



Volume Measurement Study for Large Scale Input Accountancy Tank

S. UCHIKOSHI, Y. WATANABE, T. TSUJINO

Safeguards Analytical Laboratory,
Nuclear Material Control Center,
Shirakata 2-53, Tokai-mura, Ibaraki-ken

INTRODUCTION

Nuclear Material Control Center is developing the technique for the solution volume measurement with dip-tube bubbler probe system to be applied to the input accountancy tank of Rokkasho Reprocessing Plant (RRP). All nuclear material flowing in the RRP is first measured at the input accountancy tank, the accuracy of solution volume measurement at the tank strongly influences the inventory evaluation. It is well known that the solution volume determined with the bubbler probe system, which measures the differential pressure between two dip-tubes sending air to tubes, shows best accuracy except a weighing system to be hardly introduced into Japan because of earthquake-proof. However, this method has not been applied to a large scale tank such as the input accountancy tank with 25m³ for nuclear material accountancy in Japan. It is not clear how the complex inner structure of the input accountancy tank influences the solution homogenization. High accuracy measurements need to consider the thermal expansion and the deformation caused by solution weight at the tank. And furthermore, the influence of tank ventilation system to pressure measurements must be taken into account because it may bring about the variation of reference pressure. Therefore, Large Scale Tank Calibration (LASTAC) facility, including an experimental tank that has the same volume and structure as the input accountancy tank of the RRP was constructed in Nuclear Material Control Center. Demonstration experiments have been carried out at LASTAC facility to evaluate the precision of solution volume measurements and to establish the procedure of highly accurate pressure measurements for a large scale tank with dip-tube bubbler probe system. The experiments are broadly divided into volume measurement experiments and homogenization experiments. The former results are mainly described in this paper.

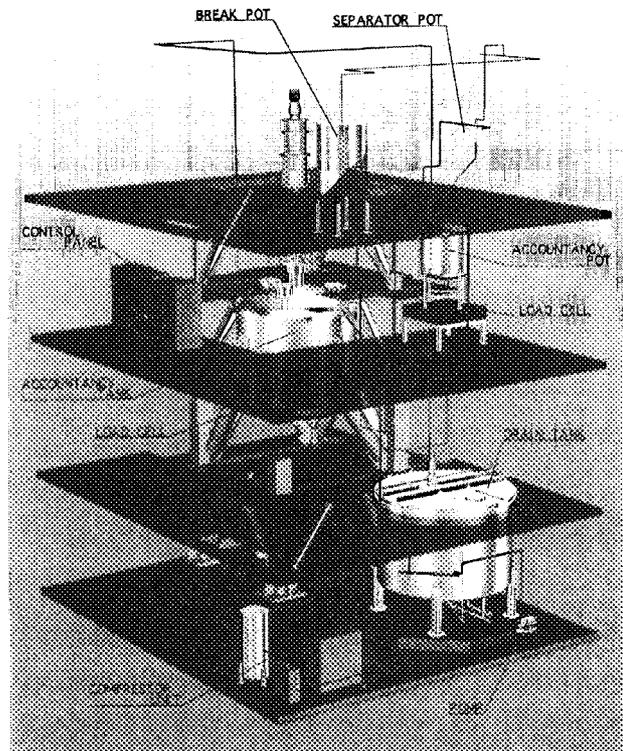


Fig-1 LASTAC Facility

Regarding tank calibration experiments carried out three times using pure water with room temperature, the results are shown as the standard deviation of these calibration curves and as the reproducibility of solution volume derived with one calibration function composed of three runs.

Outline of LASTAC Facility

LASTAC facility has four floors as shown in Fig-1. The experimental mock-up input accountancy tank is installed at the third floor and is rested on four load cells to measure the solution weight in the tank. Because of weighing, all pipes connected to the mock-up tank use flexible joints at the junction. A mechanical stirrer is equipped at the tank, and its motor with a reducer is installed at the fourth floor. The drain tank (25 m³) for preparing and storing the solution is on first floor. The accountancy pot (1.5 m³) and the vessel (0.2 m³) for weighing solution at the calibration are on third floor as other main components of the LASTAC. The siphon system for transferring the solution from the mock-up tank is on fourth floor. Furthermore, the solution heating and cooling system is attached to the LASTAC. The operations of these components, the measurement and the data collection during the experiment are automatically controlled at third floor.

Principle

Filling tank that installs three dip-tubes, the first (low) is at near the bottom of tank and the second (middle) is installed to mutually keep vertical distance [S] with solution. The third (reference) is above solution. Sending air to the dip-tubes such as grow a bubble, difference of pressure [ΔP_H] measured between low and reference is proportion to immersed depth of the first dip-tube. Also differential pressure between low and middle installed at different elevations in the tank is proportion to the density [ΔP_ρ] of solution. The former is called level measurement, and the latter is called density measurement.

The solution height (H) in the tank can be expressed as

$$H = \frac{\Delta P_H}{\rho \cdot g} \quad [1]$$

where, g is an acceleration of gravity. The solution density (ρ) in the tank can be expressed as

$$\rho = \frac{\Delta P_\rho}{S \cdot g} \quad [2]$$

Since pure water is usually used as an experimental solution in case of the tank calibration, the density of the water is determined from its temperature.

Tank Calibration

The LASTAC calibration experiments were carried out under the following procedure. After emptying the pure water in the accountancy tank into the supply tank, the water is permitted to stand for at least 24 hours until its temperature get close to room temperature. About 100 L of pure water is transferred from the supply tank to the weighing vessel, and the water is poured into the input accountancy tank. The weight of the poured water is determined with the weight difference at the weighing vessel. The water in

the accountability tank is mechanically stirred for 5 minutes, and its level and temperature are measured after the fluidity is settled down. These operations are repeated about 200 times until 20 m³.

Calibration Data

The data of the calibration function are derived from the level pressure, the cumulative solution weight and the temperature. The density, ρ , of water in the tank is determined by a handbook data. Cross section variation of the accountability tank is complex because of its inner structure. Therefore the calibration data should be divided into appropriate segments corresponding to the tank cross section to decrease the residual on a fitting function; increment-slope-plot serves as a tool for these dividing.

The example divided into three segments by an increment-slope-plot is shown in Fig-2. The solution level is plotted as ordinate and the solution volume as abscissa in the Figure, that is, it shows the cross section variation of the tank. Since the bottom of the input accountability tank has a spherical surface while the tank has cylindrical shape on the whole, the cross section of lower part on segment-1 increase with the second order. The cross section of segment 1 and 2 is relatively constant in their segment, however, it shows steep change at the border of both segment because of the inner structure change. Therefore the tank profile was divided into three segments at first. These segments were divided to decrease the residual (within ± 2 liter) on a fitting function, and finally the tank profile was determined to be divided into 16 segments. The variation of residual volume on three calibrations is shown in Fig-3.

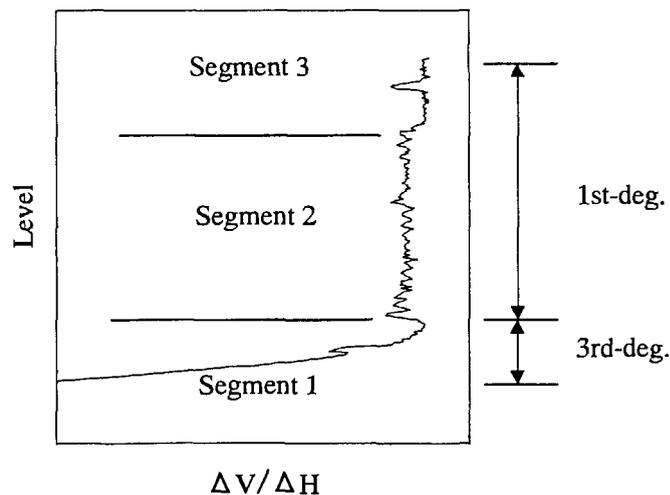


Fig-2 Rough Dividing of Tank Segment with Increment Slope Plots

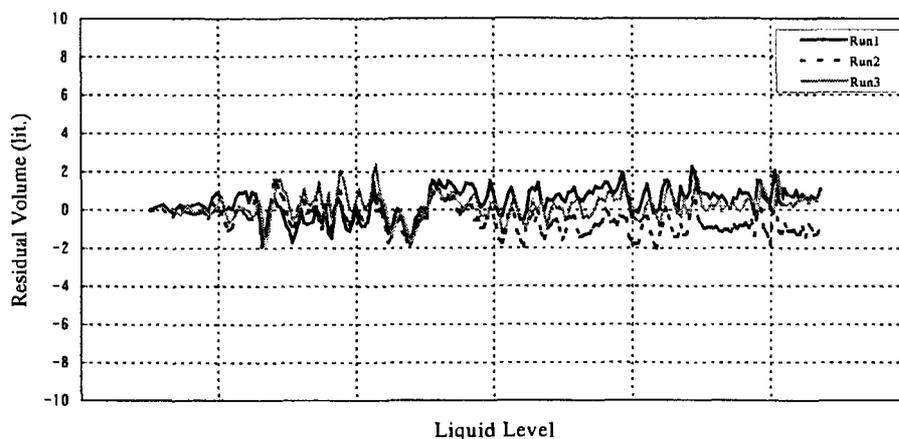


Fig-3 Profile Plot of 3 Calibration on 16 Segments

In order to evaluate the reproducibility of three calibrations, the standard deviation of these calibrations were plotted on Fig-4. In the case of Fig-3 where one common function was applied to three calibrations, the maximum residual for all tank regions was about 2.0 L, in the cases of Fig-4 where individual function was applied, the maximum standard deviation of three calibrations at 20 m³ was about 1.6 L.

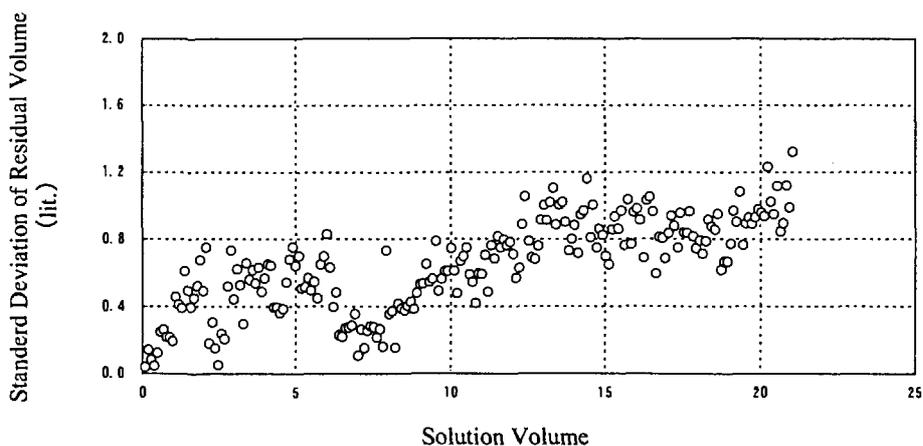


Fig-4 Standard Deviation of Residual Volume on 3 Calibrations

The solution volume derived from density pressure measurements was compared with accumulated

calibration volume. The volume difference is shown in Fig-5.

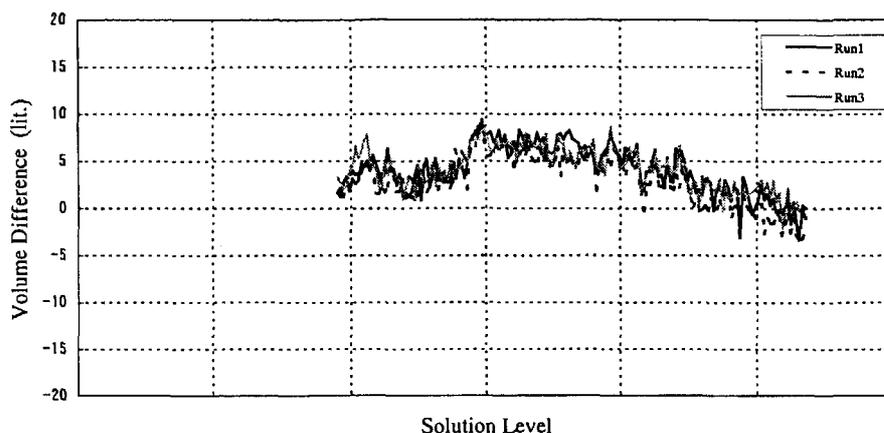


Fig-5 Volume Difference between Calibration and Ordinary Volume Measurement (before Correction)

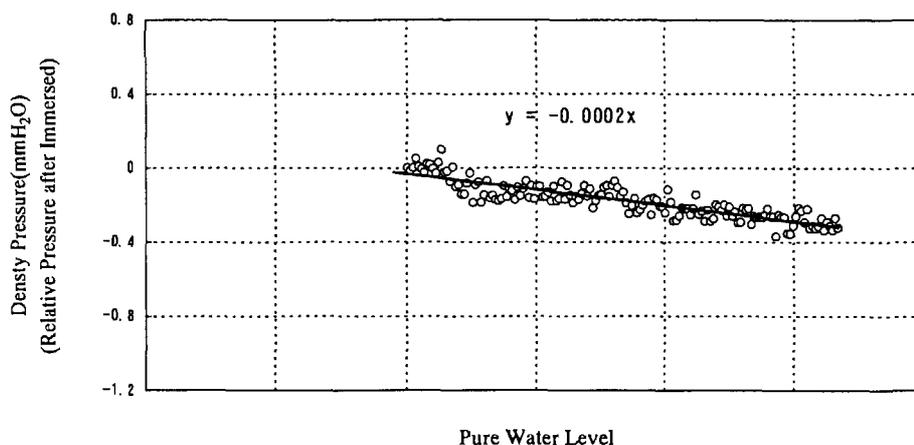


Fig-6 Level Dependence of Density Pressure and Its Regression Line

The variation of density pressure corresponding to the water level is plotted on Fig-6. This shows relative pressure value after immersing density dip-tubes in the water. Essentially, the solution density must be constant regardless of the level in the case that the solution temperature is constant. However, it was observed that the pressure linearly decreased against the level increase.

A set of two density dip-tubes is installed into a protection pipe in the mockup accountancy tank.

Therefore the bubbles produced at the tip of dip-tube may cause a lowering of solution density such as air-lift effect in the pipe; the phenomenon is strengthened with increasing air flow to the dip-tube. As this variation of density pressure gives good reproducibility for using pure water with constant air flow, the data of Fig-5 was corrected with a straight line on Fig-6. The result of volume difference shown in Fig-7 is within 5 liter in all segments. This kind of data correction is effective in using pure water. However it is foreseen that the air-lift effect of the input solution is not the same as the water. Mathematical model under the parameter of solution level, solution density and air flow should be made to stretch the meaning of this phenomenon to actual solution.

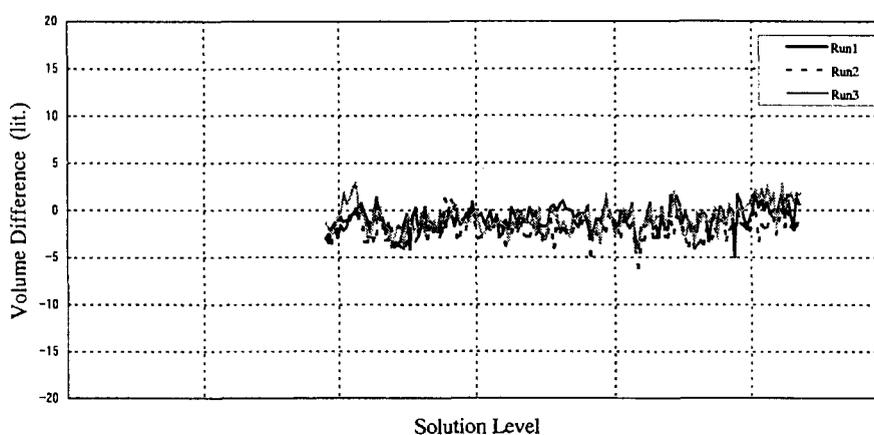


Fig-7 Volume Difference between Valibration and Ordinary Volume Measurement (after Density Correction)

Conclusion

Three calibration experiments were carried out using pure water to evaluate the reproducibility of the calibration curve and the error for the solution volume measurement at the LASTAC. The calibration function was determined to minimize the residual of fitting function on 16 segments. In the case where one common function was applied to three calibrations, maximum residual for all tank regions is about 2.0 L (0.01%), in cases where individual function was applied, standard deviation of three calibrations at 20 m³ was 1.6 L (0.008%). On the other hand, the solution volume (near 20 m³) derived from density pressure was about 10 L (0.05%) lower than the calibration volume when the latter was regarded as the true value. Thus the LASTAC calibration experiments using pure water showed good result in reproducibility. New experiments are planed to study the influence of solution property such as temperature, density, surface tension and so on. Also ventilation influence to pressure measurement will be examined in the future. Overall error related to the volume measurements will be evaluated from these experiment results.

References

- [1] ANSI/INMM : "American National Standard for Nuclear Materials Control -Volume Calibration Techniques" , ANSI N15.19 (1989)
- [2] S.Deron, et al. : "1993 International Target Values for Uncertainty Components in Fissile Isotope and Element Accountancy for the Effective Safeguarding of Nuclear Materials" , IAEA-STR-294 (1993)