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EXPERIENCE OF RUSSIAN RADIOCHEMICAL PLANT SITES WITH THE BUBBLER PROBE MANOMETRY TANK VOLUME MEASUREMENT SYSTEM[1]

Sylvester Suda, Peter Zuhoski, and Leslie G. Fishbone

Brookhaven National Laboratory
Upton, New York, USA

Oleg Darenskikh

Mayak Production Association
Ozersk, Chelyabinsk Region, Russia

Victor Purygin

Siberian Chemical Combine
Seversk, Tomsk Region, Russia

Anatoly Golosovsky

Mining and Chemical Combine
Zheleznogorsk, Krasnoyarsk Region, Russia

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Abstract

To date, bubbler-probe manometry tank-volume measurement (TVM) systems have been installed in the radiochemical plants of the Mayak Production Association (MPA), the Siberian Chemical Combine (SCC), and the Mining and Chemical Combine (MCC) as part of the Cooperative Nuclear Material Protection, Control and Accounting (MPC&A) Program between the United States and Russia. At MPA, three TVM systems in the plutonium processing area potentially permit the determination of a material balance. At SCC, a TVM system operates at one of the two input accountability tanks for dissolved irradiated reactor fuel. At MCC the TVM operates in a test mode on a uranium-solution-bearing tank. In this paper we review the experiences with these TVM systems in the three plants.

1. Role of the TVM in Material Accounting

One goal of the United States-Russian MPC&A program is to improve nuclear material protection, control, and accounting (MPC&A) of bulk materials in Russian facilities. Such materials include plutonium-bearing liquid solutions at irradiated fuel reprocessing (radiochemical) plants: dissolver, intermediate product, and waste.

For a radiochemical plant, MPC&A upgrades to flow measurements should be judged on the basis of their potential to reduce the uncertainty in the material balance [1]. Thus it is especially important to measure receipts and shipments (products) well. For this type of plant, irradiated fuel receipts, once dissolved, and concentrated plutonium nitrate solution (intermediate) or plutonium dioxide powder (final), preferably both, are bulk materials. The receipts themselves—plus most process materials within the plant—are not attractive to divert. But this is not a sufficient reason to refrain from upgrading receipt measurements. If receipts are not well-determined, the expected production would not be well-determined. A malevolent and knowledgeable insider would attempt to divert purified product just before it undergoes product measurement. Indeed, as Bennett and coworkers noted many years ago, the measurement of dissolved irradiated fuel at a reprocessing plant is the most important plutonium accountability measurement in the entire nuclear fuel cycle [2].

Automated techniques for tank volume measurements can help determine and record the nuclear material content of radiochemical plant solutions more accurately than in the past (chemical and isotopic analysis are also required). The content is required to close the plant material balance. These automated techniques can provide unattended measurements of material flows, improved precision and accuracy, reduced operator effort, and lower radiation exposure of operators--with equipment that is predominantly remote from high radiation areas.

This paper reviews the experience with the TVM system, developed by Brookhaven National Laboratory (BNL), at the radiochemical plants of MPA, SCC and MCC. The work was conducted under the US-Russian Cooperative MPC&A Program.

2. Background to Implementation

From the start, it was understood that an exchange of detailed information between the technological specialists in the radiochemical plants and the equipment supplier would be required for expeditious and successful backfitting of equipment into operating facilities. The exchange of information would include both a working knowledge of tank structures, their locations, and current instrumentation and operating procedures. Analogously, the plant operating staff had to become familiar with the TVM equipment and software. This was accomplished in four steps.

The first step involved visits to the Russian radiochemical plants by BNL staff, at which time tank-specific installation requirements for the bubbler-probe TVM systems were determined. The requirements included specifications for the instrument air, pneumatic and electrical power lines to the measurement module, and communication lines to the location of the computer. Plant staff provided a description of the existing means for tank volume measurement, pump fill and drain rates, the method for sparging and mixing of the tank contents, and the operating pressure conditions in the tank.

The second step in the exchange of information were the pre-installation work sessions held at BNL for familiarization with the TVM system. At the meetings, the principal investigator were instructed on the theory and operation of the bubbler-probe TVM system. The modular hardware design of the TVM was reviewed, with an explanation of the computer display screens; there were also demonstrations of how the various screens could be utilized to provide functional information during the measurement cycle. A computer exercise was conducted to illustrate data analysis methods by means of a spreadsheet program.

Installation requirements for the TVM system were discussed based on a component configuration design with the air-flow controllers located in one cabinet near the tank, and the measurement module located in a separate cabinet. Schematic drawings showed the tank, the installed probes, proposed location of the measurement and tank modules, and the computer.

A third step was to address tank calibration, particularly the design and manufacture of the gravimetric unit based on scales for conducting the calibration of the tank via the weight method, the method for making temperature corrections.

Finally, the fourth and last step was to address later training of personnel for working with the TVM system hardware and the LabView software.

3. Brief Description of the TVM System, its Installation and Calibration

3.1. Bubbler-Probe Tank-Volume Measurement Technique by Means of Pressure Differences

Automated bubbler-probe TVM equipment was developed by BNL and first used under operating conditions in the Tokai Reprocessing Plant (TRP) in Japan in 1979. It employed multiple probes and a pneumatic scanning valve to select the probe for measurement. The pressure gauge in the TRP bubbler-probe system was the Ruska Electromanometer [3,4].

Since then, the BNL TVM system has undergone two significant improvements. Version II is a portable system that was designed for use by domestic and international inspectors [5,6]. Pressure measurements in this system are made by the Paroscientific Digiquartz pressure transmitter.

The further improved Version III of the TVM system was installed in the MPA radiochemical plant in May 1997 [7]. It is different from the previous version in two ways. One is the use of the computer to control the air-flow meters (in lieu of rotameters), and the second is updated software based on LabView with Russian language screen displays and help units. A layout of the installation of the TVM system in a plutonium product tank is shown in Figure 1.

3.2. LabView Data Acquisition

The data acquisition software has two main screens for displaying routine measurement data used by the technological workers. The first screen is the measurement page. It is exhibits the following five types of data:

- PC system data consisting of the date, time, and tank ID.
- Measured data, density and level probe pressure readings and the tank temperature.
- Calibration data, of the probe separation and calibration curve coefficients.
- Calculated data, the density, height, volume, and mass of the solution. The basic relation is $P = \rho g h$,
- Transfer data containing the sample identification and the worker's name. When completed, the measurement data page becomes the transfer record for the batch of solution. The transfer data can be printed at the time of the measurement, and are also saved to a separate file in ASCII format compatible with spreadsheet input protocols.

The second main screen shows a plot of the pressure readings and the values of the latest measurement cycle. With a pneumatic scanner and a single pressure gauge, differential pressure readings of the density and level probes relative to the vapor head are obtained. A table containing the average of 100 readings for four pressures, standard deviation of the readings, and the airflow rates is displayed. Additional displays address equipment setup, calibration data, and measurement control.

The application program based on LabView software performs data acquisition and equipment control programs. The data acquisition routine consists of a two-minute cycle during which pressure and temperature instrument readings and measurement control data are collected, processed, and saved in data files. Staff from all three Russian sites received initial LabView training.

3.3. Tank Calibration

Preliminarily, the tank is washed with water and completely emptied. Tap water with or without nitric acid addition is used for calibration. By one method, calibration solution is added to the tank by means of volumetric provers. During the calibration process, TVM system readings and existing system level readings are registered for comparison. Throughout the calibration process, the solution temperature is held constant at about 25 ± 0.5 C.

Figure 2 shows typical calibration results. With such data, the height of the liquid can be calculated and calibration equations derived for the volume-versus-level pressure calibration method. The vertical height between the density and level probes (probe separation) can also be calculated and compared with the measured, installed distance of 200 mm.

By a second calibration method, which is predominantly used in the three Russian plants, weighed amounts of water are added to the tank; newly provided scales are highly accurate. Then the volume added is determined as a function of the weight, density and temperature.

3.4. Routine technological process and TVM

Routine technological operations are shown in Figure 3. Here we can see zones where pressure readings of the density and level probes change rapidly during plutonium nitrate solution filling and emptying, and plateau zones where the volume is not changing. In general, the TVM is an adequate indicator of the technological process except in cases of fast volume changes during solution input and output. Though following rapid process changes is not the main goal of TVM, simple programming changes can solve the problem. In these cases, the TVM instrument readings are delayed in comparison to other levels meters, which are almost inertia-free Accuracy is already reduced during periods of rapid change , and in this sense the TVM is much more suited to accounting than process control. However, the most important requirement for routine use of the TVM is the installation of a communication line between the TVM computer and plant (technological) computer.

4. TVM Experience at the Mayak Production Association

TVM-1

The Tank Volume Measurement System TVM–1 was installed on one of the two measurement tanks at the plutonium final conversion intake of the RT-1 radiochemical plant as a demonstration system. In this sense, the task has been completed in full. During continuous operation from May 1997, the TVM system has not only proven its efficacy by significantly improving the accounting of solution volume in comparison with other instruments, but has also demonstrated additional capability when coupled with an existing system. This additional capability consists of measuring, independent of laboratory sample analysis, plutonium concentration as a function of two parameters, the density (from the TVM system) and the electrical conductivity (from a conductivity meter) of the solution. The dependence $c_U = f(d, æ)$, where d and æ are, respectively, the density and specific electrical conductivity of the solution, have been obtained in sample solutions with varying concentrations of uranium and acid, simulating plutonium solutions. These dependencies will make it possible to determine plutonium concentration after necessary software corrections and modifications have been introduced—without the need for chemical analysis. Both TVM system and conductivity meter data are output to the shop computer system.

Specific qualifications of personnel and corresponding experience have been acquired, making it possible to maintain the system in working condition.

TVM-2

TVM–2 has been installed on two measurement tanks from which plutonium, isolated in the first extraction cycle, is sent to another building for further treatment. The system is functioning normally. One calibration has been performed on tank 1 and three calibrations on tank 2. In our view, the results are very good.

TVM–2 data are sent to the shop computer system. However, the LabView 5.1 software (the latest version) is constantly hanging up. Repeated attempts to eliminate this problem have been unsuccessful, so we have been forced to turn to the LabView 5.0.1 software, which works fine but can not "read" volume. Therefore, using data from measurements of pressure, we determine volume manually.

Let us explain in more detail the problems, which, if unresolved, make it impossible for the TVM system to be standard equipment, and which prevent it from being used with the necessary effectiveness.

1. In the initial stages of the joint work on improving systems for measuring volumes in the technological process chain of plant RT–1, it was proposed that these systems be developed in parallel and simultaneously with other upgrades. These others were the establishment of a nuclear materials accounting computer system and improvements in laboratory plutonium-measurement instruments. Currently, the error factor in measuring plutonium mass in measurement tanks virtually depends only on the error factor in measuring plutonium concentration, which at a minimum is an order of magnitude higher than the error factor in the TVM system. However, while laboratory measurement equipment upgrades will likely lead to rapid and significant improvements in precision, the situation surrounding the establishment of a computer accounting system and corresponding software support is another matter. Such a system, except for recent accounting subsystems for finished product, is not be expected in the near future due to a lack of financing.

Thus, there is no current need for a high precision TVM system.

2. The TVM system has not been certified by Russian metrologists. Certification requires not only calibration data but a more detailed technical description, with operating instructions, than is currently available.

3. The systems do not have spare parts, primarily for the more vulnerable mechanical assembly. Scanning valve failures took place in all TVM systems. Together, we rectified all the failures, but in the process, we exhausted all the spare parts for the scanning valve.

4. The systems have not been fully adapted to our specific plant conditions. For example, we require operational control of the high-speed transfer of solutions. We propose, before transferring a solution, to set the scanning valve on command at the level-probe position, using the previously determined value of density for calculating volume during transfer and, after stabilization of manometer readings, "relaunching" the scanning valve.

In the tank in which TVM–1 has been installed, there are significant fluctuations in rarefaction (off-gas), with pressure sometimes even reaching 0.5 to 0.6 bar. This was observed specifically on the basis of TVM data. Therefore, it is necessary to strengthen protective measures when the system is under pressure in order to ensure safety. In addition, due to the high speed of these fluctuations, it is rare but on occasion unrepresentative results occur which negatively affect the computer system. Consequently, we need software filtering of unrepresentative results. This requires the upgrading of software based on additional LabView training.

Nevertheless, despite these problems, our team decided, first, to use the TVM system for the control and accounting of plutonium from the beginning to the end of a full reprocessing campaign of spent nuclear fuel in the first extraction cycle. Before the beginning of the reprocessing, the first extraction cycle compartment was washed of plutonium, while the campaign ended with the complete removal of plutonium from process equipment of the first extraction cycle. This was performed this year. The general schematic in Figure 4 shows the technological process chain from the spent fuel storage facility to the reception of finished product, with TVM system locations. The solid arrows in the diagram indicate the main flow of nuclear materials while the dotted lines indicate losses. Accounting was conducted in tank 2 of the first extraction cycle according to TVM–2 data (volume) and laboratory sample analysis (concentration). The total mass of plutonium produced during this campaign and transferred to the subsequent technological process stage (flow 6), with account of loss (flow 5) in raffinates (waste solutions), was compared with the shipping data for the spent fuel arriving for reprocessing (flow 1). It was also compared with the mass of plutonium produced in the solution of spent fuel from the output measurement tank of the dissolution compartment in the first extraction cycle (flow 2), considering loss of plutonium (flow 3) with leached hulls. Plutonium mass in this tank was measured by means of data of the inductive level gauge, the error factor of which is ±1%, and laboratory analysis of spent fuel samples.

Second, it was proposed to compare the mass of plutonium, produced from tank 2 (flow 6) with the mass of plutonium arriving in the input measurement tank of the refining process stage (flow 8) and the mass of plutonium produced from this stage (flow 8'). Unfortunately, even from the start, we had to avoid this comparison. There were sampling pump malfunctions in the tank in which the TVM–1 system was installed. Also, in February, the scanning valve of TVM–1 was out of commission. This valve was repaired and has since then been working normally, but we are not convinced that this fix is reliable. Thus, we have not taken samples from the tank with the TVM–1.

Three factors allowed us to conclude that the cause of the discrepancy is in the significant systematic error factor during the analysis of plutonium in the initial spent fuel solution: (1) the high precision of TVM–2, revealed during three gravimetric calibrations; (2) the higher precision in measuring the concentration of plutonium in re–extract (±1 %), in comparison with the precision of measuring plutonium concentration in a spent fuel solution (±7 %); and (3) the low level of plutonium loss and traditional strict control. After discussing the results obtained, the following measures were adopted: additional standard measuring instruments were introduced to check the calibration of laboratory control instruments, frequency of checks was increased, etc. After the renewal of reprocessing nuclear spent fuel, the preliminary data indicates that the systematic error factor has been eliminated. However, it will be possible to establish this conclusively only after the completion of the next campaign of spent fuel reprocessing and extraction of plutonium from technological process equipment. The reason is that without this, the large holdup of plutonium in the equipment impedes a strict near-real-time analysis.

Figure 5 presents a standard diagram of the flow of solution between tanks 1 and 2. On the one hand, this diagram indicates how important it was to equip not only tank 2 but also tank 1 with the TVM system, because it was substantially easier to follow the movement of solution input to tank 2 and output from it. For example:

- Position 1 is the plateau regime in tank 2, which denotes the volume of a liquid before input or output of a solution from the measurement tank.
- Position 2 indicates the input of re–extract to tank 1.
- Position 3 is a peak, arising because the output of solution from tanks 1 and 2 occurs at high speed, more rapidly than the TVM system can react.
- Positions 4 and 4' denote the flow of a solution for sampling from tank 2 to tank 1 and back.

This figure not only demonstrates the wealth of precise information captured by the TVM system, but also illustrates the difficulty in complete automation of accounting. For complete understanding, each feature of the diagram requires analysis and deciphering.

TVM-3

We cannot fail to discuss the problem associated with TVM–3. Everything required from our enterprise under the task has been fulfilled. The system has been installed. All sensors with built–in thermometers stipulated by the task order have been manufactured and installed in the mixer–settler tank. The conductivity meter has been manufactured and installed for measuring, in combination with the TVM system, the concentrations of uranium (plutonium) and acid in the water phase. Moreover, under the proposed high–precision control by the TVM–3 system of the concentration of uranium in the stages of the mixer–settling tank, special modeling was conducted to present a full picture of the distribution of nuclear materials and to measure the overall quantity of uranium and plutonium in the mixer–settler tank at any time.

For a number of reasons, the TVM–3 system is more important for us. And this is not just because it is necessary for control and accounting of plutonium in real–time. The main thing is that it would help to stabilize the technological process. When the process is stable, in turn, it is much easier to more precisely control and account for nuclear material.

Although the installation was not well tested due to time constraints, we decided to launch the TVM–3, using LabView 5.0.1 software, in order to run at least one or two sensors and, using the shop computer, to attempt to determine plutonium concentration by means of solution density and conductivity measurements. The software worked but there were unexpected failures in the scanning valve. We were not able to determine the cause, and because of a lack of spare parts, we had to suspend further work.

5. TVM Experience at the Siberian Chemical Combine

5.1 Implementation Stages

In addition to the general steps described in Section 2, SCC personnel also performed additional preliminary steps:

- upgrading the TVM software for specific production conditions (schematic diagrams of the results of measurements and of calculating conditions);
- the development of software for testing TVM system units (air-flow gauge, system pressure sensor, manometer, pneumatic scanning valve, temperature data input controller, and air valve (switch); and
- the issuing of operating and regulatory documents.

5.2 Testing

The testing program stipulated the work to evaluate the use of the TVM system for measuring volume and density in tanks at the Radiochemical Plant:

- determining the distance between measurement probes in the tank;
- conducting three calibration tests of the tank using the weight method ;
- temperature testing for expansion; and
- experimental operation.

5.3 Calibration

The calibration testing procedure via the weight method included:

- weighing the water fed to the tank of the gravimetric unit;
- weighing the water remaining in the tank of the gravimetric unit after being poured into the calibration apparatus;
- calculating the weight of water poured into the calibration apparatus; and
- determining the volume of water poured into the calibration apparatus by considering its weigh and the density of water at the measured temperature according to formula.

Figure 2 shows the calibration curve obtained using the "Deming" software; the curve is divided into three ranges for level in the tank. The subdivision helps reduce the error in measuring volume in the apparatus.The limit of random error in measuring volume in the tank, at a confidence level of 95%, is as follows for the three ranges:

- in the level segment from 0 to 337 mm (volume 490 to 1770 liters), ± 8 liters;
- in the level segment from 298 to 1654 mm (volume 1770 to 7893 liters), ± 6 liters; and
- in the level segment from 2095 to 2864 mm (volume 7893 to 9139 liters), ± 18 liters.

The temperature testing for expansion indicates the necessity to take temperature into account to understand the increase in readings of the system for the level-probe measurements.

5.4 Results

The TVM system was installed in one of the input tanks at the Radiochemical Plant and has been in experimental operation since September 1999. To date, there have been two cases of sudden shutdown of the TVM system associated with the loss of electrical power and air feed. There have been no failures associated with system software. Based on the results of this experimental operation of the TVM system, it has been determined that

- The TVM system makes it possible to account for the true volume and density of product, considering temperature in the tank during scheduled technological operations.
- There is a scatter of readings of volume and density of the TVM system during transfer operations.

Scatter in readings of volume and density during transfers of solutions occurs due to the system's technical features, namely, one manometer, series–connected through the scanning valve to the measurement probes at one-minute intervals.

6. TVM Experience at the Mining and Chemical Combine

The system was introduced at MCC in May 1997 in one of the tanks of the natural uranium diffusion unit for experimental industrial testing. The aspects tested included functional characteristics and reliability and operational safety for further use in nuclear MC&A, primarily of plutonium, in several material balance areas of the radiochemical plant. Assembly of the system took place under the direct leadership of the system designers and senior specialists from BNL. This made it possible to carry out the assembly, setup, calibration and initial testing of the system in only two weeks.

Over the period of operation lasting more than three years, the system has acquitted itself as a reliable instrument in nuclear MC&A. In particular, we note:

- high precision in measurements of the volume of solution in comparison with 5% for the traditional measurement method;

- high operational reliability; during the period of operation, the computer monitor stopped operating once, because of improper connecting to the power unit;

- access for training and openness of the system; the program interface is noteworthy for its simplicity and ease of adjustment in the technological process; and

- safety; there have been no instances of radioactive solution getting into the system or of damage caused by electrical current.

7. Evaluation and Future Prospects

7.1 Mayak Production Association

We have described the installation, testing, and evaluation of non-stop operation of the TVM system for a process tank with plutonium solution during routine plant operation. Analysis of the test results showed that conditions of TVM operation were more demanding than previously thought. However, in spite of these conditions, the TVM system showed good operating characteristics such as high reliability, accurate operations of the system elements, and exceptional computer control of the scanner and air-flow meters. These achievements were only possible through training and effort and the close cooperation between BNL and MPA specialists.

This is the first equipment at the RT-1 plant utilizing a local computerized control system. It has changed the routine measurement process to a new qualitative level. Implementation of such new techniques will not only increase significantly the accuracy of measurements and reliability of tank measurement control and accounting, but will also open for MPA personnel new perspectives and new ways to improve in other measurement areas. Integration of the TVM system for routine measurements will require software modification and additional equipment.

The possibilities are apparent of extending the use of similar TVM systems to other accounting areas, for example, to measure uranium concentration (by density) in the production-line mixer-settler of the Purex process.

7.2 Siberian Chemical Combine

Based on results of testing and experimental operation of the TVM System we have drawn the following conclusions:

1. The TVM system makes it possible to qualitatively account for the level and density of solution in the tank with a high degree of accuracy (less than one percent);

2. The TVM system is convenient for operator interface;

3. On the whole, the TVM system makes it possible to improve the quality of nuclear materials accounting. At the same time, we have concluded that these systems are useful given the observance of the following conditions:
   - The tank in which the system is installed must be a measurement tank;
   - There must not be over–pressure in the tank;
   - The solution must be homogeneous; and
   - The number of technological operations conducted in the tank must be kept to a minimum, and changes in parameters in time must be slow.

In addition, we think that the use of a scanner and one high–precision manometer improves accuracy of measurements, but in turn, will lead to the following negative consequences for us:

- The scanning valve is a low failure–resistant component and requires special and labor–intensive technical maintenance;
- The use of one high–precision manometer together with the scanning valve does not make it possible to qualitatively track parameters that undergo rapid time changes.

Another specific difficulty is the procedure for calibrating the manometer of the TVM system (removal of the manometer and calibration on a stand or the development of a portable stand for calibrating the manometer without removing it), the use of expensive metrological equipment with a class above that of manometer. To conduct technical maintenance of the scanner pursuant to recommendations of the manufacturer, it is necessary to disconnect the piping from the scanner, lubricate the mechanical parts of the scanner with special lubricant, and reconnect the piping.

These operations must be performed twice a year and over time, this will require the replacement of piping and in the installation of new connectors on them. And because the existing system uses American standard piping and connections, this will represent significant difficulty in replacing these items.

In our opinion, the system software has insuffficient test software aimed at trouble–shooting the technical elements of the system. We have ourselves developed test software for the technical elements of the system; this test software has itself been tested and given high marks by maintenance personnel.

We therefore propose the following system configuration for the TVM system under conditions such as ours:

- individual, less precise, manometers for each measurement probe;
- software developed for this system configuration; and
- to enhance our ability to modify the application program, LabView software with LabView Application Builder, LabView SQL , and Automation Symbols Toolkit.

7.3 Mining and Chemical Combine

Our calibration of the installed system involved the use of an additional personal computer under the OC.MS–DOS operating system with NORTON COMMANDER. We should examine the feasibility of calibrating the system using the main process computer, having mastered the LabView software.

To support setup, maintenance and repair of a large number of systems, they should be equipped with personal notebook computers. This will permit remote access from the portable controller to the main process computer in the assembly shop to adjust system operating parameters as required.

We suggest upgrading the system with an uninterruptible power source.

The software should be altered to record technological process parameters in the system data base using MS OFFICE (Access, Excel, etc.) through the DDE ACTIVX interface.

Finally, we suggest using an air-handling unit during system operations (for cleaning the air of moisture and dust) of the type used at the MCC for pneumatic metal–working machines. This may provide a longer service life for the pneumatic scanner.

7.4 Brookhaven National Laboratory

We address two points raised by the descriptions of work at the three sites. Figure 5 shows several very detailed features of the actual process flows. MC&A does not require such continual analysis of the data for all such features, but the TVM system does save these data for analysis and for measurement control purposes. As already stated, the programming was not optimized for following rapid process changes, but rather for the needs of MC&A. In any event, the TVM system permits tracking parameters quantitatively, as Figures 3 and 5 amply demonstrate, not just qualitatively.

Regarding the manometer, the manufacturer suggests recalibration every two years, and measurement control data probably permits extending this period. It is not necessary to remove the manometer from the system more frequently. Some problems encountered were the result of interruption of installation and debugging before satisfactory completion.

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Figure Captions

Figure 1. Schematic diagram of bubbler-probe tank-volume-measurement system (TVM)

Figure 2. TVM system calibration between volume and liquid level in the tank at the Siberian Chemical Combine

Figure 3. Mining and Chemical Combine operational TVM data for tank fill cycle

Figure 4. Mayak Production Association radiochemical plant flow schematic

Figure 5. Flow of solution between tanks at the Mayak Production Association

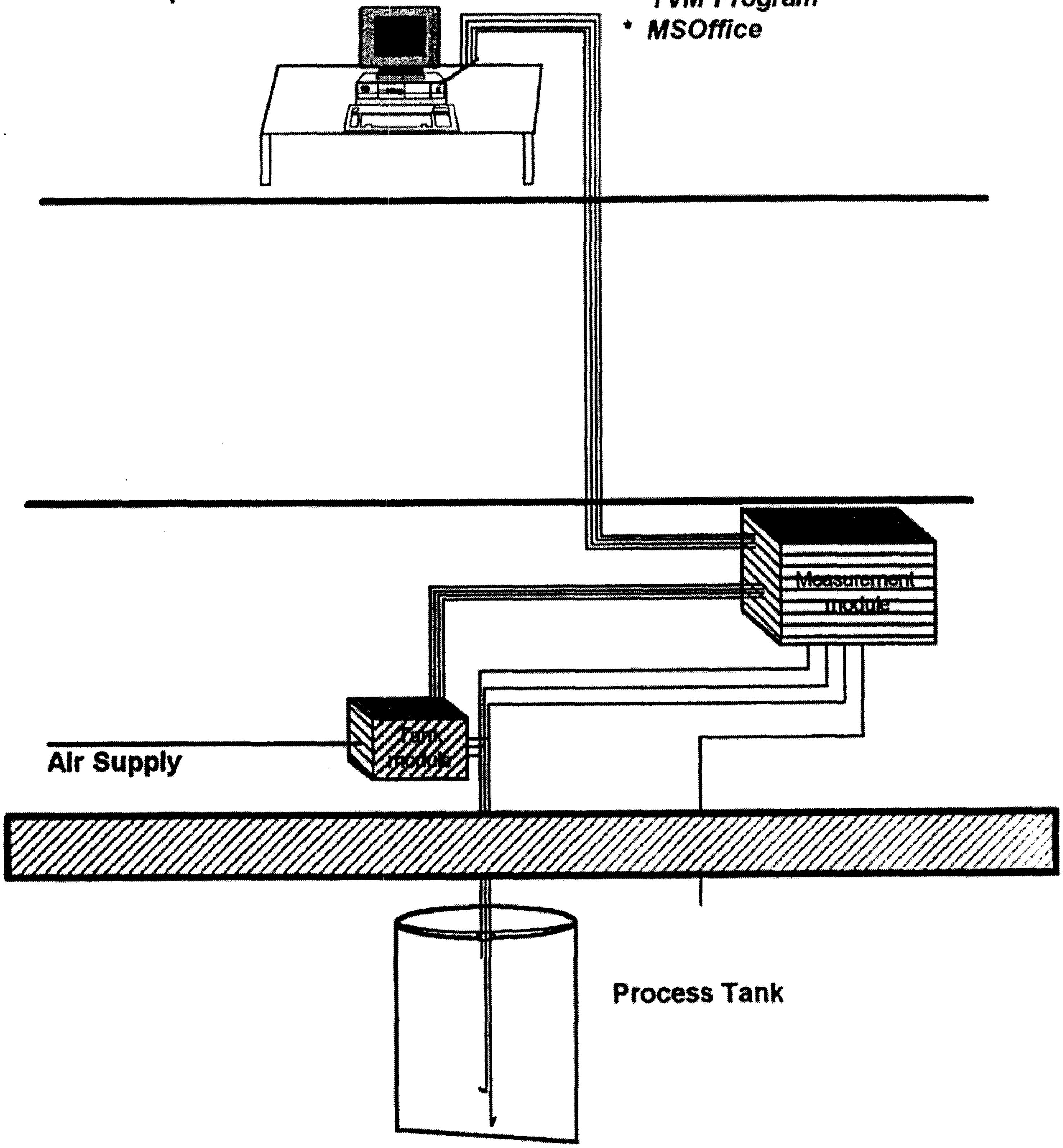
Control Room

<u>*Process signals*</u>

High frequency level probe

Tank temperature

- *Windows 95*
- *Labview*
- *TVM Program*
- *MSOffice*



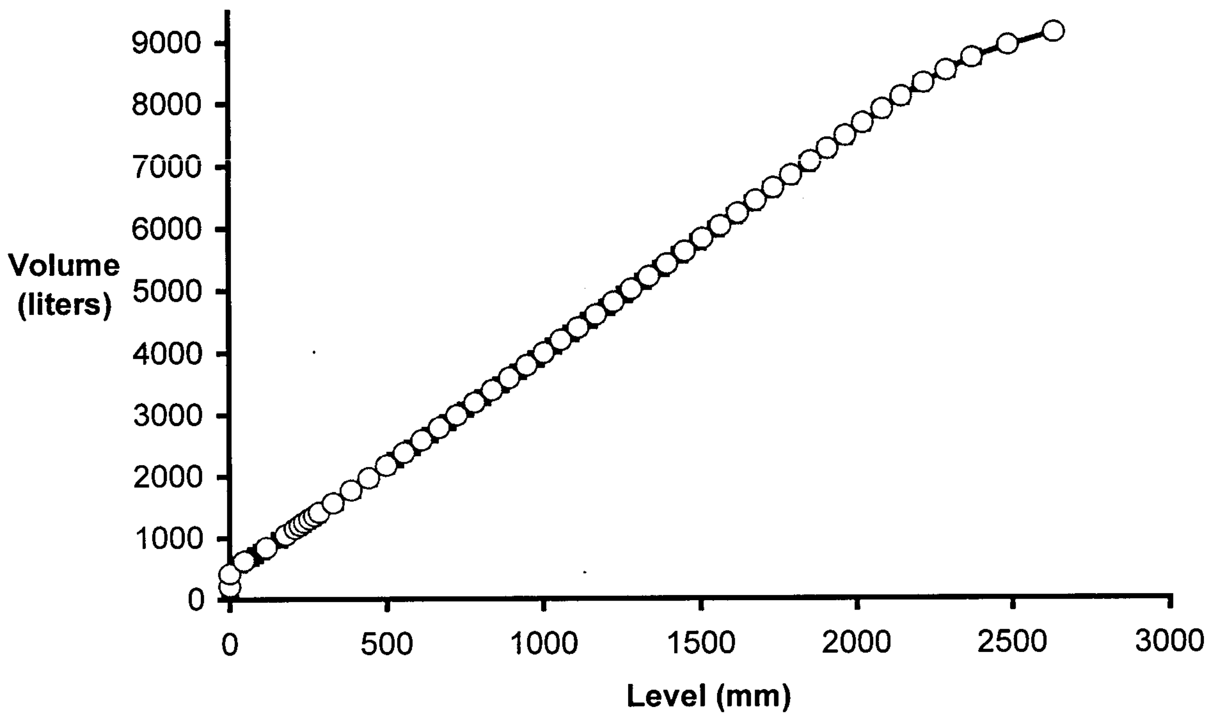
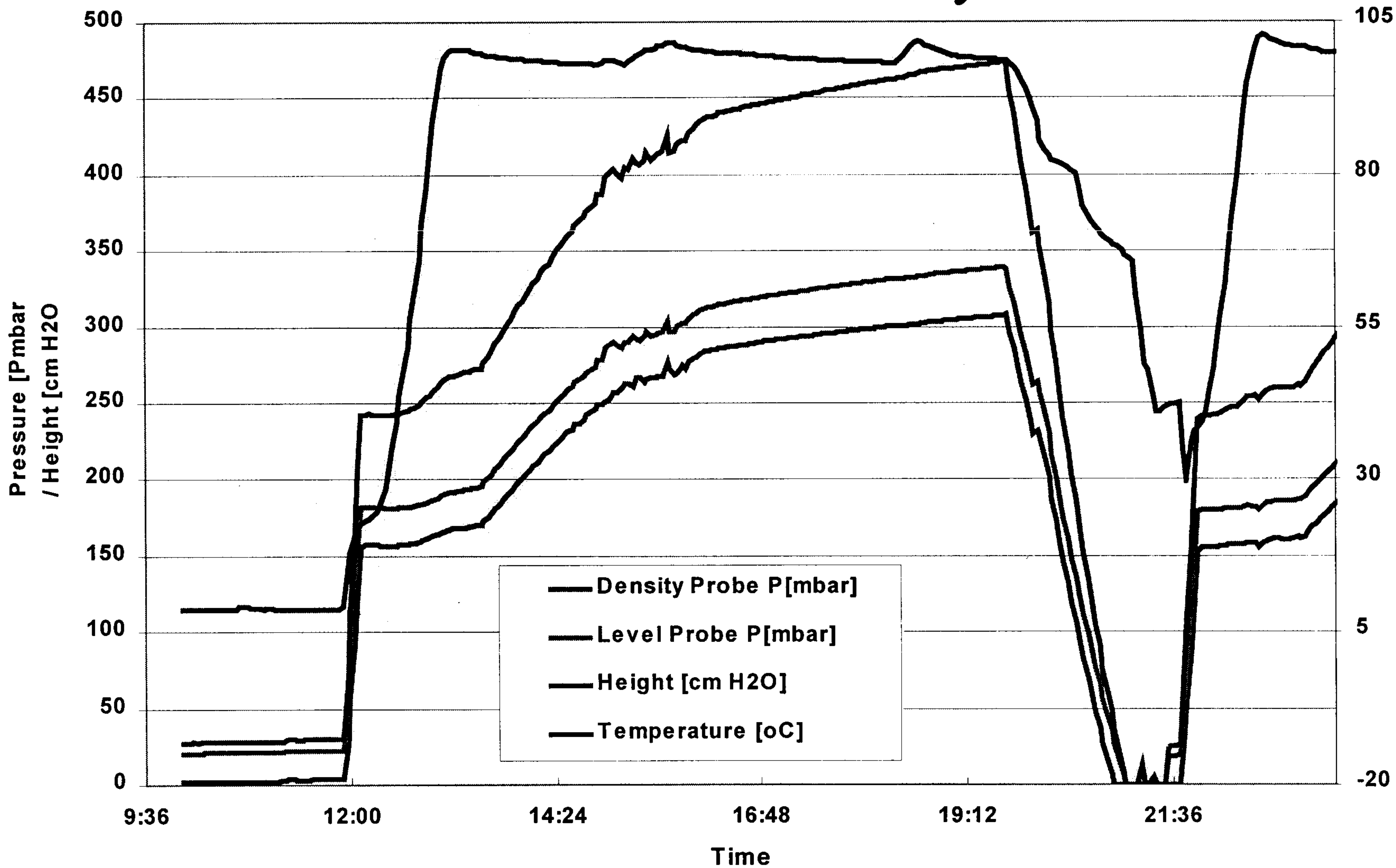


Figure 2. TVM system calibration between volume and liquid level in the tank at the Siberian Chemical Combine

Figure 3. Mining and Chemical Combine operational TVM data for tank fill cycle



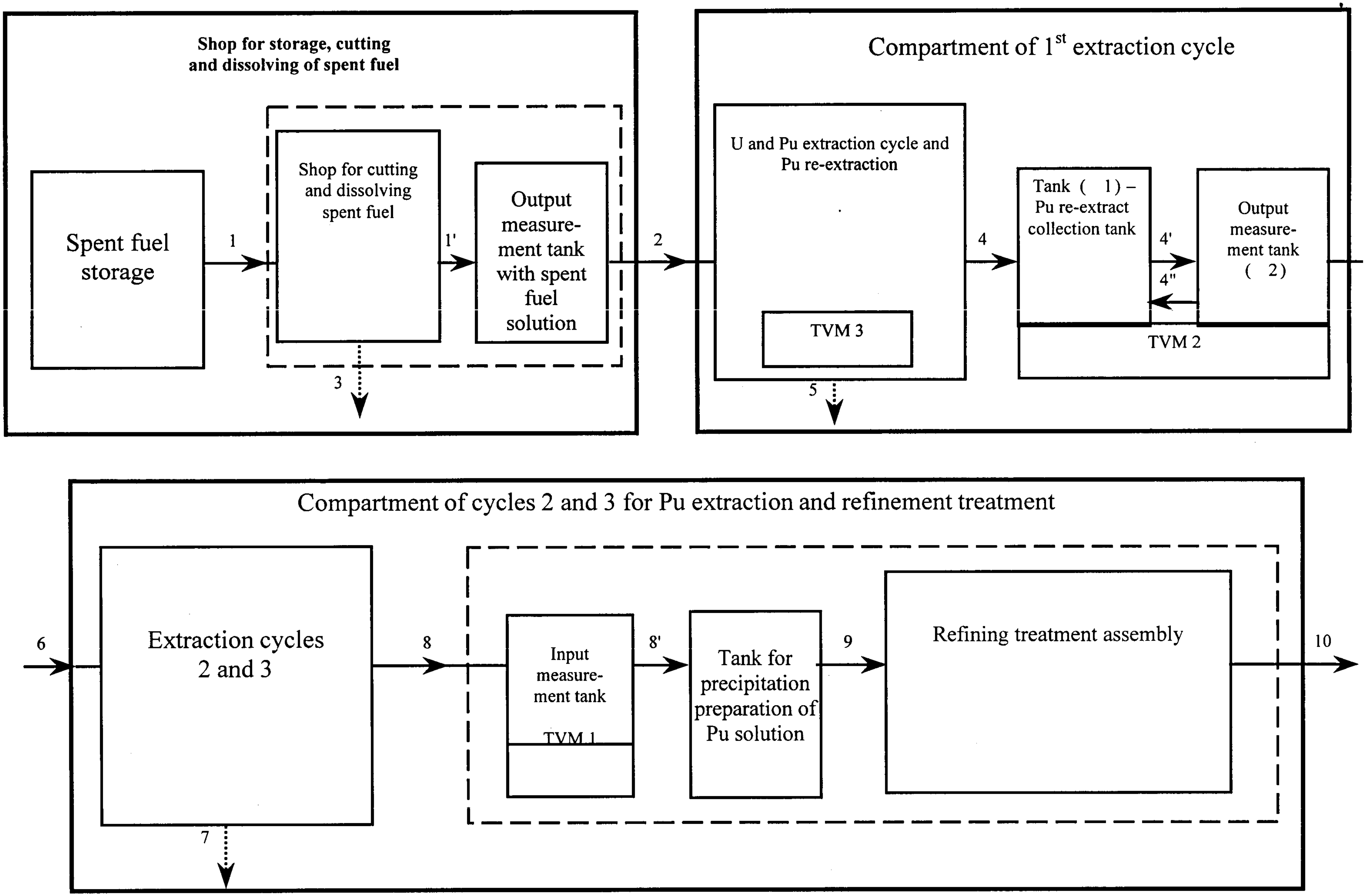

Shop for storage, cutting and dissolving of spent fuel
Spent fuel storage
1
Shop for cutting and dissolving spent fuel
1'
Output measurement tank with spent fuel solution
3
2
Compartment of 1st extraction cycle
U and Pu extraction cycle and Pu re-extraction
TVM 3
5
4
Tank (1) – Pu re-extract collection tank
4'
4"
Output measurement tank (2)
TVM 2
Compartment of cycles 2 and 3 for Pu extraction and refinement treatment
6
Extraction cycles 2 and 3
7
8
Input measurement tank
TVM 1
8'
Tank for precipitation preparation of Pu solution
9
Refining treatment assembly
10

Figure 4

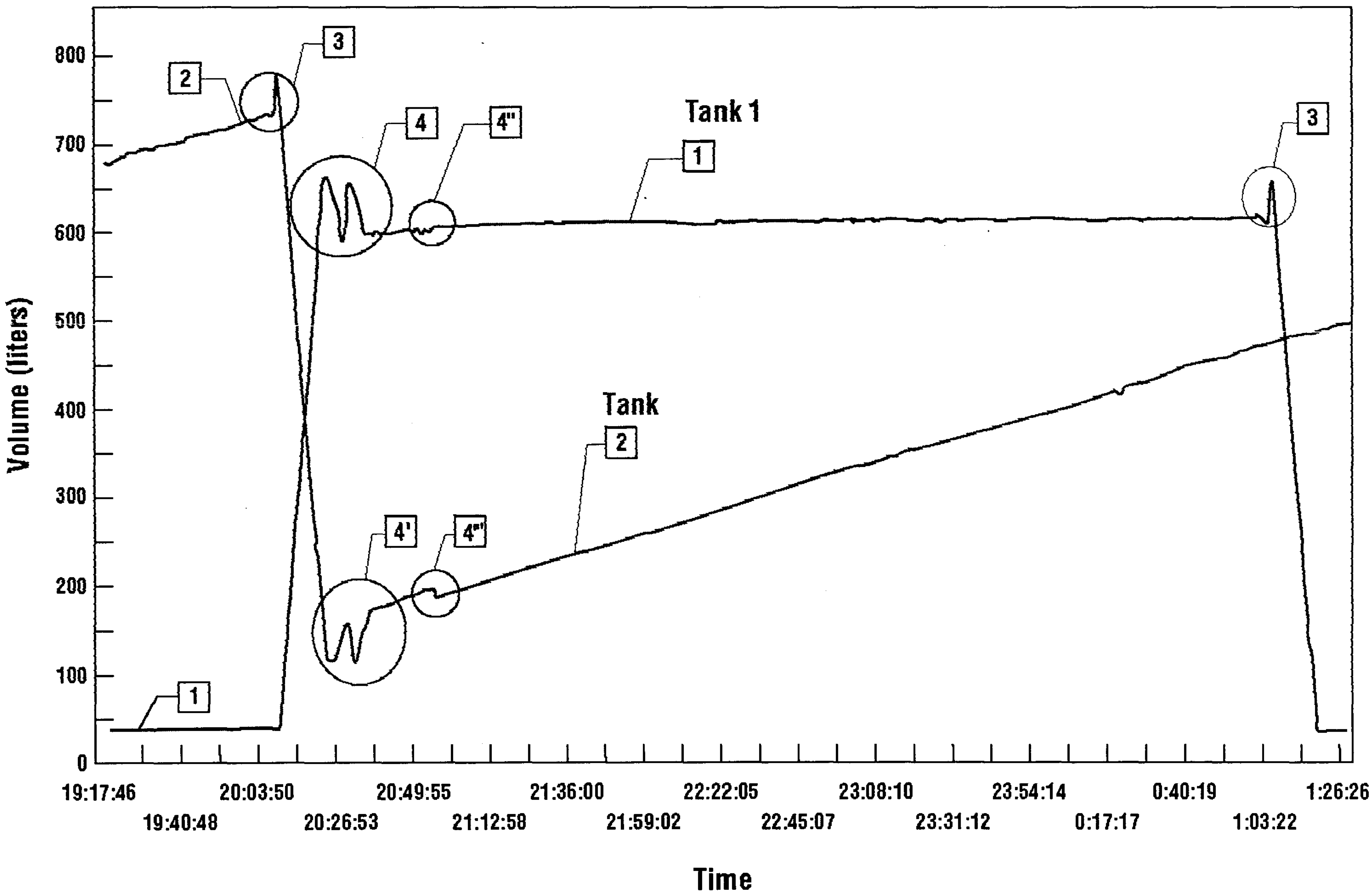


Fig. 5 Flow of solution between tanks at MPA.