Integrated Process Control for the Modern Surface Finishing Facility

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As surface finishers move into the 21st century, there are many opportunities to advance process control within the shop and provide greater quality assurance to customers. Real time, automated process control is not cost effective for most surface finishing facilities and adds an unwarranted level of complexity. The next best alternative is to provide a sophisticated laboratory/process management system. Laboratory Information Management Systems (LIMS) provide a sophisticated, but cost-effective solution for the management of process analytical data. A LIMS can provide statistical data correlating laboratory analyses to process limits set by specifications. At the same time, laboratory operations can be kept relatively simple. More sophisticated laboratory techniques can easily be integrated, allowing continuous improvement of the overall system. This framework provides a flexible approach for meeting facility process control needs as they change with the marketplace. This paper will review the implementation of a comprehensive surface finishing LIMS and introduce the tools available from such a system.

1.0 Introduction

Doing business in the 21st century challenges companies on all fronts. In order to continue to turn a profit, companies are faced with doing more efficient and quality production, often with fewer resources. Metal finishers feel pressure to cut product prices and provide better documentation of their production quality. Good process control is imperative to optimizing production as it aids in producing uniform products and in minimizing scrap and chemical usage (1, 2). Regular process control procedures generate a large amount of data. Companies need to effectively gather, catalog and interpret the process control data. Computing power is now very inexpensive and can bring a variety of tools to the control of processes. The challenge for any company is to find the right degree of control.

The pinnacle of computer-aided process control is to use real time, automated control. Controllers at the tank send data to the computer, and may actuate metering pumps to maintain the process chemistry at optimum levels. The computer analyzes the data and informs the company of the process status. This level of complexity is best applied to processes that see regular production of similar parts, or that need frequent analysis, such as electroless nickel or phosphate coating solutions. If the process is used intermittently or has highly variable load types and sizes, full automation may not be the best choice. In addition, real time, automated process control is not cost-effective for most surface finishing facilities due to both the relatively high initial cost and the need for a highly advanced maintenance system to insure that the control scheme functions continuously at a high level.

The next best alternative is to provide the facility with a sophisticated laboratory/process management system (3, 4). The Laboratory Information Management System (LIMS) is a data management tool that can provide a sophisticated, but cost-effective, solution for the management of process analytical data. The LIMS can manage process data inputs by scheduling regular analyses, and can provide statistical analysis of data correlating laboratory analyses to process limits set by specifications. At the same time, laboratory operations can be kept relatively simple. More sophisticated laboratory techniques can easily be integrated, allowing continuous improvement of the overall system. This framework provides a flexible approach for meeting facility needs for process control as they change with the marketplace. This paper will review the implementation of a comprehensive surface finishing LIMS and introduce the tools available from such a system.

2.0 The Importance of Process Control

Establishing a good process control system is key to any production quality system (2). Effective process control helps the facility manage its processes to perform consistently and predictably, and to minimize reject and scrap parts that reduce profitability because of the waste produced or the high cost of rework. In addition, process control helps to optimize material usage which then optimizes waste treatment costs, as more predictable loads are seen in the waste treatment system. Clearly, a good process control system is a cornerstone to a successful modern metal finishing shop.

Process control encompasses many activities, all of which need to be tracked. The process control systems should provide a number of functions, including:

- Schedule Analyses
- Track Process Solution Analysis Results
- Track Process Solution Life (Make-ups/Discard)
- Schedule Process Solution Maintenance
- Schedule Physical Tests
- Track Physical Test Results
- Track Process Solution Additions/Decants
- Track Chemical Usage
- Provide Trend Analysis
- Track and provide up-to-date procedures

Process control begins with analyzing the process solutions, and includes the myriad of physical tests performed to insure that parts produced perform to the intended level. These tests can be continuous, hourly, several times per shift, daily, weekly, monthly or more infrequent. The first job of the process control system is to effectively schedule the required tests. The importance is two-fold; since most of the tests are recurring, the schedule helps predict the necessary laboratory equipment and also the manpower needed to complete the tests within the time frame allotted. Table 1 and Figure 1 show the weekly laboratory process solution analysis and monthly physical test schedule for a typical facility. All of the analyses are completed at the facility with the exception of the monthly trace metal analysis. Process solution samples are sent to an outside laboratory for impurity analysis. The schedule is for a one-shift facility that operates six days per week. This particular facility is overseas and works Saturday through Thursday.

This laboratory schedule keeps four technicians and one engineer busy continuously. Extra capacity is needed to rerun tests when there is an analysis failure, and to troubleshoot when problems arise. The laboratory operation produces data from daily analysis of electroless nickel (several times per shift), twice-daily analysis of the phosphate solution, and weekly analysis of all the pre-processing, post-processing, plating and surface treatment tanks. The raw data is used to calculate process solution concentrations and in certain cases major contaminant levels. Data is also generated from the monthly physical tests, including coating weight, coating thickness, abrasion resistance, salt spray resistance, hydrogen embrittlement stress relief, and visual evidence of the processes from regular Hull cell tests, coating porosity, paint adhesion and adhesion testing. The data is interpreted and process solution maintenance is scheduled including additions, decants, dummy plating, special treatments and solution change out. The process control system must track all the inputs and generate the outputs related to each of these items.

Table 1
Typical Weekly Laboratory Process analysis Schedule

Saturday	**Sunday**	**Monday**	**Tuesday**	**Wednesday**	**Thursday**
Acid analysis A4 Nitric	Cadmium Plate	Nickel strikes	Chromium Plate	Cleaners	Black Oxide
A7 HCl	Zinc Plate	Nickel Plate	Chromic acid anodize	A1	Alum Strip
D13 HCl	Copper Plate	Nickel strip	Anodize Strip	B7	Chromium strip
E4 HCl	Silver Strike	Tin Plate	Dichromate seal	D4 D11	Cadmium Strip
F5 Passivate	Silver Plate	Lead Plate	Conversion Coats	E1	Silver Strip
F12 anodize	Bronze Plate		Aluminum Deoxidize	F1 F2	Nickel acetate seal
F13 Hard Anodize	Copper Strike			G1	
G4 H_2SO_4				H1 H2	
H5 H_2SO_4					
H8 H_2SO_44					
Electroless Ni	Electroless Ni	Electroless Ni	Electroless Ni	Electroless Ni	Electroless Ni
Phosphate	Phosphate	Phosphate	Phosphate	Phosphate	Phosphate

Monthly Test Load and Physical Test Schedule

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
▪Prepare Cad Test load ▪Cad Hull Cell ▪Nickel Stress measurement ▪Ni Hull Cell	▪Cad Plate Sample Load ▪Bake Cd HE Pins	▪Begin RSL Cad 1 ▪Begin Cad Salt Spray ▪Prepare Type III Anodize Test Load	▪Prepare Al Chromate Load ▪Cad RSL 2 ▪Anodize Test Load Type III	▪Cad RSL 3 ▪Process Al chromate Test Load ▪Type III Anodize Test Load coating wt and thickness		▪Cad RSL 4 ▪Cad Salt Spray ends ▪Type III Anodize Test Load Abrasion resistance
▪Begin AlCr Salt Spray ▪Al Cr Coating Wt ▪Al Cr paint coupons to shop Plate Nickel ▪Bake Ni HE pins	▪Nickel RSL 1 Begins ▪Cad Thickness ▪Cad adhesion ▪Cr Hull Cell ▪Begin Al Cr paint adhesion test	▪Ni RSL 2 ▪Prepare Cr Test Load ▪Al Cr paint adhesion test finished	▪Ni RSL 3 ▪Prepare Type I & II Anodize Test Load ▪Plate Cr Test load ▪Bake Cr HE pins	▪Ni RSL 4 ▪Anodize Type I & II Test Load ▪Samples to Institute for trace metal analysis ▪Cr hardness to Institute		▪Cr RSL 1 ▪Ni Adhesion and thickness Anodize Salt Spray begins ▪Type I & II Anodize coating wt
▪Al Cr Salt Spray ends ▪Cr RSL 2 ▪Zn Hull Cell ▪Prepare EN Test Load	▪Cr RSL 3 ▪Prepare Zn Test Load ▪Cu Hull Cell ▪EN Stress measurement	▪Cr RSL 4 ▪Plate Zn Test Load ▪Bake Zn HE Pins ▪EN Thickness and adhesions	▪Cr RSL 5 ▪Prepare Manganese Phosphate Test Load	▪Zn RSL 1 ▪Cr Adhesion and Thickness ▪Process Manganese Phosphate Test Load		▪Zn RSL 2 Manganese Phosphate Coating wt
▪Zn RSL 3 ▪Plate Cu Test Load ▪Bake Cu HE Test Pins ▪Silver Hull Cell	▪Zn RSL 4 ▪Prepare Silver Test Load	▪Cu RSL 1 ▪Zn Thickness and adhesion ▪Silver Thickness, adhesion and porosity	▪Cu RSL 2 ▪Woods Ni Hull Cell	▪Cu RSL 3 ▪Cu Porosity ▪Adhesion and thickness		▪Cu RSL 4 ▪Anodize Salt Spray ends

Figure 1: Typical Monthly Laboratory Physical Test Schedule

3.0 Process Control System Options

Testing generates a tremendous amount of data that must be cataloged and interpreted regularly. Various options of handling this data exist, the simplest being the hard-copy log book. It is prudent to maintain a hard-copy of the raw data, but log books do not provide any real analysis capability. The process solution analysis raw data is used to calculate component concentrations and can then be plotted on a run charts to begin to analyze for trends. Run charts can also be generated for certain of the physical tests like thickness, coating weight or abrasion resistance. Depending on how they are done, hydrogen embrittlement stress relief and salt spray can also provide quantitative data. For hydrogen embrittlement stress relief, keeping track of the hours to failure for each pin, or the failure point in percent of ultimate tensile stress, can provide quantitative data that helps track the process.

Computer spreadsheets are useful for calculating process solution component and impurity levels, establishing the schedule of analysis and tests, and tracking tank make-up, additions, decants and chemical usage. The graphing routines can be used to plot run charts, and the spreadsheet statistical routines can be used to evaluate error. Then, reports need to be generated to document and summarize the data presented. Once established, these spreadsheets will perform, but they take time to develop. The more complex the facility, the longer the development time will be. In addition, a high level of user proficiency is required to set up spreadsheets with the sort of features needed to establish the process control system.

The spreadsheets should be protected to prevent less knowledgeable users from corrupting the formulas and routines used. It may be more preferable to place all these activities in a database with a user interface, thereby limiting access to formulas, as the less adept user is only entering data. Commercial programs are available to shorten the implementation time. These programs can be customized to better reflect the actual facility and contain the routines needed to schedule analytical tasks, compile and perform calculations, plot run charts, indicate additions and decants, track chemical usage and generate reports. The variety of features and the system cost reflect the amount of customization that occurs before the user starts building the site-specific information. The benefit of a commercial LIMS is that the facility can implement one tool to manage all facets of the laboratory information (5). The commercial system can be less expensive than the time and effort needed to generate the required applications from spreadsheet or database programs.

4.0 Setting up a LIMS

Prior to investing in a LIMS -- whether constructed on-site or purchased from a vendor -- planning for the necessary features is essential. If establishing a LIMS was only about calculating and storing process solution concentrations, a simple spreadsheet would suffice. However, one of the main reasons to implement a LIMS system is to provide consistent result calculations and automatic scheduling and documentation of the management of laboratory data. Therefore, the report features are very important to consider. Another key aspect is certification that tasks were completed. Some LIMS have sign-off features for completing analyses, as well as completing tank maintenance procedures such as additions and decants. Some LIMS software packages provide capabilities for creating standard or custom rules that can perform automated tasks based on data results, including sending messages and requiring control actions. Probably the most useful feature that a LIMS can provide is the opportunity for all of the management and control functions to reside in one program. This next section will detail some of the features of a LIMS program implemented for an aerospace metal finishing facility.

The first screen in Figure 2 is the tank set up screen. On the left is the tree structure of the facility. The various process lines and tanks are accessed through a Windows Explorer-like hierarchy tree. Each process tank line and each process tank within the line is built individually. Similar tanks may be copied to speed the facility creation process. As the process tanks are built, the library of make-up chemicals is also built. In the case shown, tank A-1 is accessed. The volume of the tank is shown and can either be entered or calculated from the tank dimensions. In addition, in this screen is the ability to indicate what personal protective gear is required while working on this tank Above the tank volume area are several tabs, and these access various functions for this tank including Notes, Test, Addslip, Schedule, Make-up and Documents. Each of these tabs will be discussed briefly.

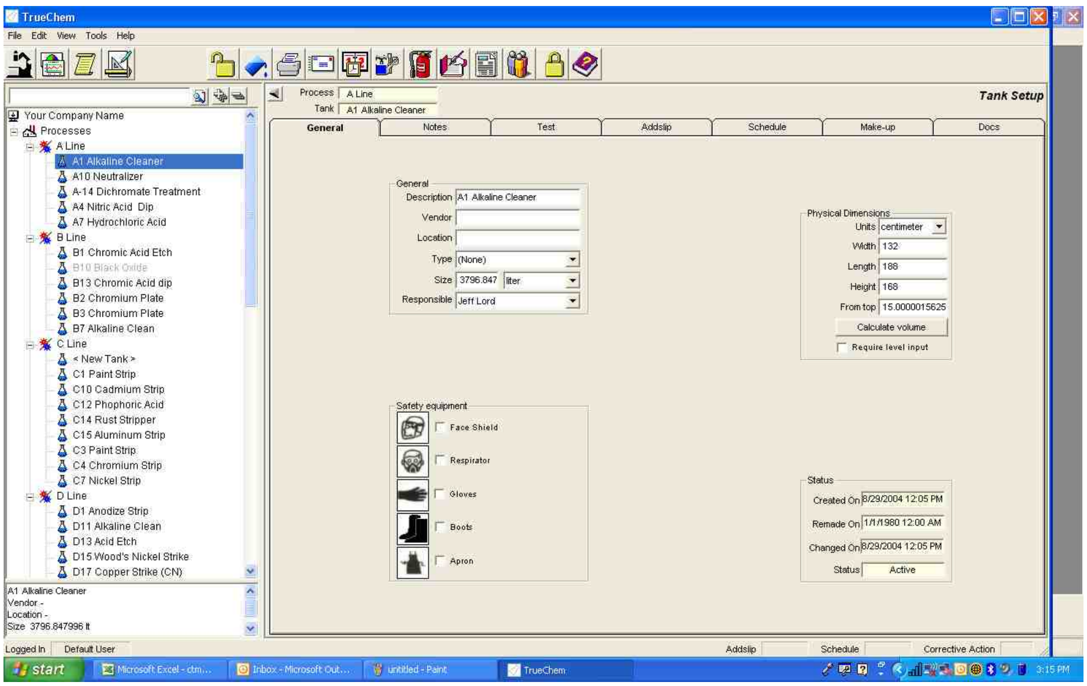

Figure 2: Tank Set up Screen

On the far right are the Make-up and Document tabs. Accessing the make-up shows the chemicals that are used to make-up the process solution and the quantities required. Links in the document section can be created to procedures, or they may be entered directly. In this particular case, the tank make-up procedure and the analysis procedure are linked to the page. Linking is particularly useful when the same procedure is used for multiple process solutions; updating the procedure outside of the program immediately updates all the tanks where the procedure is used. If the procedure is actually copied into the document section, then each tank must be updated individually when changes are necessary.

The test tab is used to build the calculations and the control limits that govern the operation of the process tank. In the background is each step in the analysis of this process solution. The calculation screen is shown in the blue outlined “Modify Test Item” window. Shown in this screen is the result calculation for the sodium cyanide concentration in a cadmium process solution. On the left is the concentration calculation where the inputs represent the volume and concentration of the titrant used. The script area allows the use of special calculations

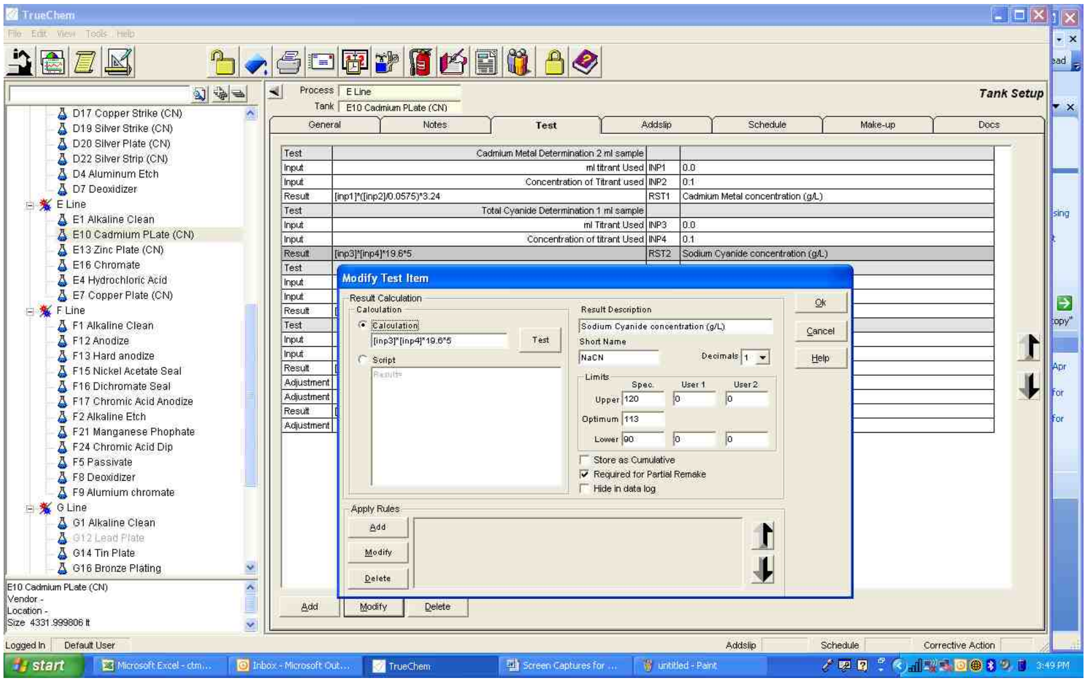

Figure 3: Parameter Control Limits and Calculation Screen

if necessary, but generally the standard calculations are sufficient. On the right is the component of interest, the upper control limit, the set point and the lower control limit. Notice that there is

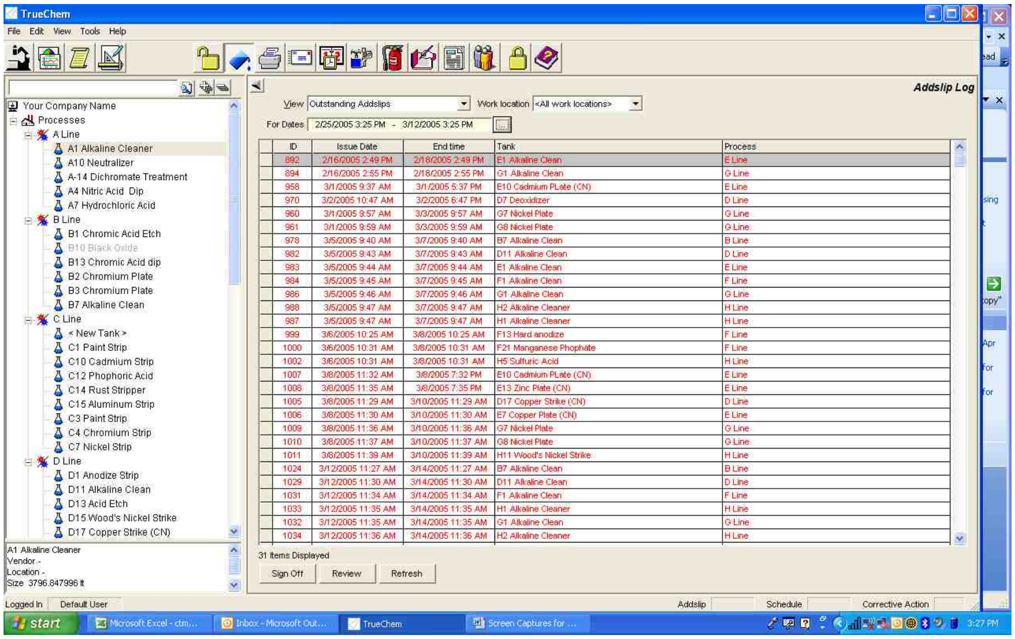

Figure 4: Daily Analysis Schedule Screen

space to define other (narrower) limits for specific users. This feature could be useful if the analysis error requires a narrower limit to guarantee that operation process solution is maintained within the operating range, or if the facility wishes to operate near an extreme to improve their operation. Also included in this window is the ability to set the number of decimal points used in the result, and to test the function of the calculation.

Once the tests for the various parameters relating to a specific process tank have been constructed, the schedule and priority of these analyses can be established. The activity is completed in the schedule tab for each process solution component. With this feature, not all parameters must be analyzed at the same time. This allows the scheduling of daily, weekly and monthly analyses. This function can also be used to scheduled regular tank maintenance procedures such as low current density electrolysis (dummy plating), carbon treatment or even filter changes. In addition, work priorities can be set in case a problem arises and time constraints force such decision-making. The program manages scheduling requirements and can generate a list of the activities needing attention for a given time period. A typical schedule is shown in Figure 4. The red items are those that need completion; the program is able to schedule down to the minute, if needed. After an activity is completed, the person completing the task signs off on the computer that the work has been done, thereby generating a record of activities and responsible staff.

One of the key features of the LIMS program is archiving the process control data. The data is entered into this program for each process tank through the Test tab. Descriptions of the test and default values for the data inputs can be entered to check the initial validity of the data. Once entered, the data is not saved to the database until the Output tab is accessed and the program is commanded to save the data. Entering the data then prompts the program to generate an “Addslip” (or Decant) if necessary and schedules when this activity must be complete. Completion of the addition is signed off in the Addslip Log and the program can be used to track

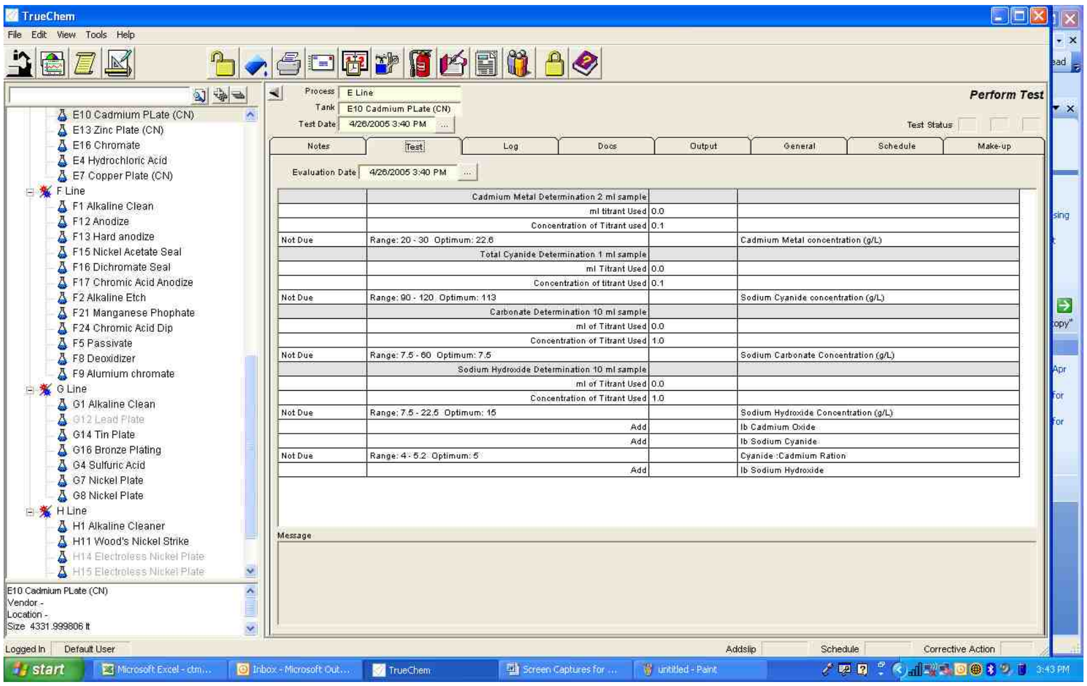

Figure 5: Tank Analysis Test Screen

the material usage by tracking the quantity and frequency of additions. The user also has the ability to override an addition or decant if some reason outside the ability of the program dictates that the planned activity is unnecessary. (For example, if the process tank is not currently in use or the sample was taken improperly etc.). The first tab to the right of the general information tab is the notes tab, and is used to generate a historical description of the tank. Dates of make-up and maintenance, such as filter changes, carbon treatment or dummy plating, are noted, as are decants or unusual circumstances. Properly maintained, the notes section can be an invaluable tool in troubleshooting a malfunctioning process solution.

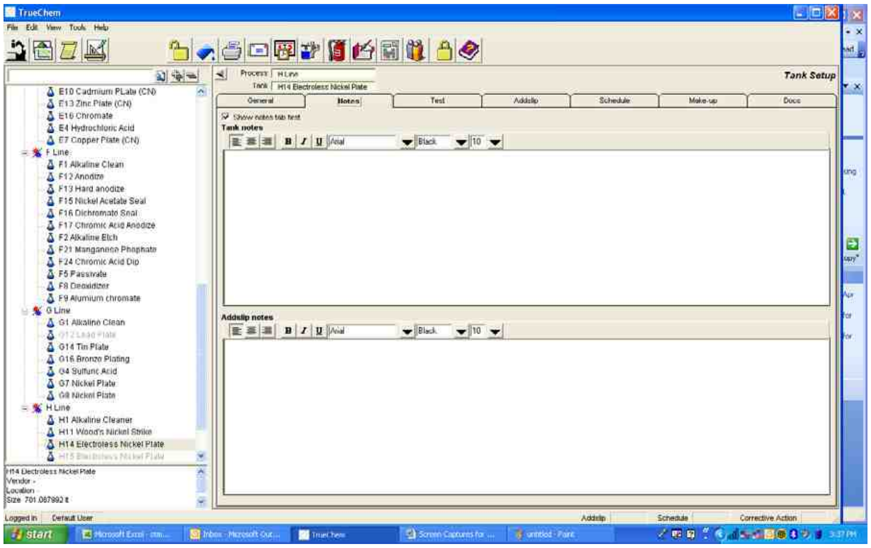

Figure 6 Notes Field Screen

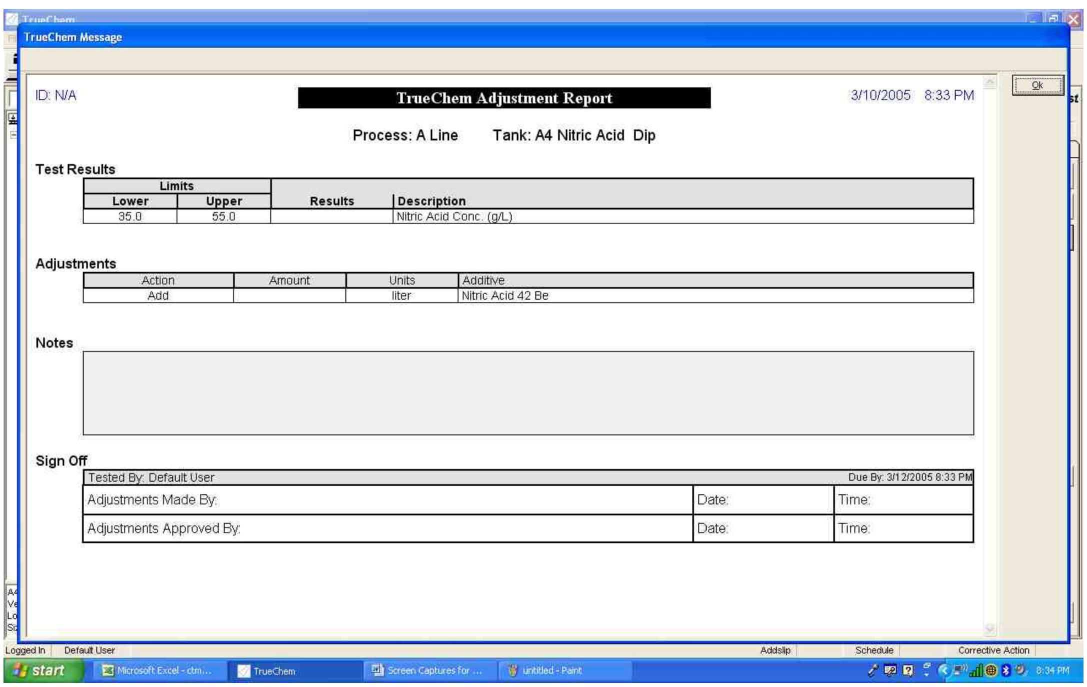

Figure 7: Tank Addition/Decant Report

Once the laboratory analysis raw data is entered into the window from the Test tab, accessing the Output tab saves the data and generates an Addslip. A sample is shown in Figure 7. These reports can be customized to show selected facility information. The standard one shown displays the process control limits and the concentration measured by the laboratory test, and indicates the action required. The notes field here can be used to generate addition instructions, such as additions needing to be performed in a particular order or within a certain time frame. At the very bottom of the Addslip are two areas to sign off that the addition was completed and, if necessary, the requirement for a supervisor to approve that the work was completed. The Addslips can then be archived.

The final screen depicts one of many tools available to display the data. This particular shot shows run charts for the calendar period selected. If desired, a different calendar period can be selected by pressing the calendar button indicated by the callout box. Run charts are shown for each component tracked by the program. Below the run charts is a histogram of the component concentration variations. The variables for statistical calculation are shown at the far bottom right. The program allows the ability to adjust the range of data displayed. In addition, the log of the data inputs can be accessed by pressing the data log scroll button as shown by the left callout.

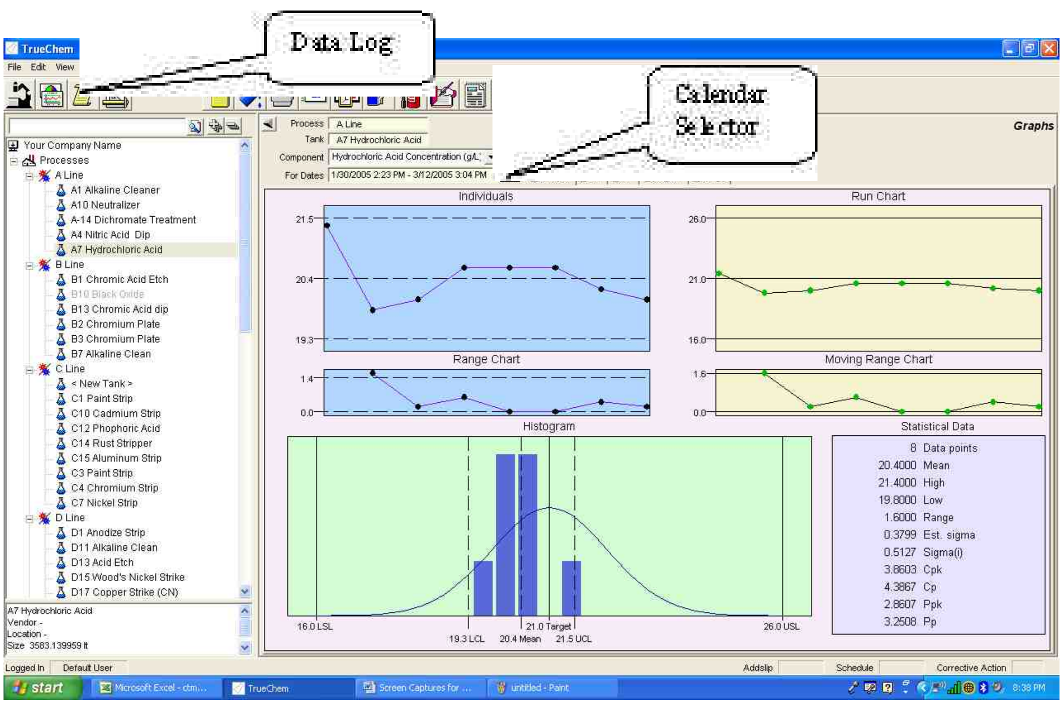

Figure 8: Run Chart Screen

5.0 Summary

A laboratory information management system (LIMS) provides powerful capability to facilitate consistent, efficient, and well-documented operation of a modern metal finishing facility. A wide variety of tasks comprise a LIMS program for a facility, and a powerful set tools can be used to set up, operate and manage a LIMS system. Choosing the appropriate system depends on the needs and resources of the facility. The main function of any LIMS is to schedule the various analyses that must be completed, store and manage the laboratory data collected, assist the facility in interpreting the data, provide reporting on the laboratory results, provide input to the facility on actions required by interpretation of the data (based on standard and custom rules and logic statements) and verify that the tasks required have been completed.

One way to implement a LIMS program is to set up a program similar to the one introduced in this paper. This particular program is moderately priced when compared to the amount of effort that would be required to create a custom in-house program. The benefit of this type of program is that all the functions needed reside in one place. This program is customized by the user but with the capabilities designed into the program, establishing a comprehensive LIMS is greatly simplified, and the time requirement to set up a comprehensive program is reduced.

Regardless of the type of laboratory information management system a facility chooses to implement, a good system will facilitate process control and documentation of the control activities required and regularly completed. The facility is able to provide better documentation of quality management of the metal finishing processes and will experience less variation in the control of its process solutions. This will ultimately translate into better process control, the production of superior products by the facility and customers that are sure of their level of satisfaction.

7.0 Bibliography

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