetate volume above the confines of the crucible (convex bubble) to increase activity while limiting the preparation time to a single simmer cycle.

Manufacturer's guidelines ($_2$) advise that over filling of the crucible does not contribute to increased generation of Technegas because the argon purge results in bubbled activity being blown off the crucible. This theory is yet to be reported in the literature. Theoretically, since the activity is blown off, it will not be evaporated within the crucible and, will not be converted to Technegas during the burn cycle. Furthermore, this additional activity may actually be heated during the burn stage, resulting in evaporation into the chamber as a wet aerosol of pertechnetate in steam and subsequent degradation in image quality due to rapid lung clearance and undesirable uptake in thyroid, esophagus and stomach ($_3$).

## THE RESEARCH QUESTION

- Is the convex bubble blown off by argon flow?
- If so, what is the extent of the lost activity?
- Is over-filling the crucible an effective means of increasing activity without performing multiple simmers?

## METHODOLOGY

A standard first generation Technegas generator (Vita Medical, Australia) was used to produce all crucible residues. Volumes in the range 0.05 ml to 0.21 ml of $^{99m}$Tc pertechnetate were assayed. A 0.14 ml volume was employed to evaluate the limits of the manufacturer specifications (0.14 ml) while 0.21 ml was the maximum single convex bubble achievable without overflow. Background was noted and accounted for on all dose calibrator assays. For each assay, a new graphite crucible was wetted with ethanol and placed between the electrodes of the generator, rotating gently to ensure good contact.

Activity within a 1 ml syringe was assayed and weighed prior to loading the graphite crucible and recorded as ‘pre-activity' in MBq and ‘pre-weight' in mg. The $^{99m}$Tc pertechnetate was loaded into the crucible. The syringe was assayed to determine the ‘residual activity' in MBq and the ‘post-weight' in mg. ‘Pre-activity' was subtracted from ‘residual activity' and recorded as ‘expected activity' in MBq. The volume loaded in the crucible was determined as the difference between the pre and post weight (mg) and expressed as mls.

Following the six minute simmer cycle the crucible was inspected to ensure complete evaporation of all activity and the graphite crucible was removed, assayed and recorded as ‘actual activity'. All activity assays were background corrected. The percentage difference was calculated between the expected activity and actual activity.

The procedure was repeated for a variety of crucible loading volumes (36 in total). The argon cylinder pressure was considered a possible confounder and, thus, all experimental data was acquired with cylinder pressures ranging between 13000 kPa and 16000 kPa. Similarly, the argon flow rate was considered a possible confounder so all experimental data was acquired with a regulator flow rate of between 16 L/min and 17 L/min.

The differences between independent means were calculated with a 95% confidence interval (CI). The statistical significance was calculated using Student's t test for continuous data. A P value less than 0.05 was considered significant. Confidence intervals without an overlap were considered to support a statistically significant difference while confidence intervals with an overlap represented differences for which chance could not be excluded as the cause.

## RESULTS

A total of 36 assays were performed with a mean crucible volume of 0.165 ml, a median volume of 0.17ml and a range of 0.05 ml to 0.21 ml. The percentage loss of activity from the crucible following the simmer cycle was tabulated (Table 1). The mean percentage loss of activity from the crucible following the simmer cycle was 2.2% (95% CI 1.4 – 3.1%). No statistically significant relationship was detected between the crucible volume and the percentage activity loss (P = 0.55).

**Figure 1**

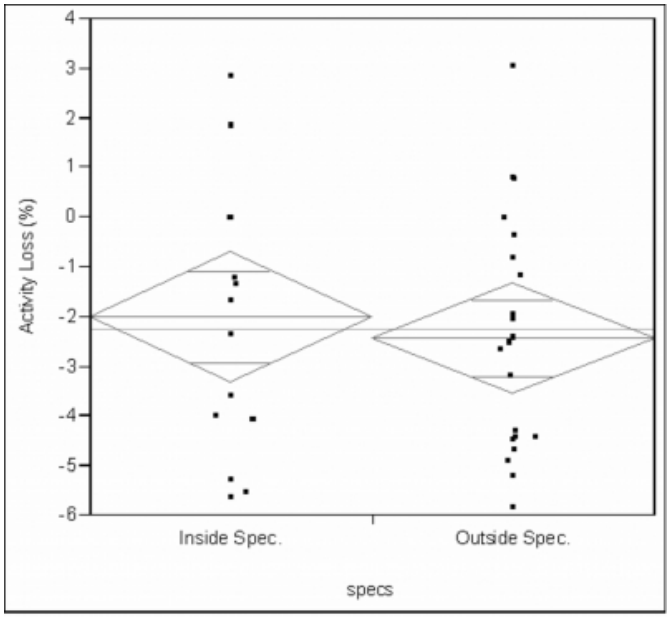
Table 1: Tabulated summary of actual and expected crucible activities for assays completed employing ethanol preparation of the crucible.

| Volume (ml) | Actual Activity (MBq) | Expected Activity (MBq) | % Difference | Unevaporated liquid post simmer |
|---|---|---|---|---|
| 0.05 | 36 | 35 | 2.86 | No |
| 0.05 | 17 | 18 | -5.56 | No |
| 0.10 | 58 | 59 | -1.69 | No |
| 0.10 | 45 | 45 | 0 | No |
| 0.14 | 245 | 248 | -1.21 | No |
| 0.14 | 221 | 224 | -1.34 | No |
| 0.14 | 242 | 251 | -3.59 | No |
| 0.15 | 83 | 85 | -2.35 | No |
| 0.15 | 54 | 57 | -5.26 | No |
| 0.15 | 55 | 54 | 1.85 | No |
| 0.15 | 47 | 49 | -4.08 | No |
| 0.15 | 50 | 50 | 0 | No |
| 0.15 | 48 | 50 | -4 | No |
| 0.15 | 234 | 248 | -5.65 | No |
| 0.15 | 42 | 42 | 0 | No |
| 0.16 | 219 | 225 | -2.67 | No |
| 0.16 | 240 | 245 | -2.04 | No |
| 0.17 | 258 | 270 | -4.44 | No |
| 0.17 | 245 | 247 | -0.81 | No |
| 0.17 | 237 | 250 | -5.2 | No |
| 0.19 | 248 | 251 | -1.20 | Yes |
| 0.19 | 222 | 232 | -4.31 | No |
| 0.20 | 267 | 265 | 0.75 | Yes |
| 0.20 | 250 | 248 | 0.81 | Yes |
| 0.20 | 234 | 245 | -4.49 | Yes |
| 0.20 | 258 | 270 | -4.44 | No |
| 0.20 | 265 | 266 | -0.38 | Yes |
| 0.20 | 81 | 83 | -2.41 | Yes |
| 0.20 | 77 | 79 | -2.53 | Yes |
| 0.20 | 58 | 61 | -4.92 | Yes |
| 0.20 | 105 | 105 | 0 | Yes |
| 0.20 | 61 | 64 | -4.69 | Yes |
| 0.20 | 68 | 66 | 3.03 | Yes |
| 0.20 | 201 | 205 | -1.95 | Yes |
| 0.21 | 241 | 256 | -5.86 | Yes |
| 0.21 | 242 | 250 | -3.2 | Yes |

The mean percentage loss of activity was stratified as those within manufacturers specifications (0.15 ml or less) and those exceeding these specifications. The mean percentage loss for volumes within manufacturer specifications was 2.0% (95% CI, 0.7 - 3.3%) while the mean percentage loss for volumes outside manufacturer specifications was 2.4% (95% CI, 1.3 - 3.5%). The overlap of these confidence intervals supports a lack of statistically significant difference (P = 0.62) (Fig. 1).

**Figure 2**

Figure 1: Comparison of the mean percentage differences between the actual activity and the expected activity within the crucible for the results stratified as those within manufacturers specifications (0.15 ml maximum) and those exceeding manufacturers specifications. No statistically significant difference is evidenced by the overlap of the 95% confidence intervals represented by the diamond overlay. This was supported by the student's t test analysis of independent means ( = 0.62).



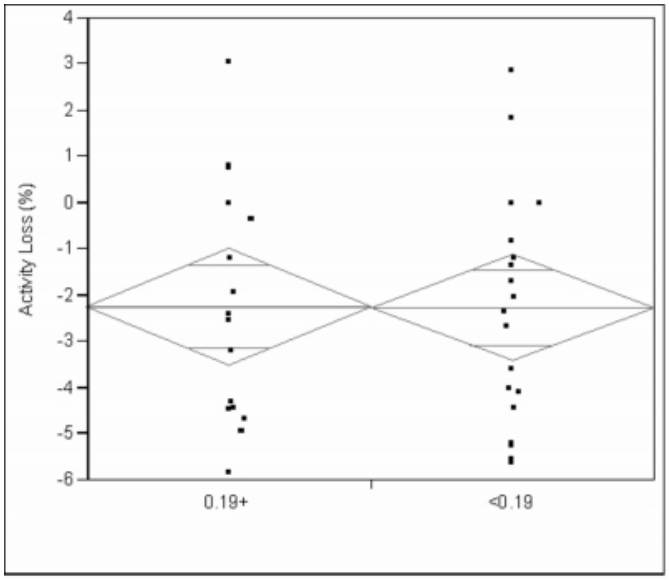

Visual inspection of the crucibles immediately following the completion of the simmer cycle demonstrated unevaporated liquid in the crucible in 38.9% (14/30) of assays. No unevaporated liquid was noted where the crucible volume of $^{99m}$Tc pertechnetate was within manufacturer specifications. Of crucible volumes greater than or equal to 0.19 ml, 87.5% (14/16) had unevaporated liquid. A statistically significant difference was not in the mean crucible volume for those assays with residual unevaporated liquid after the simmer cycle (0.20 ml with a 95% CI of 0.18 - 0.12 ml) compared to those evaporated to dryness (0.14 ml with a 95% CI of 0.13 - 0.16 ml) (P < 0.001). No statistically significant relationship was seen between the percentage lost activity and the presence of residual unevaporated liquid post simmer (P = 0.54).

The mean percentage loss of activity was also stratified as those less than 0.19 ml and those greater than or equal to 0.19 ml. The mean percentage loss for volumes less than 0.19 ml was 2.2% (95% CI 1.1 - 3.4%) while the mean percentage loss for volumes greater than or equal to 0.19 ml was 2.3% (95% CI 1.0 - 3.5%). The overlap of these confidence intervals supports a lack of statistically

significant difference (P = 0.98) (Fig. 2).

**Figure 3**

Figure 2: Comparison of the mean percentage differences between the actual activity and the expected activity within the crucible for the results stratified as those volumes less than 0.19 ml and those greater than or equal to 0.19 ml. No statistically significant difference is evidenced by the overlap of the 95% confidence intervals represented by the diamond overlay. This was supported by the student's t test analysis of independent means ( = 0.98).

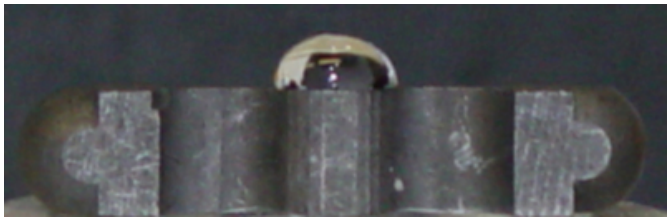



## DISCUSSION / CONCLUSION

The Vita Medical Technegas Generator User Manual ($_2$) states that if the meniscus activity is above the well of the crucible (Fig. 3), the argon flow during the simmer cycle will blow the $^{99m}$Tc pertechnetate out of the crucible into the ashtray. Contrary to this belief, these results demonstrated that the flow of argon during the simmer cycle was not responsible for overflow of $^{99m}$Tc pertechnetate into the ashtray. No statistically significant difference was noted between the mean loss of activity for assays within manufacturers specifications compared to those that exceeded these specifications (P = 0.62).

**Figure 4**

Figure 3: A photograph of the convex bubble produced when 0.20 ml of Tc pertechnetate is added to the crucible well.



While the majority of activity remained within the crucible for the various volumes post simmer cycle, visual inspection of the crucible following the simmer cycle revealed unevaporated $^{99m}$Tc pertechnetate for the majority of volumes exceeding 0.19 ml. One might hypothesise that, while the argon flow was not adequate to blow the meniscus into the ashtray, the length and/or temperature of the simmer cycle is not sufficient to fully evaporate volumes of greater than 0.19 ml. After completion of the simmer cycle, the eluant should be evaporated to dryness and leave a white crust of salt and $^{99m}$Tc pertechnetate on the graphite ($_3$). This white crust was observed on all volumes less than 0.19 ml, with no residual unevaporated $^{99m}$Tc pertechnetate evident.

The clinical significance of unevaporated $^{99m}$Tc pertechnetate following the simmer cycle is twofold. Firstly, departments over filling the crucible are not making efficient use of available activity, as this extra activity is not converted into Technegas during the burn cycle. The time and resource based theory for over filling the crucible are nullified by these technical difficulties. Secondly, $^{99m}$Tc pertechnetate not evaporated during the simmer cycle may produce a wet aerosol of pertechnetate in steam during the burn phase, causing rapid lung clearance and activity in the thyroid and stomach ($_3$). $^{99m}$Tc pertechnetate which was observed to be unevaporated for the 0.2 ml volumes exceeding 0.19 ml could degrade ventilation image quality due to decreased count density and free pertechnetate uptake in surrounding tissues. It is important, however, to note that no deleterious effects were observed for volumes exceeding manufacturer specifications by less than 0.05 ml.

While no significant loss of activity from the confines of the crucible was demonstrated with increasing volumes of $^{99m}$Tc pertechnetate, the practice of over filling the crucible to improve efficiency of the ventilation process, particularly in the presence of poor specific concentrations of pertechnetate, is not recommended. Exceeding a crucible volume of 0.19 ml leaves unevaporated $^{99m}$Tc pertechnetate post simmer which may decrease count density, increase the time required to ventilate patients and degrade image quality. Crucible volumes in the range 0.14 ml to 0.19 ml do not exhibit these deleterious effects but also fail to provide significant benefit to preparation time since the maximum increase in crucible activity will be 36% (0.19 ml). While the argon purge does not blow off the convex meniscus and there is negligible post simmer loss of activity from the over filled crucible, this practice is not an effective means of avoiding the need for multiple simmer cycles to increase

crucible activity. Alternative strategies to increase crucible activity / time efficiency may include; adjusting the simmer temperature to ensure evaporation to dryness of 0.20 ml crucible volumes, reloading the crucible after a short aborted initial simmer, or utilising a crucible oven (built into the new generation systems).

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