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RESOLVING INVENTORY DIFFERENCES (U)

by

J. H. Weber

Westinghouse Savannah River Company
Savannah River Site
Aiken, South Carolina 29808

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RESOLVING INVENTORY DIFFERENCES

Jilene H. Weber and John P. Clark
Westinghouse Savannah River Company
Savannah River Site, Aiken, S. C. 29808, USA

ABSTRACT

Determining the cause of an inventory difference (ID) that exceeds warning or alarm limits should not only involve investigation into measurement methods and re-examination of the model assumptions used in the calculation of the limits, but also result in corrective actions that improve the quality of the accountability measurements. An example illustrating methods used by Savannah River Site (SRS) personnel to resolve an ID is presented that may be useful to other facilities faced with a similar problem. After first determining that no theft or diversion of material occurred and correcting any accountability calculation errors, investigation into the IDs focussed on volume and analytical measurements, limit of error of inventory difference (LEID) modeling assumptions, and changes in the measurement procedures and methods prior to the alarm. There had been a gradual gain trend in IDs prior to the alarm which was reversed by the alarm inventory. The majority of the NM in the facility was stored in four large tanks which helped identify causes for the alarm. The investigation, while indicating no diversion or theft, resulted in changes in the analytical method and in improvements in the measurement and accountability procedures that produced a 67% improvement in the LEID.

INTRODUCTION

The inventory difference (ID) between accountability periods for one facility at Savannah River Site (SRS) exceeded both the warning and alarm limits. This required the facility to first determine there had been no theft or diversion and then investigate the cause for the alarm. A gain trend was apparent for three previous accountability periods and the alarm ID eliminated the cumulative gain. An ID is due to differences between the beginning and ending inventory measurements plus differences between input and output measurements.

Limits of error for the inventory difference (LEID) were based on variance propagation for a typical beginning and ending inventory and throughput. The alarm limits were at the 99% confidence level; which means that when the true ID is zero, the probability is less than 1% the calculated ID will exceed the alarm limits due to measurement uncertainty. An alarm ID which is not due to theft or diversion can be due to any or all of the following:

- Incorrect calculation of inventory values for one or both inventories.

- Changes in measurement methods, inventory procedures, and personnel significantly affecting the ID or the LEID.

- Incorrect LEID model assumptions.
- Errors in inventory and/or transfer measurements.
- Inadequate sampling and/or mixing of tank solutions.
- Undetected biases in tank volume or analytical measurements.
- Random chance due to inherent variability in the measurement process.

Several unique conditions helped resolve the ID. There had been no input or output from the facility for two inventory periods preceding the alarm situation. In addition, four large storage tanks accounted for over 98% of the inventory. These four tanks had been static (no inputs or outputs) for the preceding six inventory periods. The alarm ID was due to differences in the inventory measurements between the last two inventories for these four tanks. Since there had been no movement within the facility, the inventory was remeasured. The original analytical method for determining element concentration in the four storage tanks was Diode Array Spectrophotometry (DAS) and the remeasurement was by Davies and Grey Titration (D&G). In addition, the mixing and sampling of the tanks was carefully monitored for the remeasurement. The current inventory values were supported by the remeasurement; therefore, the investigation then focussed on the six preceding inventories for the four storage tanks.

The investigation identified several causes for the alarm ID including an incorrect LEID model. As a result, measurement control procedures and measurement method improvements were instituted which produced a 67% reduction in the LEID improving the safeguards detection probability for the facility. The activities involved in resolving the alarm ID may be applicable for use by other facilities when investigating IDs.

While improperly modeling the LEID does not contribute to the ID, it does determine when an alarm situation exists. Reducing the LEID increases the detection probability for a given amount of material. The solution in the four storage tanks was not highly concentrated so a significant volume would have to have been diverted to account for the alarm ID and since other safeguards had not been compromised, theft was not considered to be a creditable scenario.

INVESTIGATION

The alarm inventory difference calculation was corrected for mathematical errors, then a tank by tank inventory comparison was made for the two preceding static periods for all tanks and for six preceding periods for the four storage tanks. The major differences were in the four storage tanks. Figure 1 presents the IDs for the four storage tanks for the six preceding accountability periods, the alarm period (period 7), and the remeasured difference (period 8). All ID's have been divided by the 95%

FIGURE 1: ID FOR FOUR STORAGE TANKS DIVIDED BY 95% LIMITS

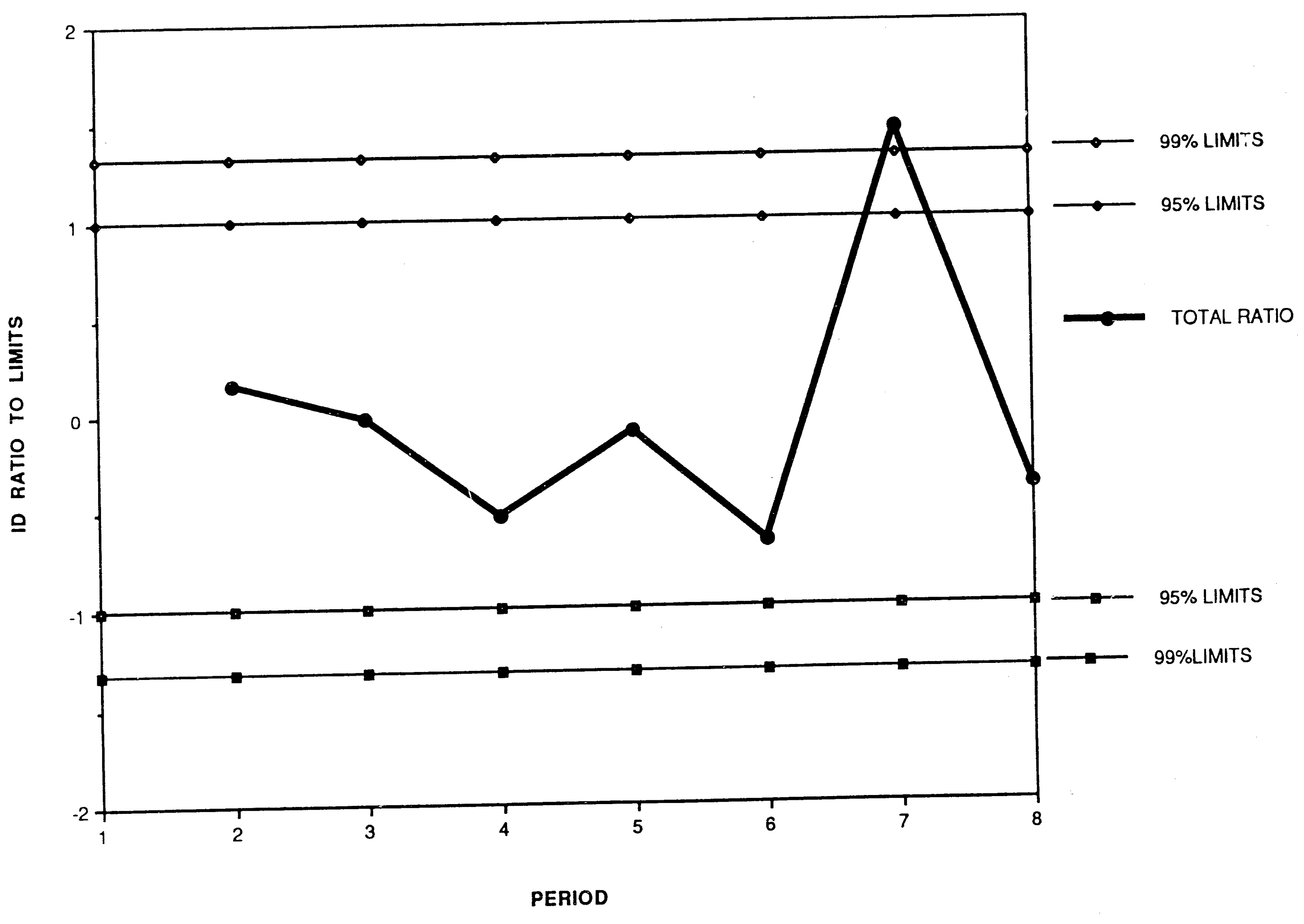
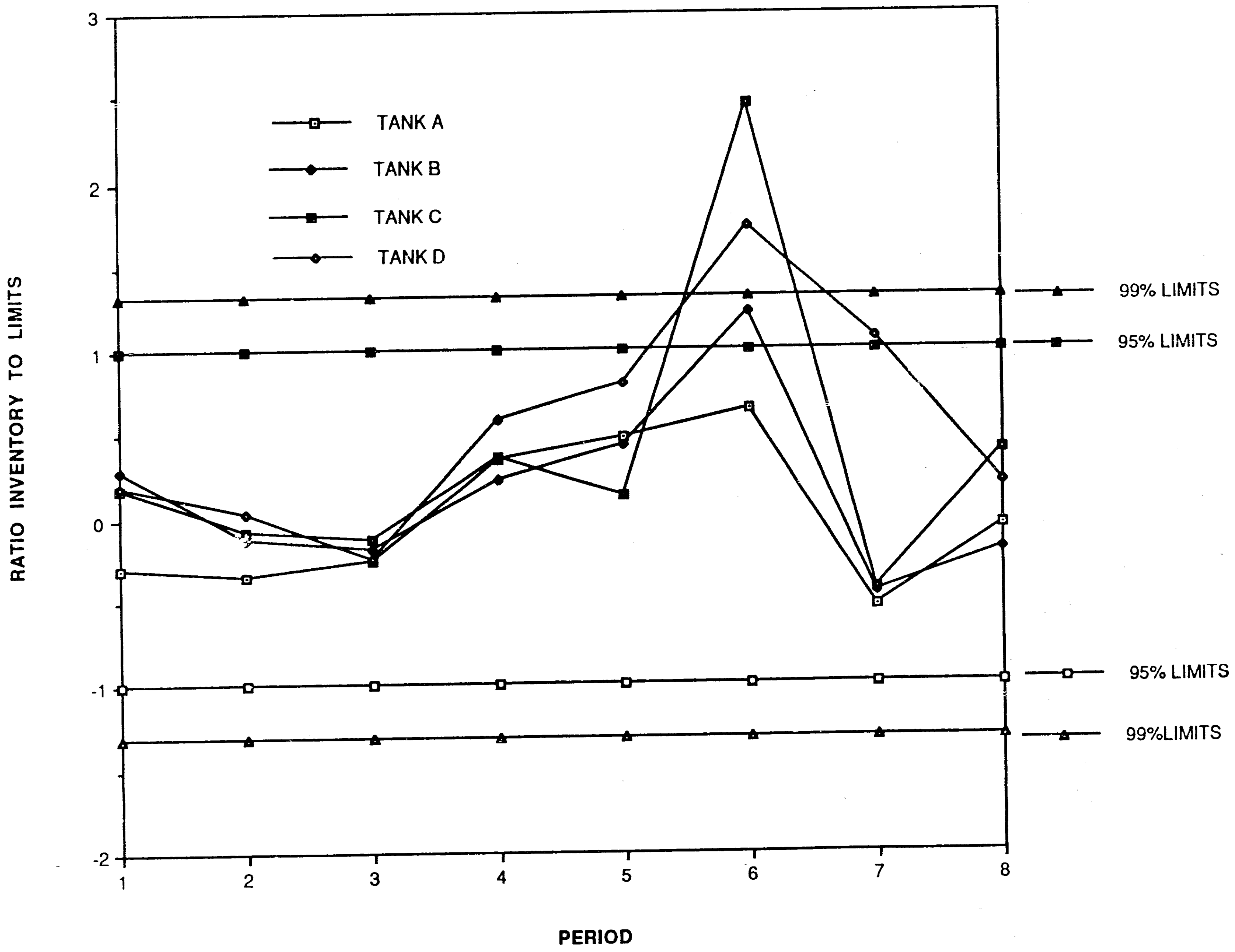


FIGURE 2: PLOT OF RATIO OF DIFFERENCE FROM FIRST THREE PERIODS TO 95% LIMITS



limits. Ratios outside ±1 are outside 95% warning limits and ratios outside ±1.32 are outside 99% alarm limits. The ID for period 7, the alarm ID, is outside the 99% alarm limits. The changes in inventory for the four storage tanks for the same eight periods have been plotted in Figure 2. The four tanks are ranked from largest, tank A, to smallest, tank D. The inventory for each period has been subtracted from the average of the first three periods and divided by the LEID 95% limits. The inventory was relatively constant for the first three periods, gained for the next three, and lost for the alarm inventory. The remeasured inventory was not significantly different from the alarm inventory nor from the first three inventories. The alarm ID is due to the apparent inventory gain for the third through the sixth periods coupled with a smaller than average inventory for the seventh period. There were also minor discrepancies for two other tanks, but these did not account for the alarm ID. All ID calculations for the inventory periods were corrected for mathematical errors.

CHANGES IN THE FACILITY CONTRIBUTING TO THE ID

Previous to the alarm inventory, a new facility custodian had been appointed. The new custodian identified the following problems:

- Each of the four storage tanks was equipped with two liquid level measurement systems, a Rosemont differential pressure gauge and either a rod (tanks B through D) or a Heise pressure gauge (tank A). The inventory liquid level was recorded using both systems and the previous custodian choose which one to use to calculate the inventory. The LEID model assumed rods and Heise gauge would be used. Calibration documentation for the Rosemonts was not available and there was evidence the Rosemonts drifted with temperature.

- Results for the four tanks were reported in units of mass but the element concentration was reported in grams per liter. The previous custodian did not convert mass to volume at laboratory temperature.

- Several different calibration charts were available for each tank to convert liquid level to weight factors. These calibration charts were all different.

- The previous custodian was not consistent in converting pounds to grams.

The new custodian instituted the following procedural changes:

- Specified rod and Heise gauge measurements were to be used to determine volume which was consistent with the LEID model assumptions.

- Identified the correct calibration charts and eliminated all others.

- Developed a spreadsheet to ensure consistent conversion from pounds to grams and to ensure the mass was converted to laboratory volume.

LEID CALCULATION

The assumptions in the LEID model used to evaluate the ID were examined. After all model assumptions were validated, the correct LEID was calculated and used to compare the ID's for the eight periods. The alarm ID was still outside the 99% limits. The following were corrected in the LEID calculation.

- The DAS bias correction, which was assumed to be independent for each of the four tanks, was applied to the element measurements for all four tanks within a given inventory period. The correct modeling of the bias short-term systematic variance approximately doubled the LEID.

- No uncertainty errors for the DAS reference standard were included nor was a change in reference standards modeled. When the change in reference standard was modeled, the LEID increased by 28%.

- The isotopic weight percent was no longer being measured. The same isotopic weight percent had been used for the last four accountability periods including the one exceeding the alarm limits. The contribution to the LEID for the isotope from mass spectrometry was small.

- The laboratory had changed the analytical method for seven smaller tanks to an alternate method that was much less accurate and precise. Since there had been very little solution on inventory in those tanks, this change did not affect the LEID significantly. However, if there had been a significant amount of material in the tanks, the LEID based on the alternate method would have been considerably larger.

MEASUREMENTS INVESTIGATED:

Since the alarm ID was still outside limits, the investigation focused on the individual measurements for the four storage tanks. Density, volume and element measurements over the eight periods were compared. In addition, random variance estimates were compared with the LEID modeled random variance estimates and across tanks, when applicable.

Two samples were taken from each of the four tanks for element and density analyses. The density measurements for both samples must pass the lab's limits for sample agreement before results can be reported to the facility. Consistent density measurements are important indicators of inadequate mixing and sampling or changes in the solution over time. The density is also needed to convert mass to volume. The following analyses were done.

- Density differences between replicate samples taken within the same inventory period and differences between inventory periods were compared using Bartlett's test for homogeneity of variances and analysis of variance. Comparisons with the average of the first six periods were made using the student's t-test.

- Volume measurements including liquid level, conversion to weight factors and conversion from mass to volume between inventory periods were compared with the average for the first six periods using the student's t-test. Estimates of random variance for the inventories were compared with the LEID variance estimates using an F-test.

- Element analyses by DAS between replicate samples within the same inventory period and between inventory periods were compared and individual differences compared with the average for the first three periods using the student's t-test. Estimates of random variance from between periods and between samples were compared with the LEID estimates using the F-test and analysis of variance.

- Measurement control measurements on the reference standards using DAS were analyzed. Bias corrections between inventory periods were compared with the inventory measurements.

- Measurement of the reference standard solution by D&G was compared with the stated value of the standard.

In addition, density, volume, and element, successive monthly differences were compared to determine if there was a trend over time and if the trend was consistent between the four tanks.

The results are presented in Figure 3 for the density measurements, Figure 4 for the volume measurements, and Figure 5 for the element concentration. The volume and element results for tank D are presented separately in Figure 6. A summary of the results includes the following conclusions.

Figure 3, the plot of the density differences from the average of the first six periods (except for tank C period 4) divided by the 95% pooled LEID indicates the following:

- There was no significant trend for density measurements for the first six periods for any of the four tanks.

- There was a potential outlier for tank C density in period 4 indicating a possible sampling and mixing problem.

- Densities for tanks A, C and D in period 5 were all considerably less than the average with densities for tanks A and C significantly different at the 95% limits indicating a possible lab problem.

- There was no significant difference between the average density for the alarm and remeasurement for tanks A though C.

- There was a significant difference for the density measurements for Tank D for the alarm and the remeasurement. An increase in density for the tank D solution was indicated starting with period 6. The cause for this difference was evident when the volume and element measurements were compared.

Figure 4, the plot of the differences from the average volume over the first six periods for tanks A through C (except for tank C period 6) divided by the 95% LEID modeled volume limits indicates the following:

- There is a significant difference for tank C in period 6, the inventory before the alarm, which contributed to the alarm ID. This was probably due to an incorrect rod reading.

- There is no significant difference between the average and the alarm and remeasured volumes for tanks A through C.

- The estimate of random variance from the first six inventories was not significantly different from the LEID modeled variance for tanks A through C.

- There were significant differences in volume for tank D compared with the average and when comparing the random variance estimate with the LEID variance. Tank D had a consistent decrease in volume except for the alarm inventory. Tank D volume differences are plotted in Figure 6.

Figure 5, a plot of the differences between the average of the first three element concentrations divided by the 95% LEID element limits for tanks A through C, indicates the following:

- The concentrations were constant for the first three periods, showed a big increase in the next period, a small decrease in period 5, a large increase in the period six, a significant decrease in the alarm concentration and a small increase in the remeasured concentration for tanks A through C.

- The alarm and remeasured element concentrations are not significantly different from the average of the first three. However, the sixth inventory (the one preceding the alarm inventory) is outside the 99% limits for tanks A and C and outside 95% limits for tank B. Since this pattern paralleled the total inventory and was the same for all three tanks, the element measurements were further investigated.

Figure 6 is a plot of the difference between the average of the first three periods for the element and first six periods for the volume divided by the 95% LEID limits. There is a steady decrease in volume except for period 7. The remeasured volume showed a

FIGURE 3: PLOT OF AVERAGE DENSITY DIFFERENCE DIVIDED BY 95% POOLED LIMITS

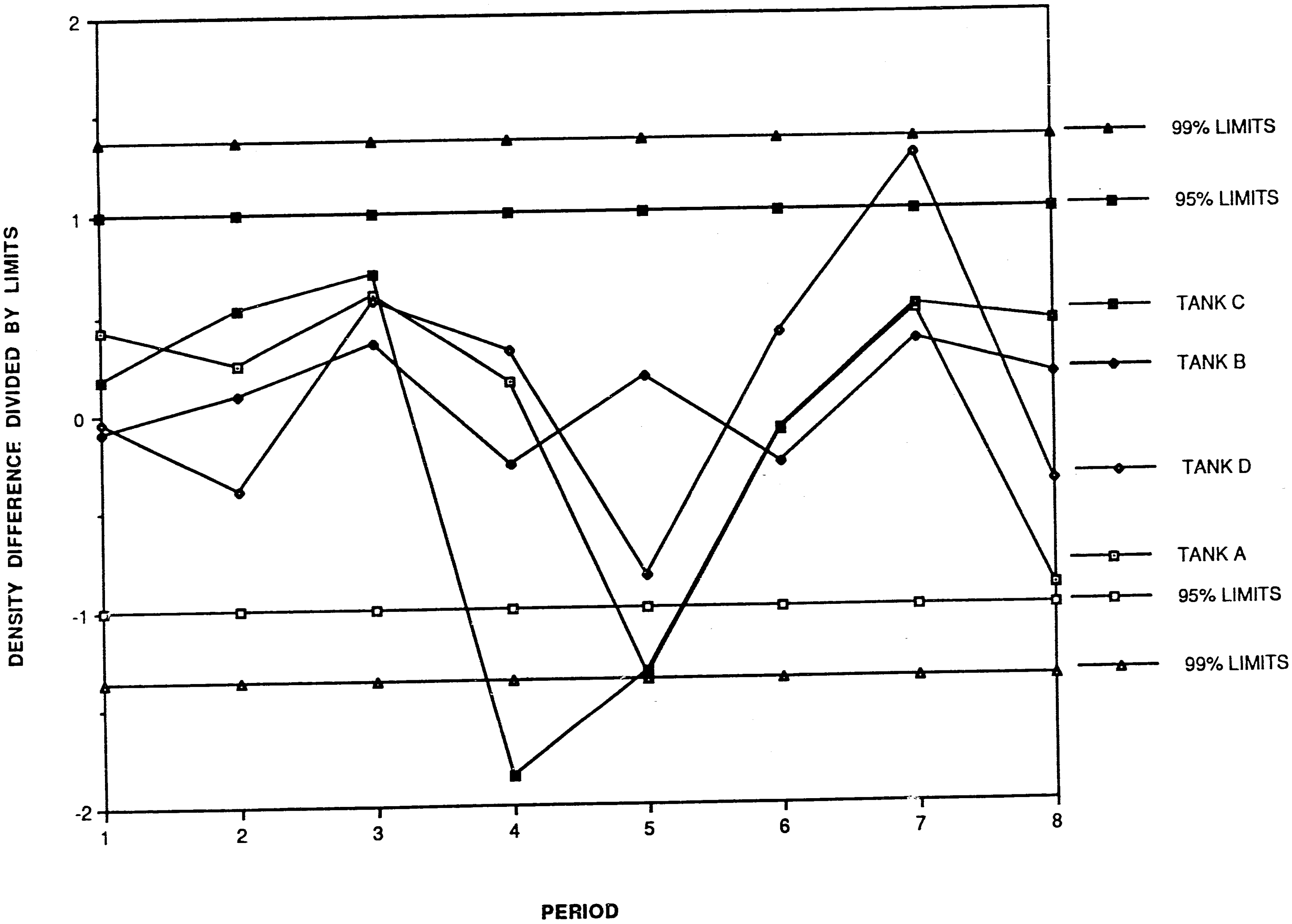


FIGURE 4: VOLUME DIFFERENCE FROM AVERAGE DIVIDED BY LEID 95% LIMITS

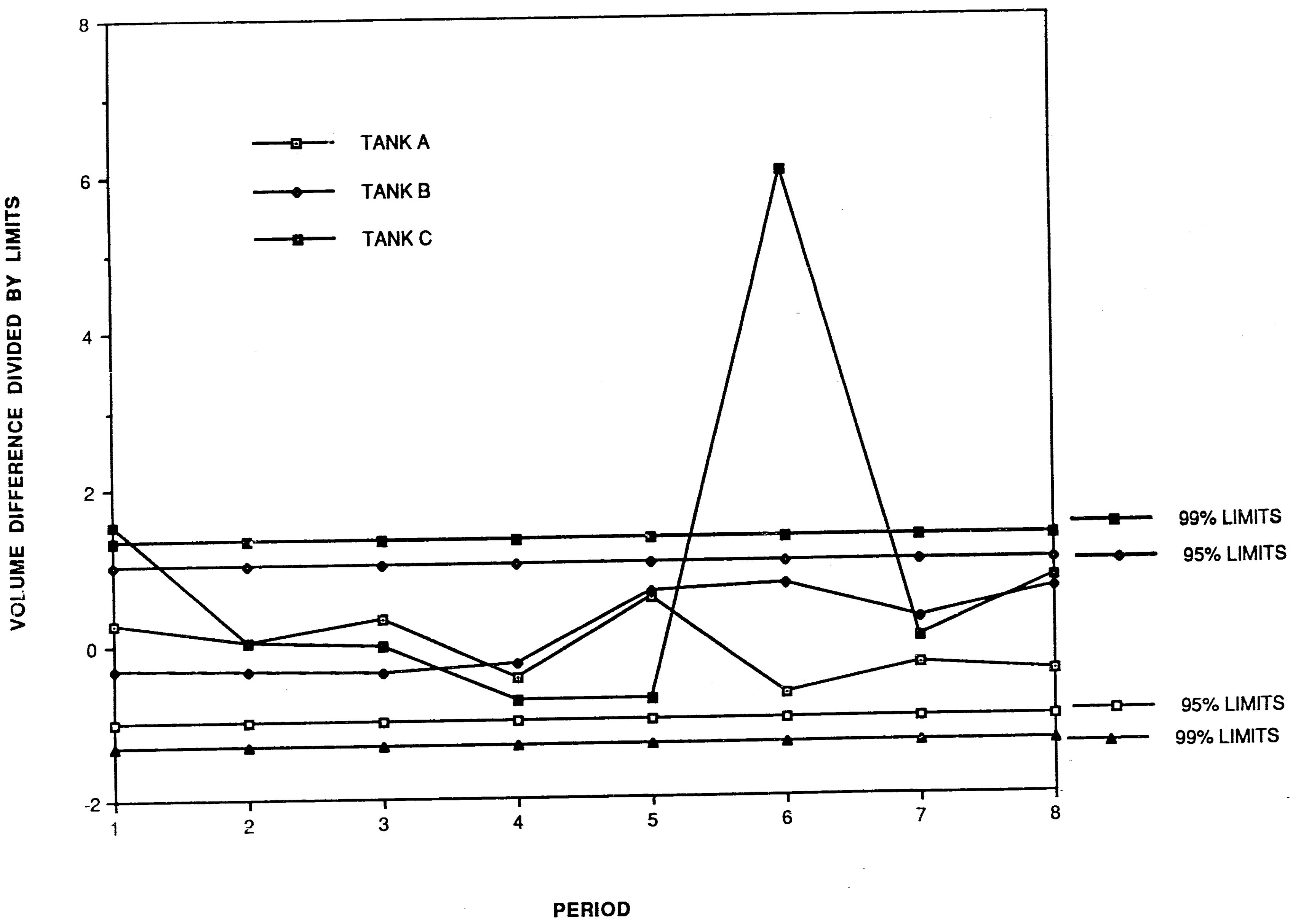
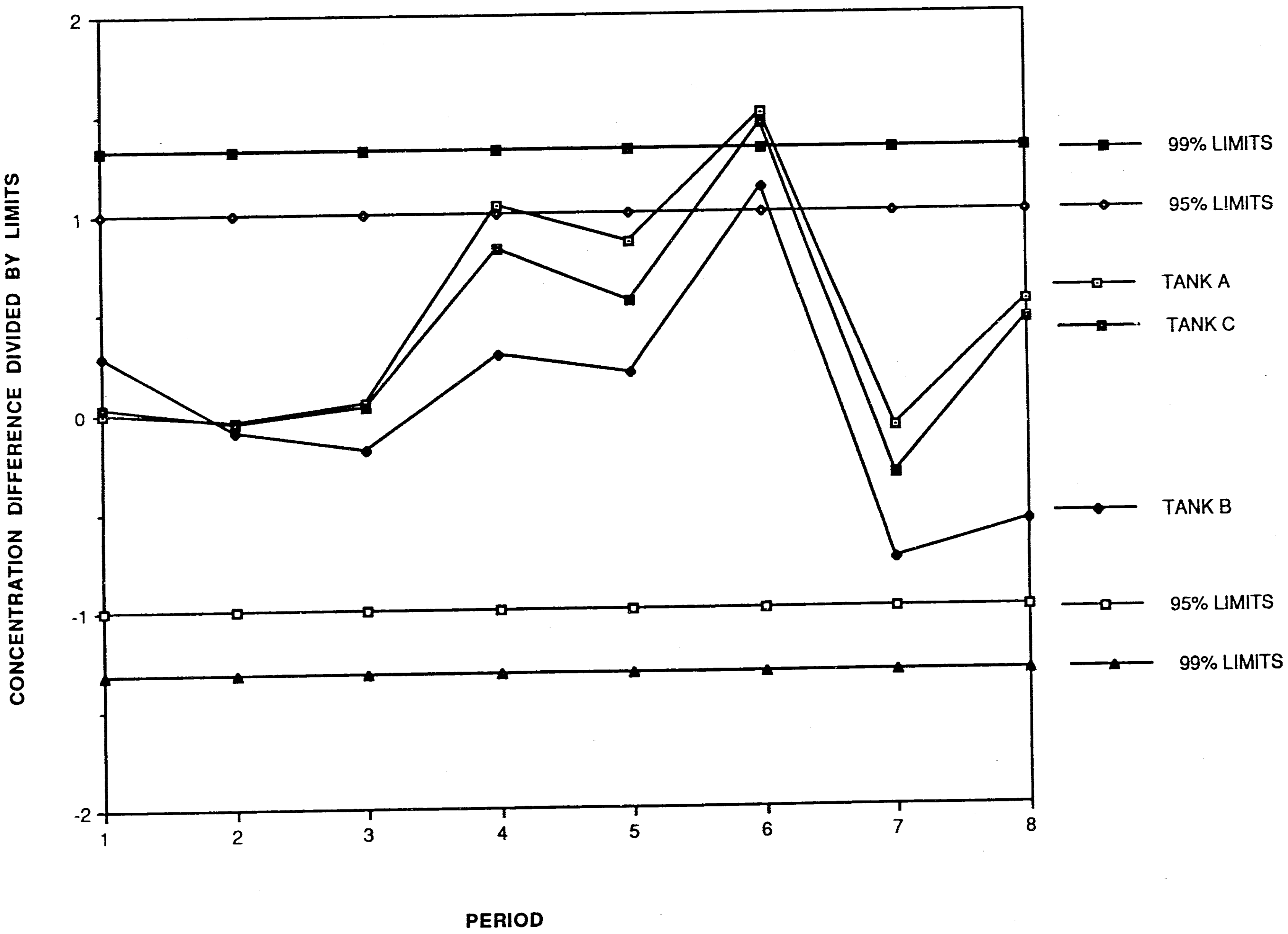


FIGURE 5: ELEMENT CONCENTRATION DIFFERENCE FROM AVERAGE DIVIDED BY LEID 95% LIMITS



significant decrease. There was a steady increase in element concentration except for a slight decrease in period 7. It appears the problem is due to a steady evaporation of solution.

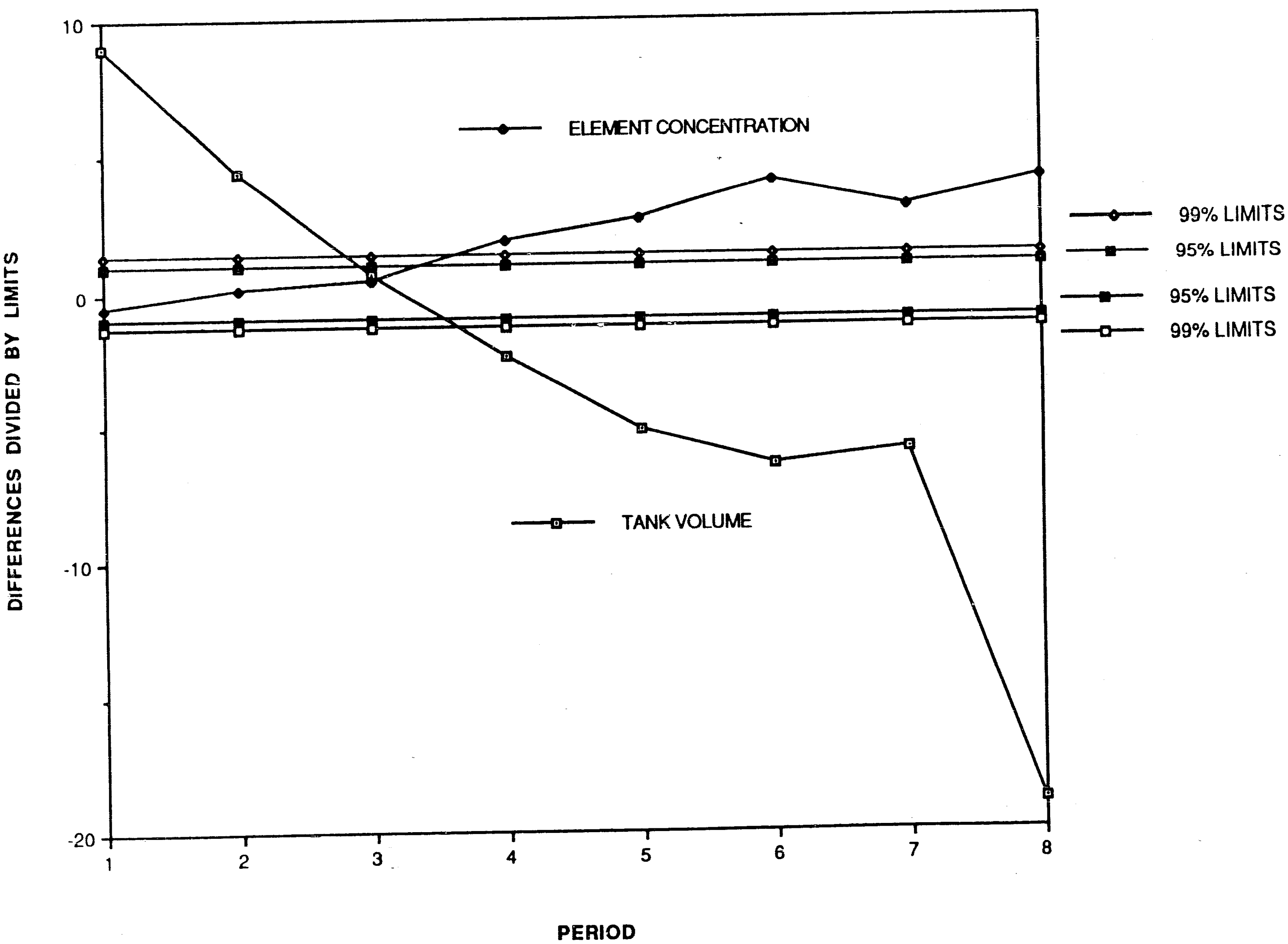
The QC and bias corrections on the standards were compared with the element concentrations for the four tanks. The same pattern of gradual increase for periods four through six and significant decrease in the alarm period indicated that the element differences were due to the bias correction. Since the D&G analysis for the remeasured inventory indicated no loss of material, a new reference standard solution was made up and analyzed by both D&G and DAS. The DAS analysis indicated a bias which could not be detected with the variability inherent in the DAS method. The preceding reference solution was also analyzed by D&G and indicated an incorrect reference value had been used. The difference between the two bias estimates for period 6 and period 7 was the major cause of the alarm situation. Contributing causes were the larger than average rod reading for tank C in period 6, incorrect inventory procedures, and an incorrectly modeled LEID.

IMPROVEMENTS MADE IN THE MEASUREMENT SYSTEMS

The investigations provided a good opportunity to recommend improvements in measurement systems and inventory procedures. The following improvements have either been or are in the process of being incorporated into the inventory procedures.

- Using the D&G method for the element analyses for the four storage tanks.
- Closely monitoring the IDs by the facility and the Measurement Control group.
- Analyzing the QC data on the D&G method by both the analytical laboratory and the Measurement Control group to ensure good measurement control of the method.
- Improving inventory measurement procedures within the facility to ensure accurate and consistent measurements with the elimination of extra calibration charts and the development of spread sheets to do inventory calculations.
- Monitoring static inventories including differences in volume, density and element concentrations over time to prevent alarm ID's.
- Accurately determining reference standards including uncertainty estimates.
- Equipping the four storage tanks with Ruska liquid level instruments and scanivalves and recalibrating.
- Doing mixing and sampling studies for the four storage tanks to determine optimum mixing time and estimate sampling errors.

FIGURE 6: TANK D VOLUME AND ELEMENT DIFFERENCES FROM AVERAGE DIVIDED BY LEID 95% LIMITS



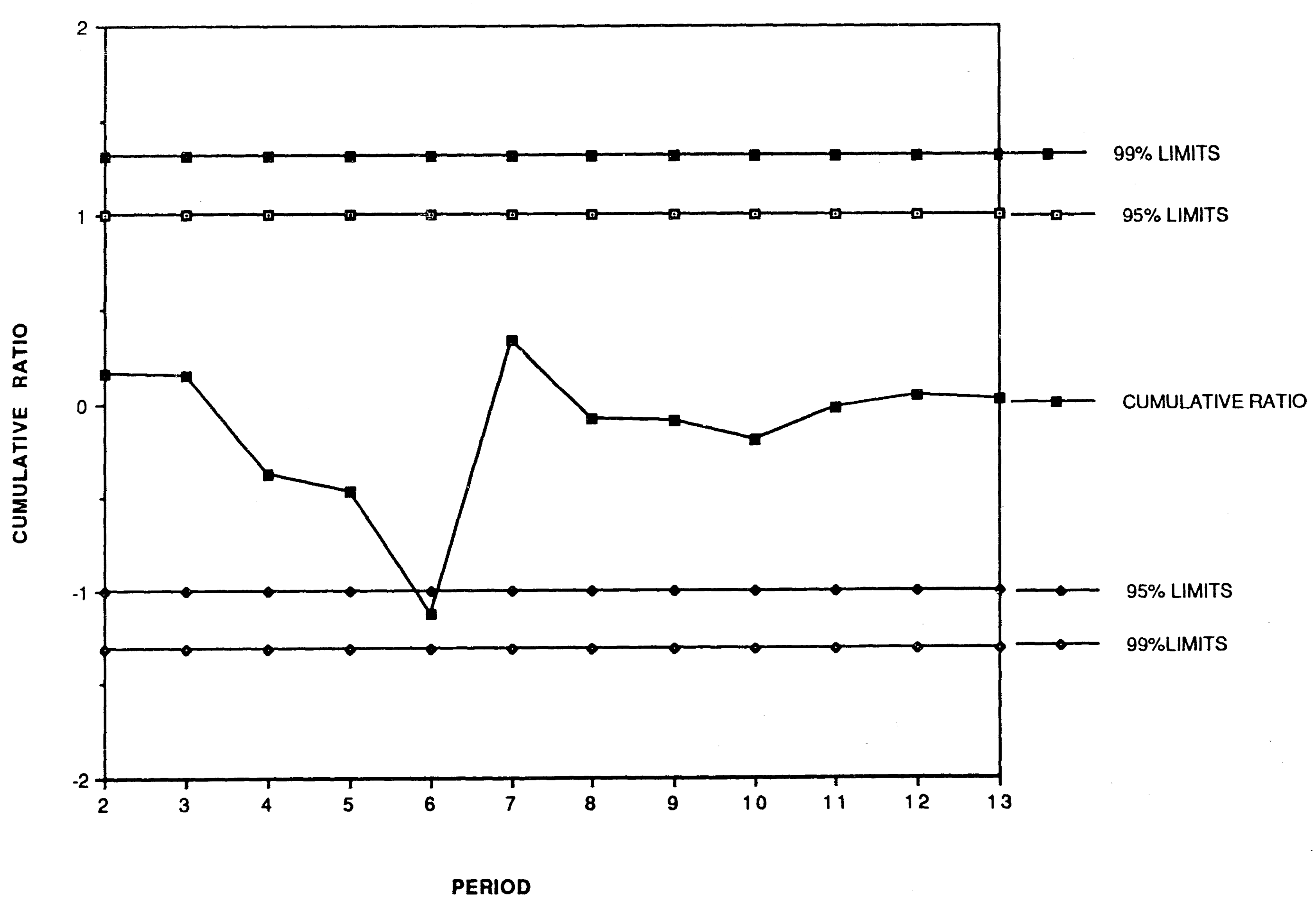
- Initiating measurement control programs to compare in-tank density with lab density to ensure representative samples.

After making many of the above improvements, the LEID was recalculated and reduced by 67%. Figure 7 is a plot of the cumulative ID for the eight periods plus five additional periods which incorporated many of the recommended improvements. The smaller variation in the last five reflect both the reduced LEID and the smaller variability in IDs.

CONCLUSIONS

In conclusion, an ID outside the alarm limits sometimes requires an extensive investigation to determine the cause. In general,there will be several contributors to the alarm situation. The investigative procedure offers an opportunity to make improvements in the measurement methods being used and in the measurement control programs used to evaluate the measurement methods. The LEID, while not a direct cause of the ID, can be used to determine the effect changes in the measurement systems make in detecting significant differences.

FIGURE 7: CUMULATIVE INVENTORY DIFFERENCES DIVIDED BY LEID 95% LIMITS



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