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IMPLEMENTING A MANUFACTURING EXECUTION SYSTEM AT CHEVRON CHEMICAL OAK POINT PLANT

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Abstract

In the past, manufacturing facilities with extensive automation opportunities, such as those around continuous processes, have been able to achieve a high level of integration. The integration has typically broken at the points where manual intervention is needed in an otherwise automated process, such as in the product movements areas, and on smaller batch processes. This partial integration at the manufacturing facility has made integration to an enterprise resource planning system fragile at best, and unsuccessful in the majority of cases.

To get around the challenges of a mixed initiative operation, manufacturers have had to make large capital investments in automating the manual tasks. These capital investments often involved long lead times, process unit shutdowns, and could be only marginally profitable in smaller facilities.

This paper describes how the Chevron Chemical Oak Point plant is using production and batch management software and the S88 methodology to implement a manufacturing execution system (MES) to manage the full life-cycle of production work orders, including manual, semi-automatic and automatic processes. The solution combines Web technology and several commercial software packages.

Introduction

In 1989, the Chevron Chemical Company Oak Point plant at Belle Chasse, Louisiana, committed to developing an in-house manufacturing execution system (MES), known as the Oak Point Information Management System (OPIMS). OPIMS, developed on a VAX system, was designed to help the Oak Point plant economically and effectively address the continuous-cycle executing and planning that is key in any manufacturing operation. Over the course of seven years, Chevron Chemical invested several million dollars in the OPIMS project.

In 1996, the Oak Point Information Technology (IT) group was charged with reviewing the overall effectiveness of OPIMS and determining if the system delivered on its original promises. The results of the review, while disappointing, confirmed what OPIMS operators already knew: that the system provided many planning tools and order-tracking tools, but had major deficiencies for operators actually executing the work order.

The decision for the Oak Point plant then became a question of whether to invest more extensively into OPIMS in order to achieve the required functionality, or whether to abandon OPIMS altogether and purchase an MES system from a third-party vendor. This was a serious question, not only due to the considerable investment already made in OPIMS, but also due to the uncertain ability of any vendor to provide the MES needed by the Oak Point plant.

The study team first reviewed and evaluated the cost of growing and maintaining the current system, buying a new one, or building a new one. The results of that study indicated that there were significant cost savings in support costs alone by replacing the current system.

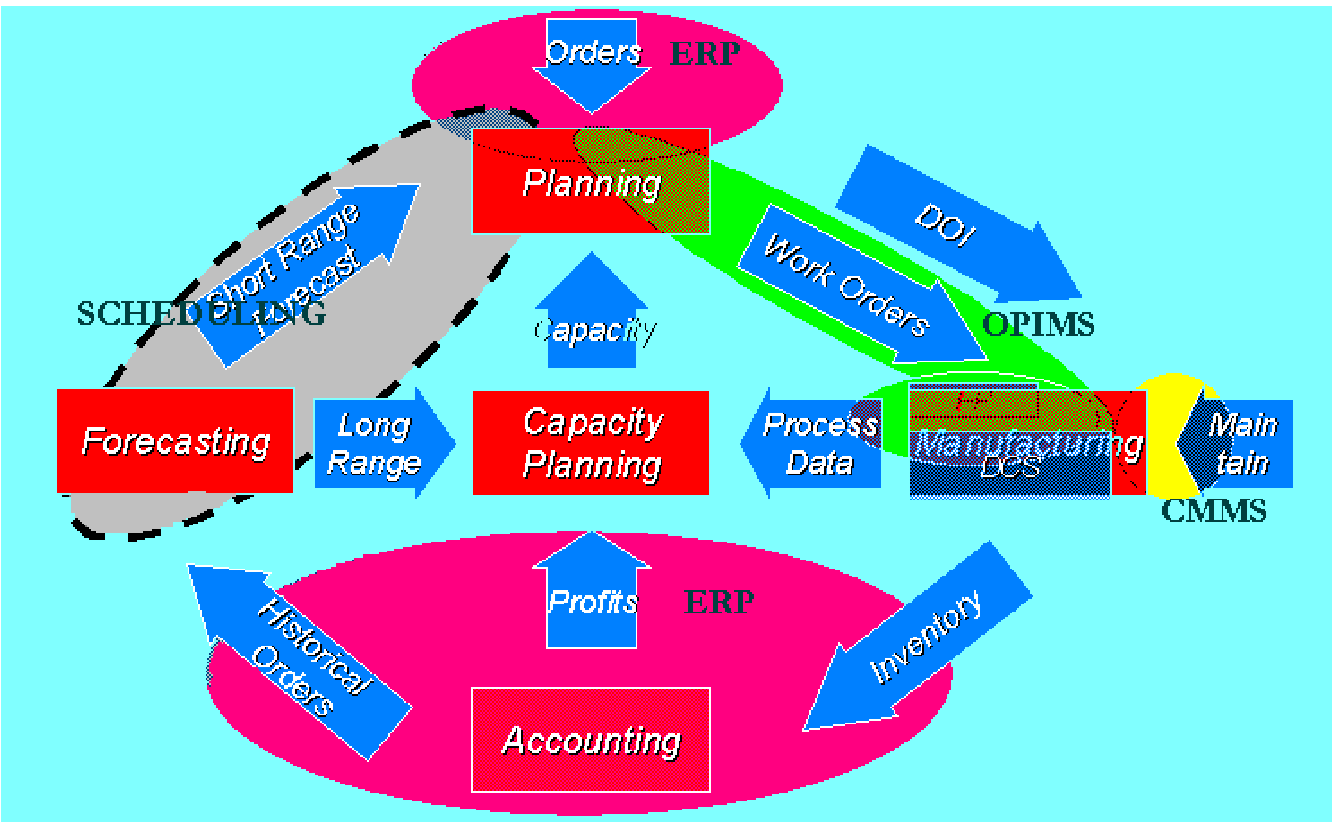
The study team determined that there were significant opportunities to improve operations. The study commissioned by the Oak Point plant analyzed the planning process already in place, and reviewed how operations actually occur.

Figure 1 is a simplified overview of the processes and information flow in place at the Oak Point plant at the beginning of the study. It attempts to give a pictorial view of the execution cycle of planning for demands using inputs of orders and short-range forecasts, manufacturing, accounting for production and shipments, and providing forecasts back into the planning cycle based on order history. It was used to provide an understanding of how the current system supported the processes. As it stands, many processes and information flows are not integrated or covered by OPIMS and the Control Systems. The work order schedules are manually passed to operations, the operators using paper forms execute the work-order procedures, and the results are manually entered into the Enterprise Resource Planning (ERP) system.

The Oak Point management team then commissioned a cross-functional team to define requirements for, select, and implement a replacement system. The team performed an in-depth analysis of the planning and execution processes at Oak Point based on three phases.

- Phase 1: Looking for Opportunities
- Phase 2: Assessing Solutions
- Phase 3: Implementing a Solution.

Figure 1.



The ultimate goal was to put in place an effective, cost-efficient, and workable MES that would help the Oak Point plant achieve maximum manufacturing levels.

At the conclusion of Phase 1, the study team determined that there were significant opportunities to improve operations, and reiterated that the existing OPIMS should be replaced.

Phase 2 concentrated efforts on developing the requirements and attendant documentation for the MES, soliciting proposals from potential vendors, reviewing those proposals, and finally awarding a contract to one of the vendors. As a result of its efforts in Phase 2, the study team chose a DCS vendor as the third-party vendor to help design, develop, and implement the desired MES at the Oak Point plant. Phase 3 is the implementation of the MES, and is currently underway at the Oak Point plant.

Phase 1: Looking for Opportunities

During Phase 1, the study team charted 19 separate "as is" plant processes; that is, these processes were reviewed as they were *actually* being performed. The document showed how the processes interacted with the IT systems and where gaps in the software caused additional work. Each of these processes involved one or more tank movements.

The Oak Point plant currently consists of over 650 tanks, ranging in capacity from 6,000 to 400,000 gallons each. The study team found that for each tank movement, each opening and closing gauge reading is looked up in an automated tank monitoring system (TMS) or hand gauged. Gauge readings are written down on a particular work order report. There are different reports for each type of work order. An example would be for a particular batch of product, an unload, or transfer of product. In total there are more than 50 different reports.

Volumes are then written down or if manual, calculated, and the volume moved calculated, adjusting for temperature and expansion factors. Operations then notes the movement totals in a daily summary log and in OPIMS. The resultant reports are sent to the Planning group, which double-checks the numbers, and logs the movement into a planning logbook. The Accounting group then records it in their own logbook. Also, each movement is entered in an MS-Excel spreadsheet by tank to provide a history of each movement in the tank. Further Accounting records volumes in the ERP system in place at the Oak Point plant. All this is done, even though volumes are usually captured in the control system. This process is repeated thousands of times each year.

This very awkward process helped to demonstrate to the study team that major opportunities for improvement existed in two key areas. First, the heavy dependence on processing with paper increased the number of people involved in the process, and therefore increased the potential for lost or incorrect data to be introduced into the system. It also meant that lost or inaccurate work would have to be redone or reworked. Second, it meant that duplicate entries were, by necessity, being made in several paper processes, as well as in the ERP and OPIMS systems.

Major Findings of Phase 1

The study team concluded the following as a result of its work in Phase 1:

- Although several large and expensive computer systems were in place, the major processes driving manufacturing were still based on paper. As a result, significant duplication existed, both from a data and a systems perspective.

- Too few system interfaces supported system integration. In addition, because some system interfaces were not robust enough to handle their assigned tasks, users had abandoned the system entirely.

- The study team did find, however, that in spite of all of the limitations of the existing OPIMS and related processes at the Oak Point plant, the Operations group remained positive about the use of computer systems at the plant.

Phase 2: Assessing Solutions

As a result of the findings in Phase 1, the study team determined that the existing OPIMS could not support the objectives of the Oak Point plant, and began the process of assessing possible solutions.

Fundamental to this assessment were the following key tasks:

- Development of proposed automated processes which reflected a "should be" rather than an "as is" process; that is, the proposed process would be what the Oak Point plant considered to be the ideal process

- Determination of fundamental requirements for an MES at the Oak Point plant

- Development of a document which detailed the fundamental requirements of the MES

- Selection and solicitation of potential vendors who could meet the fundamental requirements detailed in the document

- A review of the software offerings of each potential vendor

- Selection of the vendor and contract award

Developing Process Proposals

During Phase 2, the study team developed 23 proposed "should be" processes, going into more detail on the original 19 "as is" processes reviewed in Phase 1. Since the majority of existing systems at the Oak Point plant are manual, data eventually goes into paper-based storage. These processes proposed to automate a variety of routine tasks include the following:

- Tank gauge capture and tank monitoring system update
- Sample label printing and pre-login
- Stock control
- ERP work order entry
- ERP purchase order entry and update
- All work order reports.

In addition, because the new process proposals focused on automation, they also promised reductions in manpower in the following three plant departments:

- Planning, in which many double entries would be eliminated
- Inventory Accounting, in which work-order entries would no longer be required
- IT support staff.

Developing a Functional Requirements Document

The study team then developed functional requirements and associated documents to ensure that these promises could be achieved. The overall objective of developing these functional requirements was to design and implement one system, which would provide the following:

- The Planning group with the tools to schedule the operations of the plant
- The Operations group with the tools to monitor and execute the schedule
- The Inventory Accounting group with the data to account for the cost of manufacturing
- Would eliminate human interfaces between systems
- Would eliminate paper required to plan, record, and report order production.

Boundary conditions for the project included a recently selected Scheduling system, which would provide a feed of Manufacturing, Blending and Shipping Work Orders. On the back end of the process is the ERP system that will be used to account for the manufacturing, blending, and shipping processes. The ERP system is also responsible for Sales Order entry and Invoicing.

The 23 future processes were summarized into a detailed requirements document. The requirements were split into three groups along the life cycle of a manufacturing work order. The requirements of the three groups are highlighted below.

Requirements for the Planning Group

The study team recommended automated tools to schedule the operations of the plant for the Planning group. The highlighted goals for these tools were the following:

- Receive work orders from scheduling system
- Enter new work orders
- Link and prioritize work orders
- Automatically add a standard list of instructions when a new work order is created
- Maintain links to sales and purchase orders
- Allocate equipment and raw material resources
- Enter order attributes such as raw material setpoints
- Release work orders for execution
- Monitor progress of work orders

Requirements for the Operations Group

The study team recommended automated tools to monitor and execute the schedule for the Operations group. Highlighted goals of these tools were the following:

- Easily view, execute, and record work order procedures and instructions
- Easily monitor progress of work-orders by production train and work-order type
- Enforce consistent work-order procedures
- Capture and allow viewing of the date and time of starting and completing each instruction

- Capture and allow viewing of the operator's initials, as well as information on who started and completed each instruction
- Note the start of timed instructions such as heating and mixing, allow viewing of the time to completion of timed instruction, and apprise appropriate personnel when a timed instruction completes
- Display and determine when pumping should be completed
- Allow appropriate personnel to easily take the proper action for the instruction
- Interact with Laboratory Information Management System (LIMS) to initiate samples and get sample result information
- Allow the supervisor or person of proper authority to override the requirement of completing an instruction before proceeding
- Allow the supervisor or person of proper authority to override the requirement of completing an associated work order before starting a work-order
- At the completion of pumping instructions, the study team recommended that the system perform the following tasks:
    - Compare the total amount of inventory produced versus the total amount of inventory used, and then indicate if the work order is balanced
    - Allow the operator to correct pumping records, with a required comment on each corrected value
    - Transmit the pumping results to the ERP system
- Interact with automated DCS systems for automated instructions such as batching and blending
- Provide work order execution reports for each work order completed.

Requirements for the Inventory Accounting Group

The study team recommended that data be available in order to account for the cost of manufacturing for the Inventory Accounting group. The goals for the system were the following for monthly inventory balancing were:

- Provide a list of "bulk" materials that are "out of balance"
- Provide a list of tanks that are "out of balance"
- For each material or tank on the list, the user should be able to traverse to a detailed list of events for the month.

Selection of Potential Vendors and Software Review

Once the functional requirements were established and a document composed, the study team selected three potential vendors to whom the functional requirements document was delivered. These vendors were selected on the basis of the study team's assessment of their perceived capabilities to deliver the required MES system, and included an ERP vendor, a traditional MES vendor, and a DCS vendor.

As part of the selection process, each vendor was required to present its software solution to the study team. The process consisted of the development of approximately 15 scenarios, selected by the Oak Point study team, in which each vendor was to employ Chevron Chemical data. Vendor demonstrations were based on these scenarios. Each vendor was provided with approximately 30 days to prepare its presentation, and was given two days to present its solution to the Oak Point team.

The ERP Vendor Proposal

Overall, the study team found that the proposal presented by the ERP vendor was cumbersome and required many changes in work processes. Major areas of concern included the look and feel of the system and its awkward manipulation. Further, significant gaps in the software would require a lengthy development time because of the company's development cycle.

The Traditional MES Vendor Proposal

The study team had selected the traditional MES vendor as a candidate based on that company's stable software, easily configurable recipes, and advanced features offering multiple signoff layers. However, after evaluating the proposal, the study team determined that the traditional MES vendor's solution was not aimed at the petroleum-based specialty-chemicals business. The vendor had no experience in solving the complex problems in balancing expandable liquid movements in a chemical plant, which may be going several different directions at once. Further, the solution did not fit well with the current infrastructure, a detriment that would have required the development of many interfaces. The study team decided that the fit would require an unnecessary amount of work and a learning curve that would be too steep to be effective.

The DCS Vendor Proposal

The Oak Point study team elected to award the contract for the MES project to a DCS vendor on the basis of the following four key factors:

- The DCS vendor provided a simple and easy-to-use operator interface
- The solution could integrate with the Oak Point plant's current infrastructure, which, among other benefits, would reduce operator training
- The system provides an open architecture to allow development of specific Oak Point business rules.
- The DCS solution yielded a 90% fit to requirements.

To address all of the requirements of the MES, however, the DCS vendor would commit to developing interfaces to new software, along with implementing new versions of some existing software.

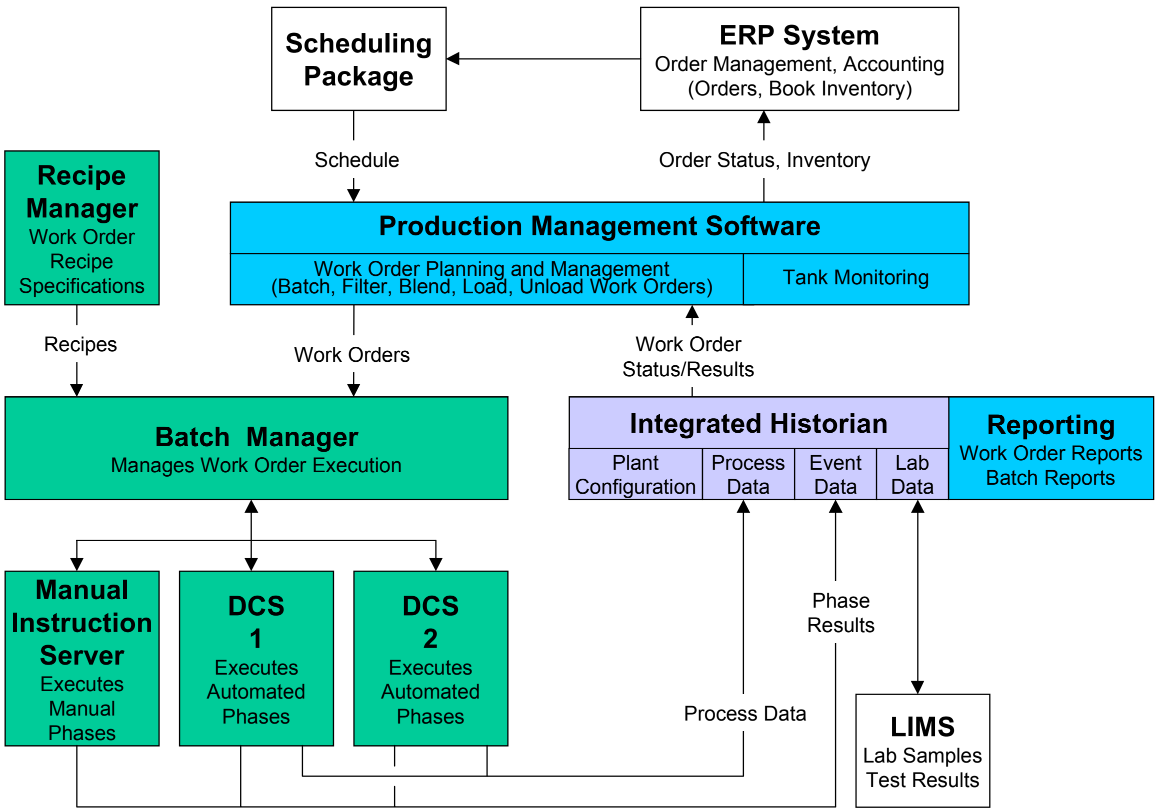
Phase 3: Implementing the Solution

The MES implementation project kicked off in November 1999. As of this writing, the implementation team has prototyped several processes and completed initial pilot testing with operations. Equipment and material hierarchies have been established, and interfaces have been defined, and several have been developed.

The Oak Point plant anticipates full deployment of the system into manufacturing operations in late 2001, with deployment into blending and shipping operations early in 2002.

The MES solution that meets Chevron's requirements consists of a production management software package that is integrated with an S88 batch management system for work order procedure specification and execution, and an integrated historian that provides the execution records and results back to the production management software and to the ERP system. The software architecture is shown in Figure 2.

Figure 2.



The production management software package receives work order schedules from the scheduling package, which receives demands, sales orders and forecast demands, from the ERP system and Production forecasting system respectively. The production management software package allows planners to view the current work order schedule by process area, equipment, product, or raw material. The package also provides an interface for planners to create new work orders or add attribute data to existing orders. On a daily basis, the planners release the work orders to operations for execution.

An S88 batch management system is then used to execute the work orders based on predefined procedures created using the batch management systems' recipe manager. The batch manager then coordinates the execution of the individual work order instructions, which are implemented as S88 phases, using one of two DCSs for automated phases and a manual instruction server for the manual phases. The manual instruction server presents and records the required instruction information to and from the operators as defined by work order procedure. The selected system uses Web technology to execute and prompt for completion and parameter entry for the manual instructions.

As the work order is executed, process, event, and lab data is collected and consolidated in an integrated historian. Appropriate results and statuses are sent back to the production management software to provide ongoing status to the planners and work order activities. After appropriate inventory balances are checked and corrected, order and inventory information is sent to the ERP system. In addition, reporting and analysis applications that work with the historian are used to create work order execution reports and inventory reports.

The open architecture has allowed straightforward integration between systems. For example, an interface has been developed to allow entry of new lab samples into a third-party lab system to be a step in the execution of the work order. The lab system then prints out a label with the required handling documentation and sample requirements into the process area.

Benefits of MES Solution

The following section contains a description of the expected benefits of the MES system.

Enforce Record Keeping, Procedural Consistency, and Compliance The MES system will now force operators to execute the work order procedures the right way and the same way every time regardless of the automation level. The work process will now be automated without the need to automate all of the equipment. The procedural consistency and compliance will improve quality and cycle time.

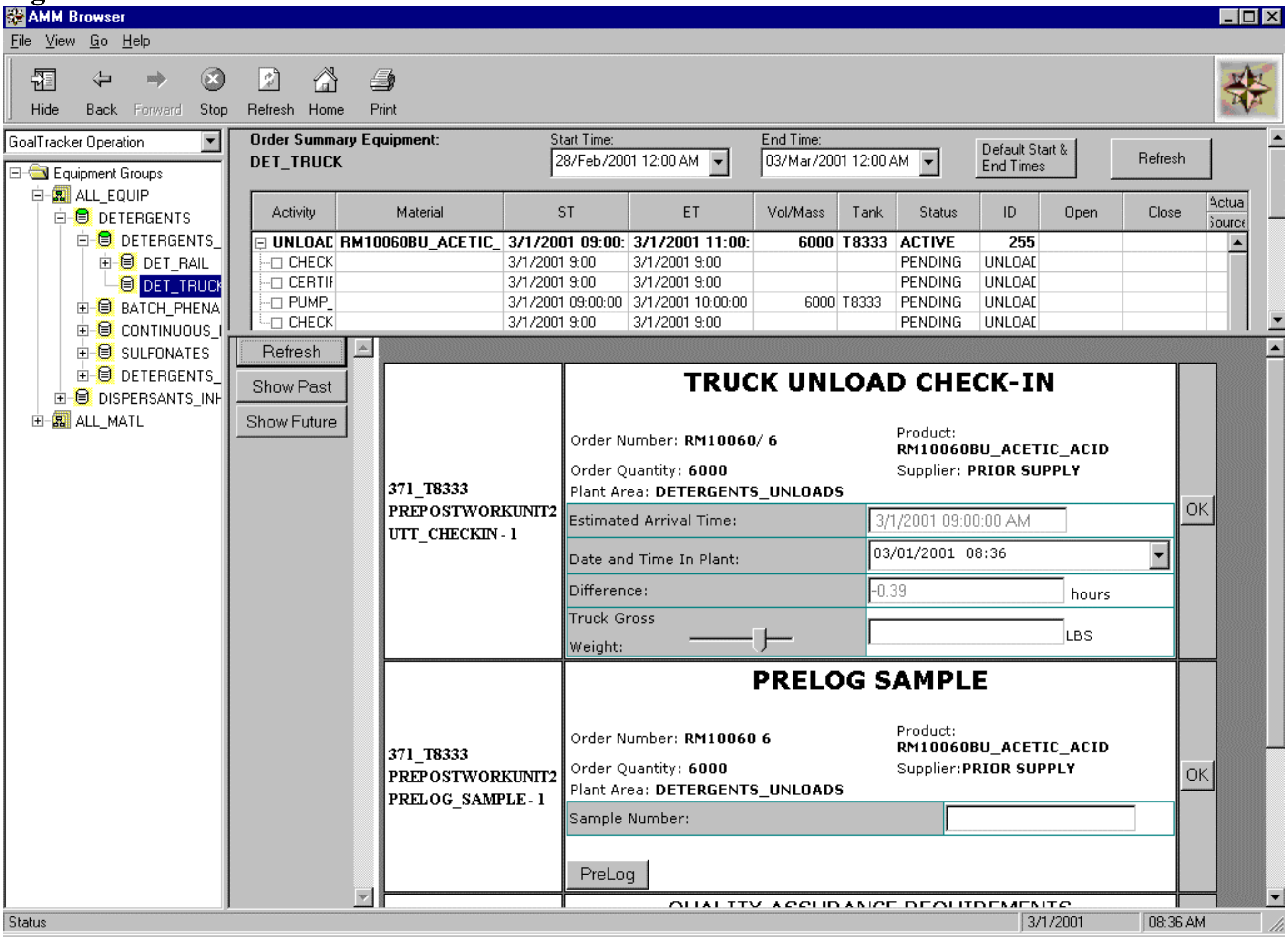
Improve Operator and Plant Efficiency Operator and plant efficiency will be greatly improved by removing verbal instructions, manual reporting and paper trails from the work practices. Currently Chevron operators spend 25% of their time on paper work. This number will be greatly reduced by the MES system. In addition, the Web-based instruction pages will be able to execute and time, time-based functions, interface with the LIMS system, and notify operators when actions and events are complete versus requiring lookup. The Web-based environment of the selected MES system allows instructions to contain any HTML functionality. Instructions will be able to contain scripts to execute timing functions for the operators and display information from the LIMS system.

User Interface Consolidation The integrated user interface (UI) allows planners and operators to navigate through the same equipment and material models to schedule, monitor, and execute work orders and instructions. Order information, tank information, batch instructions, operating instructions, and lab data could all be viewed and accessed from the same UI.

From the user interface, the operator will view the work order and work order details by process area, equipment, product, or raw material. The planners will use the same UI to view and maintain the current work order schedule. In addition, the operators can view and execute the individual work order instructions from the same UI, as well as view the status of automated instructions (phases), and process information such as trend profiles and tank information. Additionally, the sample instructions interact with the LIMS system to bring its data and information to the same UI.

Figure 3 shows one view of the software's UI. The top pane shows a list of work orders for unloading of trucks in order area of the plant. The second pane shows exactly what instruction needs to be completed next for a particular truck unload.

Figure 3.



System Tracking and Optimization As shown on the software architecture diagram, the integrated historian will consolidate the process, event, and LIMS data for the automated and manual processes. All work procedure events will be automatically recorded with appropriate attributes and time stamps. This will provide Chevron with the environment to analyze and optimize the processes.

ERP Integration The ERP integration provided by the MES system will eliminate lags in reporting and tracking processes. Electronic checks on the manual entries, the automatic tank balancing at the end of material movements, and the ERP integration will give Chevron a more accurate and faster response of inventory. This can enable e-Commerce and free up working capital.

Key Performance Indicator Determination and Tracking A potentially large benefit that was not envisioned at the beginning of the project is the implementation and use of key performance indicators (KPIs). The capture of KPIs will allow the Oak Point plant to collect the statistics fundamental to an agile manufacturing process. Properly instituted and evaluated, KPIs can provide the facility with a new way to measure its performance, and therefore, its capability.

The following are some initial KPIs that can be tracked:

Batch yield versus standard
Batch cycle time versus standard
Reaction cycle time versus standard
Certification cycle time versus standard
Cool-down cycle time versus standard
Pump-out cycle time versus standard
Raw material consumption vs. recipe

Time of vehicle/vessel on-site
Safety compliance reports
Certification cycle time
Plan vs. actual order quantity
Vehicle/vessel preparation cycle time
Pumping cycle time
Individual transfer quantity balance
Vehicle/vessel checkout cycle time.

Tank Movements in the new system Recall in the beginning of the paper the arduous task of recording and reporting a single tank movement. After implementation, a tank movement can be a simple four-click operation. If the tank is automated, the gauge will be automatically captured and operator will be presented with the step to setup to pump the material. One mouse click will indicate the pump was started. A second mouse click will indicate that instruction was completed. A third mouse click will indicate the pumping was completed. The fourth will indicate the pumping complete instruction was completed. All data is captured by the system, calculating how much was moved. Opening and closing gauges are logged so a history of the tank movements can be easily reported. And the transaction will be recording in the ERP system in near real time.

Benefits of Using S88 for Work Order Specification and Execution

As indicated in the software architecture, S88 batch management software was used to provide the work order procedure specification and execution environment for the MES solution. S88 and modular batch automation proved to be an ideal environment for the specification and execution of work order procedures and instructions. This section discusses the benefits of implementing work order procedures as S88 procedures and instructions as S88 phases. Early on, it was decided that instructions would be treated as phases versus individual phase steps to allow for a more flexible system and to collect and mark events records such as start- and end-time on a per-instruction basis.

Reusability – With S88, work order procedures and instructions are reusable for different equipment and materials. For example, the same truck unload procedure can be used for all materials and the same capture gauge instruction can be used for capturing initial and final gauges in all unload, load, and transfer work-order procedures. In Chevron Oak Point's case, approximately 10 manual work order procedures, 650 tanks, and 80 materials, will be implemented with a similar number of procedures and approximately 30 instructions using the S88 batch management software.

Specification and Execution Standardization – The S88 environment provided specification and execution standardization for the MES system by providing the environment to define and maintain standard procedures using a standard work instruction library.

Recipe Management Flexibility - The ability to use SFC specifications for work order procedure management allows instructions to be executed in parallel, sequential, and with divergent paths based on specific work-order attributes. In addition, as shown by the software architecture, the manual and automated steps and processes are integrated through the recipe procedures.

Conclusion

The goal of the Chevron Chemical Oak Point plant was to implement an effective, cost-efficient, and workable MES that would help the plant dispense with its heavy reliance on a paper process, automate its activities, and achieve maximum manufacturing levels. After a thorough investigation and gap analysis of its current situation compared to its desired position, the Oak Point plant was able to ascertain the functional requirements of the appropriate system for the facility. After selecting a vendor to provide the system and prototyping the implementation, the Oak Point facility is realizing the potential benefits of the MES system and the benefits of using S88 batch management for the specification and execution aspects for the MES work order procedures.