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ESTABLISHING A VOLUMETRIC MEASUREMENT CONTROL PROGRAM (U)

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Establishing a Volumetric Measurement Control Program*

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Abstract

At the Savannah River Site (SRS), several facilities have nearly all their special nuclear material in solution and therefore, volume measurements play a key role in the accountability of these materials. Normally, facilities rely on frequent instrument calibrations, periodic tank calibrations and proper instrument configuration to ensure measurement control. At SRS, methods have been employed that go beyond these basic steps to monitor the volume measurement systems and provide real time indication of measurement control. These methods can be used to indicate if a tank requires recalibration, if there is a sampling problem, or if there is an instrument problem. The methods include: sample density comparison, in-tank to laboratory density comparison, redundant instrument comparison and tank to tank transfer comparison. This paper describes these methods and the generation of control charts to track these comparisons in real time.

Introduction

At SRS, F Canyon is a facility that handles special nuclear material (SNM). Since this facility is involved with tanks that fit the measurement control requirements of DOE Order 5633.3A, a complete volumetric measurement control program was conceived and implemented for some tanks. "Strategic" tanks were selected on a graded safeguards approach. This project involved the analysis of historical data, the construction of control charts, the implementation of these charts on strategic tanks, and strategic tank to tank transfers. The result was a comprehensive program that covered all aspects of the volume measurements on key tanks in these facilities. Problems associated with the measurement instruments, sampling, and mixing can be detected through these charts.

Volumetric measurement control can be addressed in five areas:
1) redundant instrument comparisons,
2) in-tank density to laboratory density comparison,
3) tank to tank transfers,
4) tank sample comparison and
5) a tank individual instrument program.

The goal of such a program is to address all aspects of determining the contents of a tank. This can include: the volume measurement, an in-tank density measurement, and sampling. The analytical method to determine concentration is also very important, but is beyond the scope of this paper.

Redundant Instrument Comparisons

Many tanks at SRS have redundant instrumentation. Fortunately, this is true for the tanks in F Canyon that are considered "key tanks" from a graded safeguards sense. These tanks were included in the volumetric measurement control program. For these tanks, Ruska DDR 6000 differential pressure sensors were installed in parallel with Fischer-Porter units. Historical information is available that contains simultaneous readings of these two instruments. The task for this portion of the program was to make an

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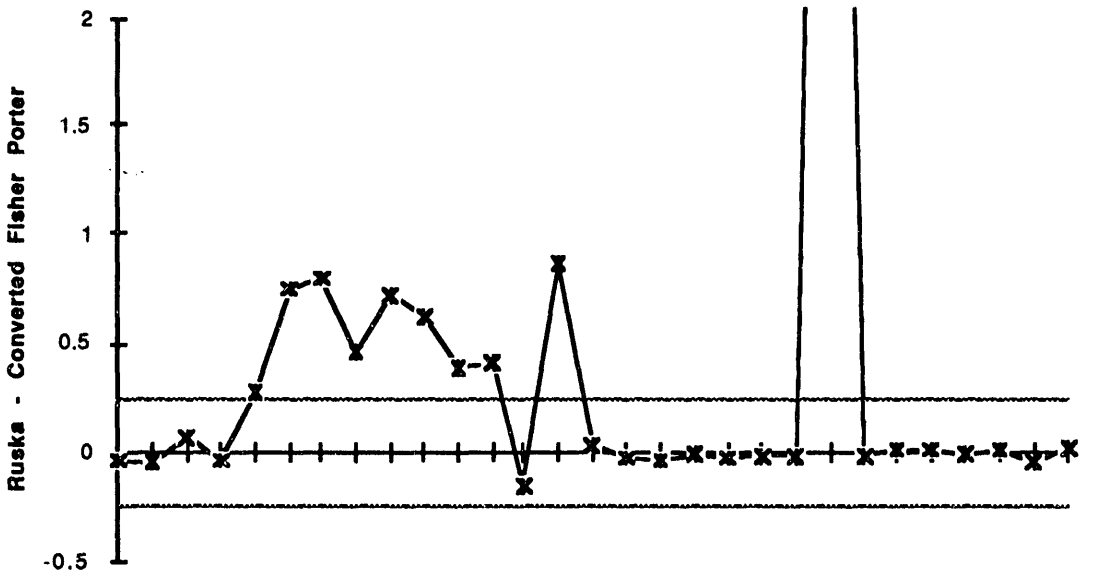

Figure 1
Control Chart of instrument comparison

appropriate comparison for these instruments.

This can be accomplished by comparing the response of two instruments to the same input. These instruments can be either of identical or of different make and model. The goal in is to have two independent responses to a common input that can be compared.

For example, if the instruments are essentially identical, the response to a common input can be compared directly. If both instruments are in good working order and are in calibration, they should have the same output within statistical limits. These limits should essentially be the propagated result of the allowed calibration bias and the random error of the instruments. If these values are well known, the statistical limits can be determined. However, a more realistic set of limits can be calculated using historical data.

If, as in F Canyon, two instruments of different make and/or kind are compared, the output of one may need to be translated into the same type output of the other. For example, a Ruska DDR 6000 has an output of 0 to 10 volts. Depending on the input range 10 volts can be 1.000 psi, 100.0 psi or something else. Rosemont and Fischer-Porter transducers have a 4 to 20 milliamp output scaled to its input range. Therefore, the outputs of the two instruments cannot be directly compared without some translation. through historical information the output of the Ruska can be regressed onto the output of the Fischer-Porter yielding an equation. This equation translates the Fischer-Porter output into a value that can be directly compared to the Ruska output. Once the outputs are comparable, one can be subtracted from the other. This difference can be control charted using a Shewhart Chart, or a CUSUM Chart.

Figure 1 is a Shewhart chart plotting the difference between redundant instrument on a tank. The determination of the control limits were calculated using historical information. In this chart, one of the instruments went out of

calibration starting with the fifth data point. It came back in control at the 15th point, after calibration. If this chart had been followed, and the points plotted in real time, the instrument would have been calibrated when the first point when outside the control limit.

The instrument responses were result from a common input. These measurements were be made within a small enough time frame so that any time related physical differences in the input were within the random error of the instruments.

In order to obtain control limits to be used for these charts, it was necessary to convert one instrument reading into another. Initial plots of the data for the instrument comparison suggested a linear fit between the Fischer-Porter instrumentation and the Ruska Differential Pressure Sensor. These graphs made visual detection of different calibration periods fairly easy since recalibrations resulted in distinct lines. Before regressions were done, outlier observations were eliminated from the data sets. Including these observations would not only result in a poor fit, they may also lead to an artificial inflation of the control limits. After the equations were determined, to make the units consistent, differences between the instruments readings were calculated. This comprised the historical data that was then used to obtain the control limits. An error propagation was not done; however, use of historical data should accurately combine any sampling and measurement errors with random errors that are present. The targets for the control charts were set at zero, with alarm limits set at ± 3*s, where s is the standard deviation of the historical differences. Warning limits were set at ± 2*s. If the data follow a normal distribution and the conversion equations are still valid, then the probability that a difference would fall outside of the warning limits is 0.05, and outside the alarm limits, 0.003. The differences should fluctuate randomly around the target line. Generally, the Western Electric rules are followed to determine whether or not a point is out of control. These rules define a process as being out of control when any one of the following three events occurs:

1) One value falls outside of the alarm limits;
2) Two out of three consecutive values fall outside of the warning limits;
3) Eight consecutive values fall on the same side of the target line.

In-Tank Density to Laboratory Density Comparison

If a tank's instrumentation has the ability to measure in-tank density, a very comprehensive check on the measurement system is to compare the in-tank density measured by the tank instrumentation to the laboratory measurement of a sample taken from the same tank. All of the F Canyon tanks under the volumetric measurement control program are capable of making in-tank density measurements. Historical information on these tanks is also available to analyze for this comparison.

In order to properly make this comparison, two criteria must be met: the tank measurement must be made within a very short time of taking the sample (5 minutes) and the in-tank density must be temperature corrected to match the laboratory measurement. The modern density meters typically used in laboratories are based on tight temperature control at 25.00 C. Once this treatment is done, the two density measurements can be directly compared.

Control charting of the difference between the in-tank and laboratory density measurements can reveal several possible problems. If both the tank instrumentation, and the laboratory method perfectly represented the density in the tank, one would expect the data to

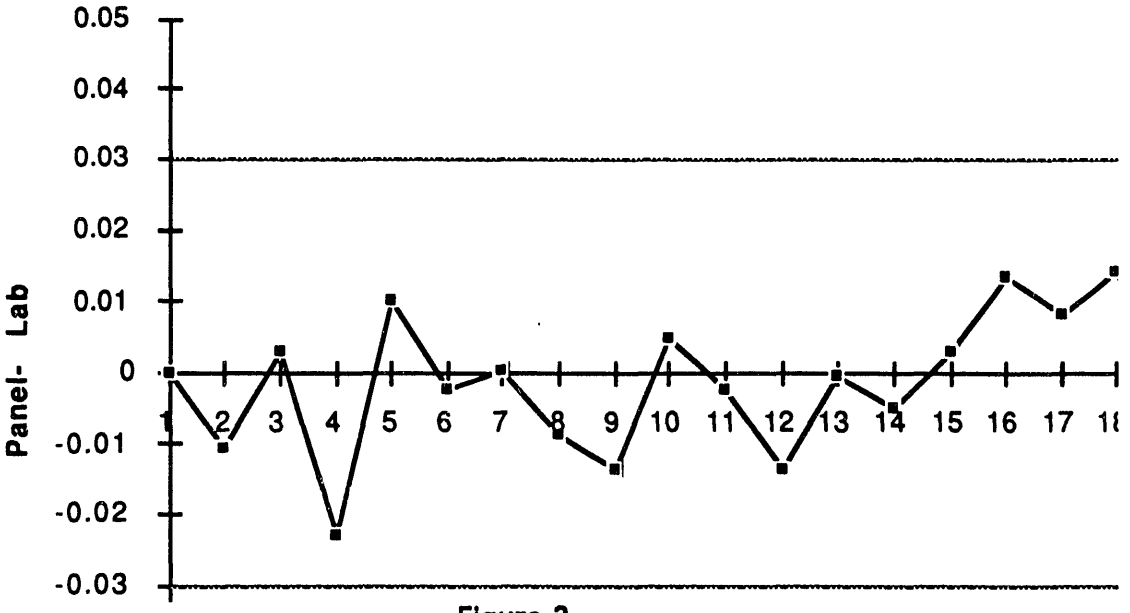

Figure 2
In-Tank to Laboratory Density Comparison

average to a difference of zero, with variability that is proportional to the resolution of the instrumentation and calibration tolerances. Deviations from zero greater than this base variability can be due to instruments being out of calibration, sampling problems, and/or biases introduced to the measurement system such as installation problems or inappropriate mathematical treatment of raw data. Figure 2 shows a control chart based on this comparison.

The establishment of control limits for these control charts followed much the same pattern described earlier. Differences between lab reported densities and densities obtained from in-tank instrumentation were used to calculate standard deviations for the historical data. Target lines for the control charts were again set to zero, and warning and alarm limits were set at +/- 2*s and +/- 3*s, respectively.

Sample Density Comparison

An efficient way to test the validity of the tank sampling systems is to compare the density on two or more independent samples. The samples should be taken within the same time frame to avoid any concentrating effects from evaporation or other effects that may change the concentration. Density is normally the analysis chosen for comparison, since it is a quick measurement with excellent precision and accuracy.

The density of the first sample is subtracted from the second, and the result is control charted. The control limits are based on the variability between samples when the tank is well mixed at its optimum level. A mixing study is employed to find out at what point the tank is optimally mixed.

Again, the control charts used can be a Shewhart chart and/or a CUSUM chart. When a limit on a chart is exceeded, the action is to reject the samples. If the control limits are at the 95% level, for example, then one is 95% confident that the samples are not representative of the tank contents and a second set will need to be taken after further mixing.

Tank to Tank Transfers

Tank to tank transfers is an effective method to help track material through a material balance area (MBA). It also takes into account all variability associated with the volume measurement systems of the tanks being examined.

The contents leaving one tank is compared to the volume increase in the receiving tank. The volume reduction in the sending tank is calculated by subtracting the volume at the end of the transfer from the initial volume. The volume increase in the receiving tank is calculated by subtracting the initial volume from the resulting volume. If the volume decrease in the sending tank is subtracted from the volume increase in the receiving tank, this result can be plotted on a control chart.

If a Shewhart Chart is employed, the centerline of the chart may not be zero. This may be normal if the contents are transported via a steam jet which adds volume to the solution due to the steam condensing. Another reason the centerline is different from zero is that there is a bias in the measurement systems between the two tanks. This can be due to bias in the calibration curve or bias in the instrument calibration.

The limits of the Shewhart chart will need to be determined through historical data. The variability of the instruments, instrument calibrations, and tank calibrations on both tanks all contribute to the total error limits.

Individual Instrument Program

This program takes steps to insure each instrument can deliver as error free a measurement as possible. Every instrument can yield poor performance if it is neglected or installed in a way that enhances process variability or bias. A detailed knowledge of how an instrument functions will normally give some insight into this issue.

For example, when using the bubbler probe manometry method in tanks, process variability can be introduced to the instrumentation through the bubbling action. Normally, a differential pressure (DP) sensor, is used. If this device is sensitive enough to respond to the pressure changes associated with the bubbles forming and breaking off the end of the tube, this random variability will affect its output, causing fluctuation. This problem is solved by time-averaging the instrument's output. Averaging should be done over a long enough period of time to eliminate this induced process variability. This was done for the key F Canyon tanks using the Ruska DDR 6000 instruments.

The DP cell's output can be biased as a result of improper installation. A real example of this was an instrument that obtained its reference pressure from a vacuum header common to several tanks. Normally, the reference pressure is obtained through a pressure line to the vapor space in the top of the tank being measured. Since, in this example, the reference was to a vacuum header, the instrument output was biased.

Another example is in the use of capacitance probes. If, when draining the tank, a measurement is made immediately after transferring, the measurement will normally be biased high. This is due to the fluid draining off the probe. The probe is measuring the level of fluid in contact with it. The solution to this problem is to wait until the fluid has drained off the probe before measuring.

In all the above examples, understanding how the instrument functions lead to a method of reducing process induced error. Vendors are always willing to consult on their products. If a local expert is not available, soliciting the vendor's aid is recommend.

Calibration frequency plays a major role in this type of program. If possible, instruments should only be calibrated if there is an indication that it is needed. Control charting the measurement of a working standard or frequent comparison through another means will yield such an indication. Frequent, unnecessary calibration of an instrument can induce more long term variability than if it is done only when necessary.

If a comparison method is impractical, a calibration frequency will need to be established. This frequency can be established based on historical data resulting from calibrations performed on an arbitrarily assigned frequency. If the instrument is always found to be out of calibration tolerances, the frequency is too long. Conversely, if the instrument is always found to be in tolerance, the frequency is too short. The final frequency should be determined based on a realistic probability that the instrument has not yet gone out of tolerance, yet has a high probability of being out of tolerance if another period were to pass. Probability levels need to be 95% or 99%.

Conclusions

With the five aspects of the volumetric measurement control plan outlined in this paper applied to the key tanks in the F Canyon at SRS, a comprehensive measurement control program has been established. Through use of control charts, the F Canyon technical support personnel can detect problems as they arise and can react to a specific aspect of the measurement system. This avoids unnecessarily reacting to inventory differences and blindly attacking measurement systems with no indication as to whether they are in control or not. By examining control charts, any tank measurement problem can be quickly pinpointed.

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