ABSTRACT

A menu-driven, SAS-based system has been developed to generate the product specification conformance reports that are now required by many customers of tin-plated and cold-rolled steel products. This system, which was designed for use by the Quality Assurance Department, also serves a dual function of guiding the quality control engineers in taking any required corrective actions that may be necessary to maximize product capability. It provides authorized users with SAS/AF and SAS/IFSP screens to define the nature and contents of each customer's reports, the properties to be included, their control limits, and time period(s) to be covered by the reports. Based on these report characteristics, the SAS system then builds a custom SQL query to extract the required data from the various DB2 foundation data systems. A typical customer's report could cover the shipments for the most recent month and quarter and include shipment summary reports, QC control charts, distribution histograms and several measures of capability. The internal reports for the QC engineers include summaries of any out-of-specification properties, all shipments, recommended process changes to improve capabilities and a listing of the raw data along with any codes or database keys that would assist them with relating the reported property data back to the production data systems.

INTRODUCTION

The Sheet Product Conformance Reporting System that was developed for Bethlehem Steel's Sparrows Point Division is a SAS-based computer system that generates customized product conformance reports for key customers. This system serves as a significant communications link in Bethlehem's efforts to develop partnership relationships with their most important suppliers and customers. As such, it needed the ability to generate reports that were customized to the needs of the individual customers.

For ease of operation and security purposes, the system was designed to function in two main modes: the first being the definition and storing of a customer's reporting criteria and, the second being the generation of the reports based on those reporting criteria. The foundation data are read from a series of pre-existing, general-access order, property and production history DB2 relational database tables. Finally, for accounting purposes, the system accesses the individual user's logon profile and bills the computer charges directly to the user's computer charge account number that was in effect when this system was accessed.

SYSTEM DESIGN

As discussed above, this SAS/AF system is divided into two functions — definition of the reporting criteria and generating reports. Both functions, which will be described below, are globally controlled by the standard ACF2 security system that limits overall read or read/write access to computer datasets by user ID.

Report Definition Portion

The report criteria definition portion of this SAS/AF system contains a two-path internal security system that limits functional access by user ID and, thereby, builds upon the global ACF2 security system. Specifically, pre-authorized computer IDs that are classified as system administrators will be able to define and/or modify the reporting criteria and generate reports whereas other pre-authorized computer IDs that are classified as general access users will only be able to browse the previously defined reporting criteria and generate reports. All other computer IDs will be denied access to the system. Each of the system functions will be discussed below.

System Administrator's Main Menu

The first screen that will be seen when a system administrator enters the system is shown below and is used to select from among any of the four indicated options — add, edit, delete, or run reports.
General Access Main Menu

The first screen that will be seen when a general access user enters the system is shown below and is used to select from among any of the two indicated options - browse or run report.

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Report Generation Portion

The report generating portion of the system gives both the authorized systems administrators and general users the ability to generate reports based on predefined reporting criteria by selecting the appropriate option on their respective menus. As will be discussed below, depending on the options selected, the system generates a series of up to nine different types of data summaries that provide information to evaluate how well the properties of the shipped products conform to the customers specifications. Six of these types of data summaries contain no proprietary information and were designed specifically to be distributed to the customers whereas the remaining three types contain confidential information that is proprietary to Bethlehem Steel and were designed solely for the use of Bethlehem Steel personnel as diagnostic tools. Furthermore, some of the reports are generated automatically while others are only generated when they are requested in the definition of the reporting criteria.

The system was designed to only consider the property data in full month increments based on the product's shipping date. Thus a report that was specified as a three month report ending January 1993 would cover all coils shipped from November 1, 1992 through January 31, 1993, inclusive. Furthermore, depending on the options selected, these reports may cover either one or two time intervals that have the same completion date. For example, if both one and six month time periods were requested, the report could be used to compare the performance in a single month with that of the six-month period to detect trends in performance.

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REPORT DEFINITION OPTIONS

The report definition portion of the system (i.e., the edit, browse, add and delete options) uses a series of SAS/AF menus and SAS/FSP formatted data entry screens to define the reporting criteria for a customer. These criteria define the scope of the report including the time period(s) to be covered, the properties to be evaluated and the types of data summaries that are to be included in the final report. Once defined, that reporting criteria is retained in memory and no further action is needed unless the criteria needs to be updated to, perhaps, better fit a changing order pattern.

Editing An Existing Report Criteria

As discussed above, the first screen to appear is the customer selection screen that is shown below. This screen is preloaded with the names of all of the customers that have existing (i.e., previously defined) reporting criteria and the desired report is selected by simply entering a letter "E" (for edit) in the blank in front of the selected customer.

Specification Input Screens

The next eleven screens give the user the ability to actually modify or view the reporting criteria for the selected customer. The information entered on these screens will be stored as the standard report for the customer. The contents of a report may be altered by changing any of these eleven screens. Thus, once the criteria for a customer's report has been entered into the system, it will be retained for future use and these screens need never be re-accessed unless the reporting criteria need to be modified.
Taking into account the provided partial text, here is the natural text:

**General Information Screen**

This screen is used to define the main reporting criteria such as the customer name, reporting time intervals, types of reports required, and the properties that are to be included in the reports.

| Command ———> | Obs 1 Screen 1 |
| Note: This application uses 11 screens. |
| CUSTOMER NAME: | LOCATION: |

<table>
<thead>
<tr>
<th>Report Criteria</th>
<th>Time Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of Months</td>
<td>1 2</td>
</tr>
<tr>
<td>Order Info</td>
<td>(X/W)</td>
</tr>
<tr>
<td>Capability (C/S/B)</td>
<td></td>
</tr>
<tr>
<td>Histograms</td>
<td>(Y/N)</td>
</tr>
<tr>
<td>IR Charts</td>
<td>(Y/N)</td>
</tr>
</tbody>
</table>

**DATA INCLUDED IN REPORT**

- THICKNESS: Statement Code
- OIL LEVELS: Statement Code
- SURFACE: Statement Code
- ROCKWELL: Statement Code
- SPRINGBACK: Statement Code
- OIL COATING: Statement Code
- TENSILE: Statement Code

Use PF7-PF8 to switch customers. Use PF3 to save/exit.
Use PF10-PF11 to move forward/backward in customer.

**Thickness Input Screen**

The thickness criteria input screen shown below is representative of the ten different property criteria definition screens—each of which may be used to define up to ten different evaluation criteria for that property. Most of these screens permit the users to use alternate product or process units of measure to define the classification variables. For example, in the thickness input screen shown below, the user may define sheet thickness in terms of base weight (a method common in the tin-coated sheet market) or gauge (the more universally accepted term). This eliminates the potential for error that would be introduced if the users had to convert their data specifications from one set of units to another. As a note of interest, the transparent use of either/or designation such as this one is handled internally by using macros to actually write the relevant SAS code.

**Rockwell Input Screen**

The Rockwell hardness reporting criteria screen is similar to the thickness reporting criteria screen except that the hardness data are classified by the ordered heat treatment code or the strip temper designation depending on how the strip was ordered and the scope of the hardness study may be optionally limited by the product code and/or a range of strip thicknesses or base weights.

The first input area provides space for the customer's name, shorty name, and, optionally, a shipping location as defined in Bethlehem's order entry and accounting systems. The shipping location is only used if the report is to be limited to coils that were shipped to a specific location rather than to the company as a whole.

The second input area defines the number of months that are to be included in one or, optionally, two reporting periods and the types of data summaries that are to be generated for each of the reporting periods which may include order information, capability and statistical data, histograms, coil shipments report, and IR Charts.

The third input area on this screen defines properties that are to be included in the reports. These data override the definitions on the following ten screens that even if a report is defined on the appropriate definition screen, it will not be included in the report unless the appropriate input area is marked in this area. Thus a property's reporting criteria can be defined once and easily added or removed from the customer's report.

**As an example, to include a report on strip thickness, the following steps should be followed:**

1. Place an A or an R in the field labeled INCLD to stipulate that an evaluation of strip thickness should be included in the report and whether the customer specifies it as an aim or as a required property. Any other character will cause the information on that line to be ignored.

2. Enter the ordered strip thickness expressed as either a gauge (i.e., as inches) or base weight depending on how the strip was ordered.

3. Enter the upper and/or the lower specification limit expressed as inches.

4. (Optionally) To further restrict the scope of the report, enter a product code (YPRODUCT) and/or a heat treatment code (YHEAT).

Steps 1-4 may be repeated for up to ten different strip thickness evaluation criteria.

**Rockwell Input Screen**

The Rockwell hardness reporting criteria screen is similar to the thickness reporting criteria screen except that the hardness data are classified by the ordered heat treatment code or the strip temper designation depending on how the strip was ordered and the scope of the hardness study may be optionally limited by the product code and/or a range of strip thicknesses or base weights.
Surface Roughness Input Screen

The surface roughness reporting criteria screen is similar to the thickness reporting criteria screen except that the scope of the roughness study may be optionally limited by the product code and/or a range of strip thicknesses or base weights.

Springback Input Screen

The springback reporting criteria screen is similar to the thickness reporting criteria screen except that the springback data are classified by the ordered heat treatment code or the strip temper designation depending on how the strip was ordered and the scope of the springback study may be optionally limited by the product code and/or a range of strip thicknesses or base weights.

Tensile Properties Input Screen

The tensile properties (i.e., yield strength, tensile strength and tensile elongation) reporting criteria screen is similar to the thickness reporting criteria screen except that the tensile data are classified by the ordered heat treatment code or the strip temper designation depending on how the strip was ordered and the scope of the tensile study may be optionally limited by the product code and/or a range of strip thicknesses or base weights.

Pinhole Input Screen

The pinhole reporting criteria screen is similar to the thickness reporting criteria screen except that the pinhole requirements may be expressed in two different ways and the scope of the pinhole study may be optionally limited by the product code and/or a range of strip thicknesses or base weights.

Tin Coating Weight Input Screen

The tin coating weight reporting criteria screen is similar to the thickness reporting criteria screen except that the tin coating weight data are classified by their respective ordered coating weight code and the scope of the tin coating weight study may be optionally limited by a range of strip thicknesses or base weights.

Oil Level Input Screen

The oil level-reporting criteria screen is similar to the thickness reporting criteria screen except that the top and/or bottom oil level data are classified by the ordered oil level code and the scope of the oil level study may be optionally limited by the product code and/or a range of strip thicknesses or base weights.

Chrome Coating Input Screen

The chrome coating reporting criteria screen is similar to the thickness reporting criteria screen except that the top and/or bottom metallic, and/or non-metallic chrome coating data may all be evaluated and the scope of the chrome coating study may be optionally limited by a range of strip thicknesses or base weights.

Thickness Deviation Input Screen

The thickness deviation reporting criteria screen is similar to the thickness reporting criteria screen except that the thickness data are classified by a range of strip thicknesses and/or base weights and the scope of the thickness deviation study may be optionally limited by the product code.

Adding A New Report Criteria

The ADD option is functionally similar to the EDIT option discussed above except that the Customer Selection Screen will not appear and the set of eleven FSP screens will all be blank.

Deleting An Existing Report Criteria

The DELETE option will bring up a Customer Selection Screen that is similar to the one that first appears when the EDIT option is selected. This screen is preloaded with the names of all of the customers that have existing (i.e., previously defined) reporting criteria and the desired report is selected by simply entering a letter “D” (for delete) in the blank in front of the selected customer.

Browsing An Existing Report Criteria

The BROWSE option will bring up a Customer Selection Screen that is similar to the one that first appears when the EDIT option is selected. This screen is preloaded with the names of all of the customers that have existing (i.e., previously defined) reporting criteria and the desired report is selected by simply entering a letter “B” (for browse) in the blank in front of the selected customer. The only difference between this browse option and the edit option that was discussed above, is the fact that edit option permits the system administrator(s) to edit the report criteria whereas browse option only permits the general users to browse them. Otherwise, the screens are identical.

Report Generation Option

The RUN option will bring up a Customer Selection Screen that is similar to the one that first appears when the EDIT option is selected. This screen is preloaded with the names of all of the customers that have existing (i.e., previously defined) reporting criteria and the desired report is selected by simply entering a letter “R” (for run) in the blank in front of the selected customer. A second screen follows to permit the user to control the printing location for the reports.
DESCRIPTION OF REPORTS

Customer Reports

The six types of data summaries that were designed for distribution to the customers are as follows:

Cover Page

The cover page of the report is automatically included in every report and serves to both time-stamp the report and document the reporting criteria that were in effect when the report was generated. It is functionally divided into four areas: As shown in Figure 1, the first of these areas, which occupies the top half of the page, contains the customer's name and shorty name, the day and time that the report was generated and the time span of the shipments that were included in the report. The second area, at the bottom left of the page, documents the types of reports and reporting periods that were requested; the third area, at the bottom center of the page, documents the properties that were to be included in the report; and the fourth area, at the bottom right of the page, summarizes the number of coils that were shipped and included in the report for each month of the reporting period.

Order Information

The order information summary, which includes information for every order that had a coil that was shipped during the specified reporting period, is only included in the report if it is specifically requested when the reporting criteria are established. As shown in Figure 2, this report includes information on the reporting period for shipments that were included in the report, the mill order number, the sold-to and ship-to addresses, shorty name and shipping location, the customer order number, the application and specification descriptions, the ordered decimal thickness and base weight, the number of coils shipped and a list of coils shipped. When two reporting periods are requested, to eliminate duplicate output, this order summary will print a single list that includes all of the coils that were shipped during both reporting periods.

Capability and Statistical Information

The capability and statistical summary will only be included in the report if it is specifically requested when the reporting criteria are established. Input options permit selecting either one or two time periods and, separately for each time period, whether the reports will include either (1) the statistical data such as the number of tests, mean, minimum, maximum, standard deviation and number out of specification for each requested property (Figure 3 - first time period), (2) the capability data which includes the specification limits, CP, CPL, CPU and CPK capability indices (Figure 3 - second time period), or (3) both classes of data.

Data Distribution Histograms

The property distribution histograms will only be included in the report if they are specifically requested when the reporting criteria are established. Separate histograms will be generated for each requested property using the Histogram Option in SAS/QC's PROC SHEWHART. When two reporting periods are requested, separate histograms will be generated for each of the reporting periods.

Shewhart IR Charts

The Shewhart IR charts will only be included in the report if it is specifically requested when the reporting criteria are established. Separate charts will be generated for every requested property and, when two reporting periods are requested, separate charts will be generated for each reporting period. The horizontal axes of these charts is a sequential shipping number.

Listing of All Shipped Coils

A listing of the shipped coils will only be included in the report if it is specifically requested when the reporting criteria are established. As shown in Figure 4, these listings identify the time interval for the shipments that were included in the report and each shipped coil is identified by its coil number, shipped date, and the shipping sequence. Finally, the relevant specifications presented as both the codes and their interpretation, the requested properties and the actual test data. When two reporting periods are requested, to eliminate duplicate output, this summary will print a single list that includes all of the coils that were shipped during both reporting periods.

Confidential Diagnostic Reports

Summary of All Shipped Coils by Specification

A hierarchical summary of the specifications of all shipped coils will always be included in the report to assist in the determination of how well the requested specifications reflect the actual specifications that were shipped during the reporting period(s). As shown in Figure 5, when two reporting periods are requested, separate summaries will be generated for each of the reporting periods.

Listing of All Out-of-Specification Coils

A table of all out-of-specification coils will always be included in the report to assist follow-up quality improvement activities. When two reporting periods are requested, to eliminate duplicate output, this summary will print a single list that includes all of the coils that were shipped out-of-specification during both reporting periods. As shown in Figure 6, these
tables contain the specification limits and the actual test data for each of the out-of-specification conditions.

**Impact of Possible Corrective Actions**

A table showing the impact of possible corrective actions will always be included in the report to assist follow-up quality improvement activities. When two reporting periods are specified, this table will be based on the longer period. As shown in Figure 7, this report summarizes the effect of changes in a property's mean and/or standard deviation values on its CPK capability index. This report was included to illustrate the quantitative improvements that could be made in the capability indices when one or both of those parameters are changed. The top portion of the report is a recapitulation of the capability data that were included as part of the optional statistical and capability summary report. The first section at the bottom left of the report, denoted as Case I, computes the standard deviation that would be required to achieve CPK=1.00 and CPK=1.33 if the property's mean value can not be altered by reasonable process changes. The second section, denoted Case II, computes the effect of a modified Mean on the CPK if the standard deviation is unchanged and then computes the standard deviations that would be required to achieve CPK=1.00 and CPK=1.33.

For illustrative purposes, we will focus on the data for the Rockwell hardness evaluation which involves a two-sided specification. As shown at the top of the page, there were 492 tests on the coils that were produced to meet a hardness specification of 45.0 to 52.0. Furthermore, these coils had a mean hardness test value of 46.5163 and a standard deviation of 1.25137 and, as a result, a marginally less than adequate CP of 0.93, a far less than adequate CPL of 0.40, a more than adequate CPU of 1.46 and a far less than adequate CPK of 0.40.

These capability data show clearly that the process currently is not capable of producing the product ordered by the customer and they give some indication of the scope of the work that would be necessary to change the process to make it adequate for producing that product. Specifically, the less than adequate CP value shows that the sample variability (i.e., the standard deviation) needs to be reduced while the major disparity between the CPL and CPU shows that the mean also needs to be shifted toward the mid-point of the specification range. The information under Case I shows that, if the mean remains unchanged, the standard deviation would have to be reduced significantly from the current 1.25137 to 0.50542 to achieve CPK=1.00 or even more significantly down to 0.37907 to achieve CPK=1.33 — both of these reduced variability levels would be quite difficult to attain. Under Case II, we see that if the mean is shifted to the specification mid-point of 48.5, the CPK computed using the current standard deviation would be 0.93 which could be improved to 1.00 if the standard deviation is reduced to 1.16867 from the current of 1.25137 or be improved to 1.33 if the standard deviation could be reduced to 0.8750. Thus it would appear that the most reasonable approach to improve the hardness capability of this product would be to combine a change in the chemistry and/or heat treatment to raise the mean by about 2 points with a tightening of the standard practices to reduce the product variability.

The analysis of these data for directing the improvement in the capability for meeting the other customer two-sided specifications would be similar to that discussed above for Rockwell hardness. The approach that would be used for one-sided specifications would be similar except that, instead of shifting the mean toward the specification mid-point, it would be shifted in the direction away from the specified limit. For example, for a one-sided specification that only had a LSL, the mean value would have to be increased whereas, if it only had a USL, it would have to be reduced.

**CONCLUSIONS**

SAS was very successfully used to develop the Sheet Product Conformance Reporting System that is being used by Bethlehem Steel's Sparrows Point Division. SAS provided the unique ability to directly access all of the file types (e.g., flat files and DB2 relational database tables) and data formats that were generated by the foundation data systems and merge them together into the single, cohesive data file that was needed to generate the required reports. The availability of macros that could be used to dynamically-generate customized query and analytical codes made it possible to generate user-customized reports that fit the needs of the individual customers without requiring continual reprogramming. Finally, the ability to easily modify the SAS/FSP formatted data entry screens made it possible to rapidly prototype and adapt the screens to the changing customer and production environments.
Figure 1. Sample Cover Page

Figure 2. Sample Coil Shipment Report

Figure 3. Sample Capability and Statistics Report
**Figure 4. Sample Listing of All Shipped Coils**

<table>
<thead>
<tr>
<th>SHIP</th>
<th>DATE</th>
<th>COIL</th>
<th>SHIPPER</th>
<th>NUMBER</th>
<th>SPEC</th>
<th>TYPE</th>
<th>PRODUCT</th>
<th>SWAY</th>
<th>TENSION</th>
<th>COGENT</th>
<th>CURTAIN</th>
<th>GAUGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>010</td>
<td>02/12</td>
<td>0001</td>
<td>1000000</td>
<td>1</td>
<td>3400</td>
<td>1010000</td>
<td>V-1</td>
<td>1050</td>
<td>11000</td>
<td>11000</td>
<td>11000</td>
<td></td>
</tr>
<tr>
<td>010</td>
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</table>

**Figure 5. Sample Summary of All Shipped Coils By Specification**

<table>
<thead>
<tr>
<th>TIME</th>
<th>TYPE</th>
<th>NO. OF</th>
<th>BAKE</th>
<th>COIL</th>
<th>HEAT</th>
<th>COIL</th>
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<tbody>
<tr>
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<td>93</td>
<td>3500</td>
<td>(11)2100</td>
<td>(41)0000</td>
<td>(11)2100</td>
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<td></td>
</tr>
<tr>
<td>010000</td>
<td>312000</td>
<td>2</td>
<td>93</td>
<td>3500</td>
<td>(11)2100</td>
<td>(41)0000</td>
<td>(11)2100</td>
<td>(41)0000</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 6. Sample Listing of All Out-of-Specification Coils**

<table>
<thead>
<tr>
<th>CONFIDENTIAL REPORT 2: SUMMARY ALL OUT OF SPECIFICATION COILS SHIPPED BETWEEN (GAUGES AND 312MPS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO. SHIPPED</td>
</tr>
<tr>
<td>010000</td>
</tr>
</tbody>
</table>

**Figure 7. Sample Report On The Impact Of Corrective Actions**

<table>
<thead>
<tr>
<th>CONFIDENTIAL REPORT 2: SUMMARY ALL OUT OF SPECIFICATION COILS SHIPPED BETWEEN (GAUGES AND 312MPS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO. SHIPPED</td>
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<tr>
<td>010000</td>
</tr>
</tbody>
</table>