

Calibrating Instruments Automatically with SAS Software

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ABSTRACT

Most automated manufacturing processes use delicate instruments to monitor specific characteristics of raw materials or end products. The information derived from these meters must be accurate in order to provide any benefit to quality and consistency. As a result, the instruments should be checked and calibrated regularly. Unfortunately, manual calibration can lead to significant downtime and therefore loss of productivity.

To alleviate this dilemma, we developed a SAS/AF application that evaluates historical data and provides recommendations for software-based calibration of instruments. The client-server application reads sample data from Informix, performs analysis within SAS, and permits user-initiated update of calibration parameters in Informix. The system offers audited exclusion of outliers in the data as well as ad hoc historical analysis.

INTRODUCTION

Manufacturers make money by manufacturing large quantities of quality product. To achieve this goal, companies must monitor factors that affect quality as well as the final product itself. In addition, they must control the factors that affect quality without stopping the manufacturing process. Halting the process and creating poor quality product cost money.

Factors that affect quality must often be monitored by sophisticated instruments that require occasional calibration, but the calibration process may require that the production process stop until the calibration is completed. In some cases, however, it is feasible to calibrate the readings rather than the device itself.

For example, if you know that a thermometer is reading 5 degrees below the actual temperature, you can simply take the thermometer reading and add 5. Not all devices are so simple. For example with infrared moisture meters, the deviation from actual moisture may vary depending upon the actual moisture level. Most instruments are designed to account for this type of variation, but you still need to calibrate them occasionally.

We were asked to develop a system using SAS software that would automatically monitor the calibration of several types of meters. The system notified operators when calibration equations were no longer adequate. In addition to providing daily or on-demand reports, the system enabled authorized users to update compensation factors in the production environment.

In addition to multiple meters, the system also had to evaluate the variation in calibration per product. For example, the relationship between the infrared moisture meter and the actual moisture varied with the product components. We maintained separate equations for each product line. Users could group similar products in order to combine the data for several different products.

TIMING

In real-time, moisture meter readings were collected every 5 seconds. For calibration purposes, however, we could only collect 4 to 6 readings per batch, which may run for about one to two hours. To calibrate moisture, for example, engineers would take a grab sample of product at the same time that the moisture meter readings were sampled. The grab samples were then baked down in an oven to determine the actual moisture content.

Unfortunately, the baking process is not instantaneous, so the matched meter reading and oven moisture may not show up in the data for 24 to 30 hours. As a result, our technique is not used to monitor the stability of the process, but is used to calibrate meters that typically do not change very often.

Due to the slow turn around on oven readings, the autocalibration process was scheduled to run automatically each night, importing new data for each day. Each morning, the quality technicians would review the nightly report on meter calibration parameters to see if any meters needed recalibration. Our system did not perform the calibration without manual initiation, although users could request a recalibration at any time.

CLIENT-SERVER DESIGN

The calibration system was designed using a SAS/AF graphical user interface on a Windows 95 workstation that linked to a Unix server with SAS/CONNECT software. This client-server design placed the majority of calibration processing on the server, while all control of processing and display of results resided on the workstation.

In addition, the meter data was retrieved from an Informix database on a second Unix server. The workstation never communicated directly with the Informix database. Using a three-tier design, the Unix application server handled all queries and updates to the Informix database.

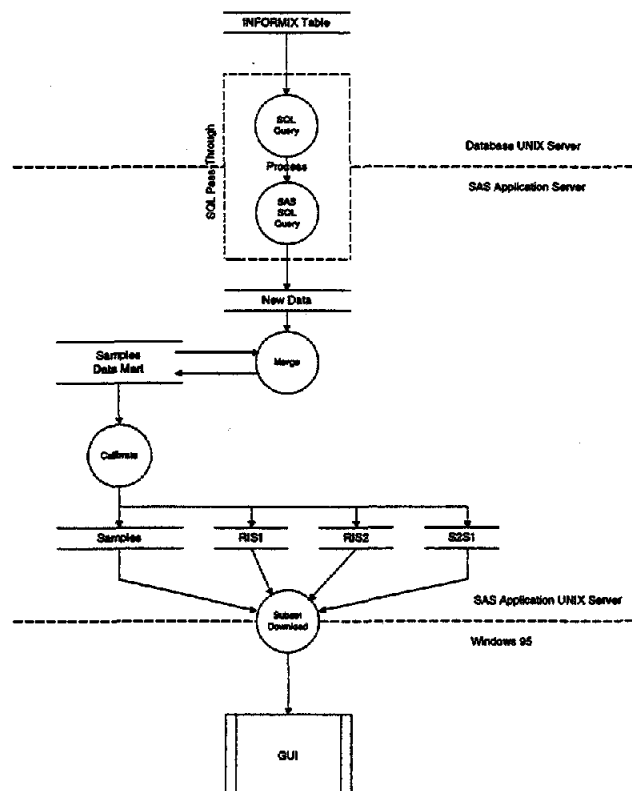


Figure 1 Client-Server Design

STATISTICAL SUMMARY

The makers of infrared moisture meters document that the typical calibration curve for their meters is a straight line with a slope of 1. We found that both the intercept and slope varied for different raw materials that were being monitored.

To calibrate the instruments we used a simple linear regression analysis to predict oven moisture (actual moisture) from the meter moisture. Our client preferred to use the terms zero and span instead of intercept and slope, so in all of our further discussions and examples, the intercept will be called zero and the slope will be called span.

As a result, our regression equation (model) was:

Oven moisture = zero + span*meter moisture + error

Because this presentation will focus on the application software rather than the statistics, I will not discuss further details of the analysis. During the autocalibration process, we performed several additional tests, including identification of outliers and recognition of significant change in zero or span.

We also provide the option to calibrate the meter based on a second standard. In the case of moisture, we provided calibration results for an Infralab. Throughout the system, the user was permitted to view the calibration results based on the oven or the Infralab, in addition to viewing a comparison between the oven and the Infralab.

VIEWING THE RESULTS

From the main menu of our application, users could determine if there were any devices that needed calibration. In addition, they were also notified if outliers were detected in the data. Using the Critical Success Factor class, red indicated that at least one instrument was out of calibration, while yellow indicated that at least one outlier was found in the data.

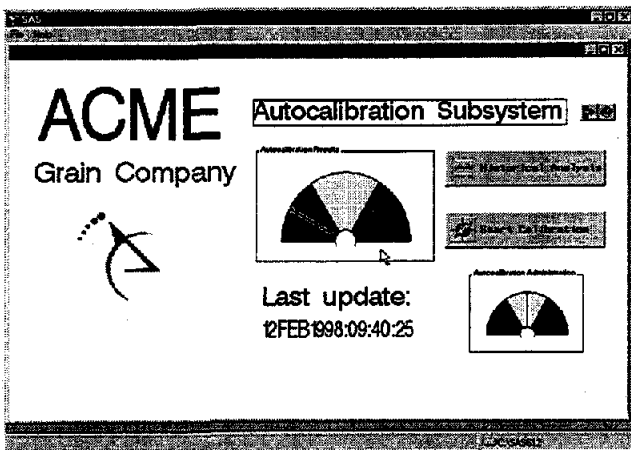


Figure 2 Autocalibration Main Menu

By clicking on the Critical Success Factor, the user could then view the details of the autocalibration results for each instrument and each material type.

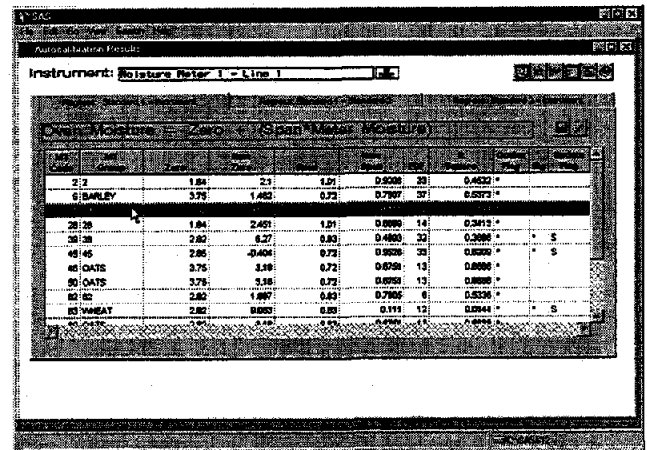


Figure 3 View Results

In the View Results window, the user can select from three tabs, which contained results for oven vs moisture meter, Infralab vs moisture meter, and oven vs Infralab. A table editor subclass is used within each tab to display the results.

Each row in the table represents the calibration parameters for one material type. The view displayed the old zero and span, the suggested new zero and span, the R square for the regression, flags to identify materials with outliers and calibration parameters that need adjusting.

Because some materials are known to be similar, the client wanted the ability to group certain materials together into a material group. Our system enabled the administrator to define material groups, which were used during the regression analysis. In the results display, we still list the results per material type, but all members of the same group will display the same new zero and new span.

To view more details about the data that was used in the regression analysis, the user can select a row in the results table, and drill down to a list of raw data, a residual plot, or a regression results plot.

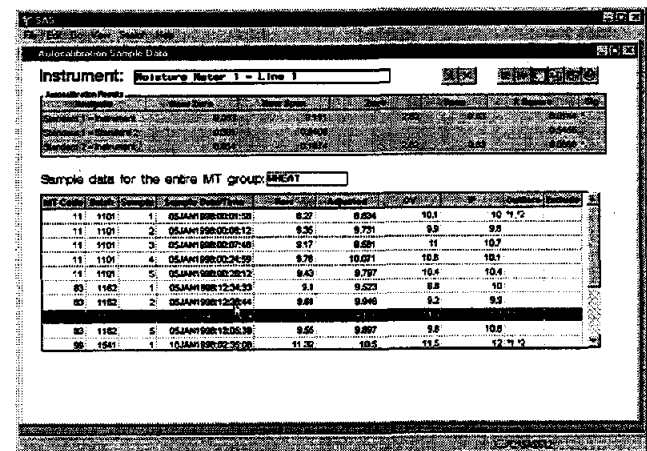


Figure 4 Detailed Sample Data

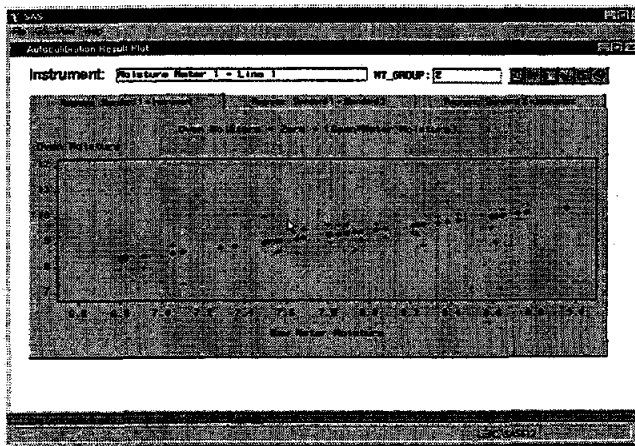


Figure 5 Regression

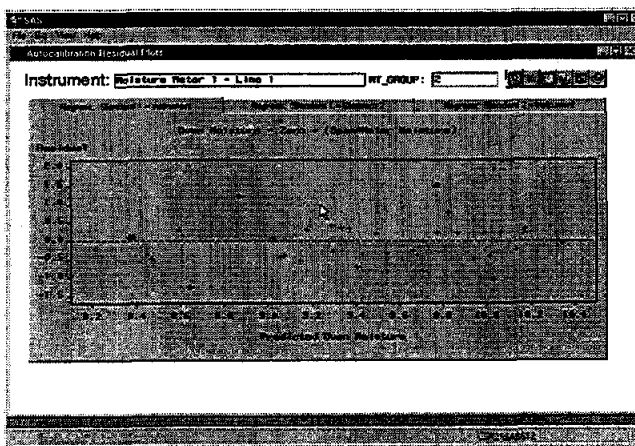


Figure 6 Residual Plot

Within the detailed list of data, the user could mark any point for exclusion from analysis. The system would not delete the point, but would simply exclude it from the regression analysis and any plots. If the user excluded a point, they were required to provide a reason for marking it for exclusion.

JUMPING BETWEEN WINDOWS

When viewing calibration results, we wanted to permit the users to jump from the results window to the sample data window to the result plot window and to the residual plot window in any order. To achieve this, we used a common "control frame" that displayed an empty white background. Each time the user selected a new window, the active window would close passing the target window to the control frame. The control frame would display the next window.

Using this technique, the control frame could also be used to prepare the appropriate data sets for display in the next window. Because the windows displayed small numbers of rows compared to the number of rows in the total database, we used the control window to download subsets of data, which were displayed in the windows. Using the smaller data sets improved performance of scrolling and searching.

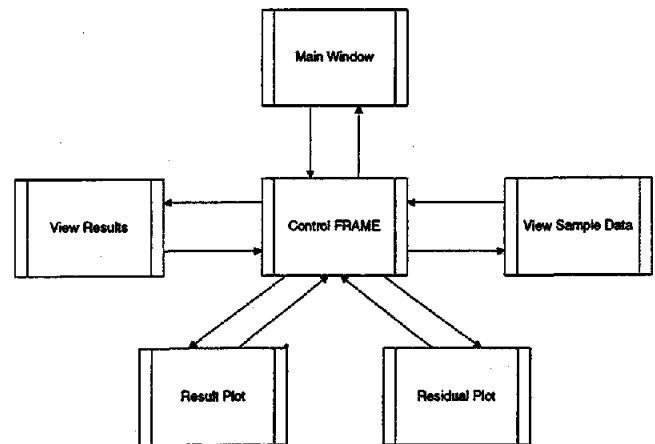


Figure 7 Actual Design

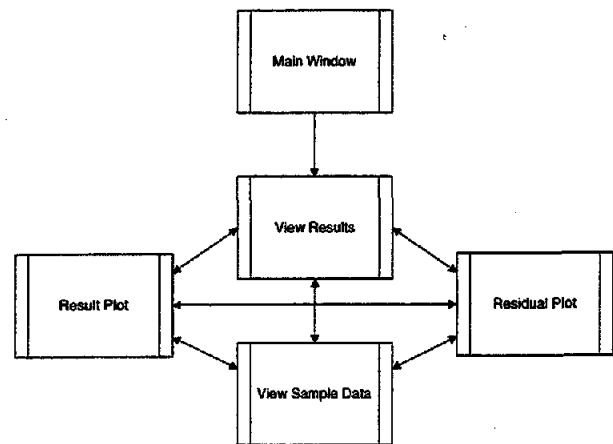


Figure 8 Effective Design

UPDATING CALIBRATION PARAMETERS

Once convinced that a calibration parameter must be changed, the user must press the **Update** button in the **View Results** window. The resulting view displays all calibration parameters that were suggested for change or were marked for change by the user. At this point, the user can edit the parameters and select exactly which parameters should be applied to the production Informix database.

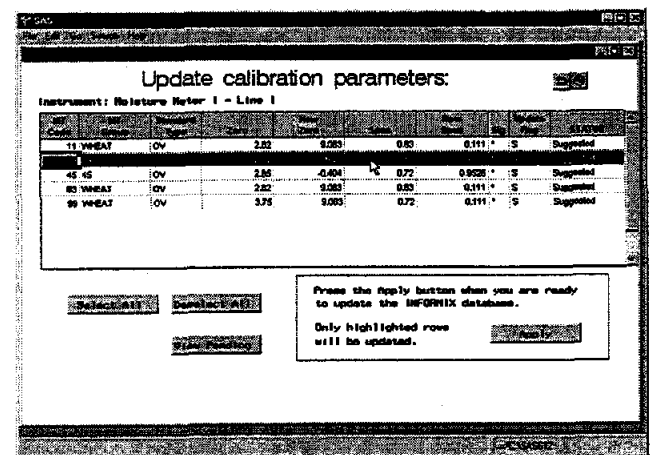


Figure 9 Update Calibration Parameters

APPLICATIONS DEVELOPMENT

Using SAS/ACCESS to Informix, the selected parameters are updated when the user pressed the Apply button. The application software updates Informix. If successful, the application also updates an image of the parameter table that is maintained as a SAS data set. If that is successful, a parameter history file is also updated.

The parameter history is maintained to provide an audit trail of changes as well as to provide data for later historical analysis.

SUMMARY

To ease the pain of calibrating instruments used on manufacturing applications, we created a SAS/AF client-server application to calibrate instruments using software and to monitor those parameters over time. The application provided several additional functions, but I described only the calibration process.

Using base SAS, SAS/AF, SAS/FSP, SAS/CONNECT, SAS/ACCESS to Informix, SAS/STAT we were able to develop an effective three-tier client-server application. By splitting the calibration process into three steps:

1. Regression analysis
2. User review
3. Selective update

We provided an efficient means for quality technicians to monitor instrument calibration and make suggestions for recalibration without automatically changing production parameters unexpectedly or shutting down the process.

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TRADEMARKS

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