Measuring, Managing and Maximizing Performance in Petroleum Refineries

O. A. Bascur, Ph.D. and J.P. Kennedy, Ph.D.
OIL SYSTEMS, INC.
The Woodlands, TX and San Leandro, CA.

Invited Lecture for the Japanese Petroleum Institute, Kaneko M., Ed. COSMO Hirakawa-cho,Chiyoda-ku, Tokyo 102, Japan, January , 1995.

The implementation of continuous quality improvement is the confluence of Total Quality Management, People Empowerment, Performance Indicators and Information Engineering. The supporting information technologies allow a refiner to narrow the gap between management business objectives and the process control level. Dynamic performance monitoring benefits come from production cost savings, improved communications and enhanced decision making. A refinery workgroup information flow model is presented to help automate continuous improvement of processes, performance and the organization.

Rethinking Refinery Operations

In this period of challenge and change to our industry, we are going to see increased demands on the types, quantity and priority of information. The pressures of governmental regulations and self-imposed safety and environmental initiatives will require that a real time information product be made available to all our personnel. Everyone from Engineering, Maintenance, Operations, through to top management and outside authorized customers, suppliers and governmental agencies must be served.

Information technologies are emerging faster than many organizations can take advantage of them. The top priority is to align information systems with corporate goals. Success stories show how important it is to get the strategy right before keying on the information technology.

To meet these challenges, companies have automated a number of plant operations, such as those for process control, maintenance, inventory control and product development. The business, management and administration departments have also set up computer systems for tracking sales, forecasting production, entering orders and paying accounts.

The isolation between disparate systems - especially between the plant and business systems - strongly limits a company's ability to deal rapidly with changing economic, market and product cycles.

Standards and technology for bringing information to the desktop has greatly evolved in the recent years with the introduction of high-speed networks that can transfer data between the various computer in a plant. With proper design, information in different computers can then be viewed, replicated or written to the desktop using a graphical user interface. The routing and access of the information can also be organized by workgroups, thus enhancing the work procedures and making interaction by people more efficient. The implementation of such systems required a profound knowledge of the petroleum business and the emerging new technologies.

This paper will highlight practical information technologies that are being applied in the development of enhanced dynamic performance monitoring systems and integrated workflow systems. The impact on the plant organization is discussed and a high level plant work flow model is presented. This information flow adds another dimension to enhance the productivity of the plant. The concept of the knowledge coordinator is introduced. Here one's focus on the processes, not the functional aspects of the work. Every employee is adding value to the information and not simply routing or processing goods or information.

The key ingredients for such a integrated system to work are the Total Quality management philosophies, Empowering People, Business Refinery Performance Strategies, and Information Engineering Technologies.

Dynamic Performance Monitoring

The objective of the plant information network is to bridge the gap between process control and business information systems, and provide adequate information to maximize day-to-day economic performance at the plant through fast, on-line and off-line optimization. A refinery data warehouse integrates the information necessary to act on opportunities in economics and planning, safety, maintenance, engineering, laboratory, environmental, advanced supervisory controls, scheduling and crude supplies.

Plant information systems must integrate business objectives with process control. It is amazing to discover that each business day many companies throw away a valuable corporate asset, their high fidelity history of production. A plant information system automates the collection and archiving of this information and makes data from the all operating areas available to the whole company.

Included is a real time data historian (RTDH) which scans and historizes information from different sources, e.g., Process, Business, Laboratory, tank gauging systems, manually entered readings, and provides viewing , reporting, analysis and communication tools for operators, engineers and managers. The data are transformed into information via business rules and performance calculations. Plant personnel monitor performance indices to identify problems and their root causes. Process managers identify initiatives to correct problems and analyze costs and profits.

Table 1.- Benefits of Refinery Performance Monitoring and Control

Increase yields of more valuable products at the expense of lower value products
Increase capacity by identifying, pushing and optimizing constraints
Increase margins by better and faster coordination of activities
Optimize energy costs
Improve product quality for customer satisfaction and government compliance
Increase equipment life and stream factor
Improve plant and personnel safety
Improve staff utilization and efficiency
Provide faster response to change
Minimize or eliminate operator errors
Reduce less profitable capital expenditures to achieve equipment results
Better and more timely production, engineering and management information
Enable improved work flow procedures
Add value and performance indices to raw data
Better response to emergencies and better analysis of past incidents
Empower the organization
Decrease manpower used for reporting, analyzing and compliance
Implement work flow processes with associated procedures and training methods
Effective decision making at the proper level
Greater flexibility of plant operations
Faster response to opportunities
Improved planning, scheduling and coordination of the refinery
Improved recipe for specialty products
Reduce inventory requirements
Enhance productivity of engineering team
Better communications between corporate, plant management and operations
Less time spent gathering data, more time spent solving problems and acting on opportunities
Improve understanding of plant operations and economics

The key elements of real time performance monitoring control and monitoring system are:

1.- Agreement on the critical few
2.- Agreement on the methodology of measuring performance
3.- Corrective Action Planning
4.- Clarification of roles and Responsibilities
5.- Regular progress reports and review meetings
6.- Recognition of progress and achievement

Once these key performance indices are defined such product yields, quality indicators, costs indicators, energy indicators, safety indicators, environmental indicators, their calculations methods need to be defined and they must be monitored continuously. As such, each area take what it needs to monitor and learn how to control these indices. Each area also needs to define the cause and effects related to their mayor activities.

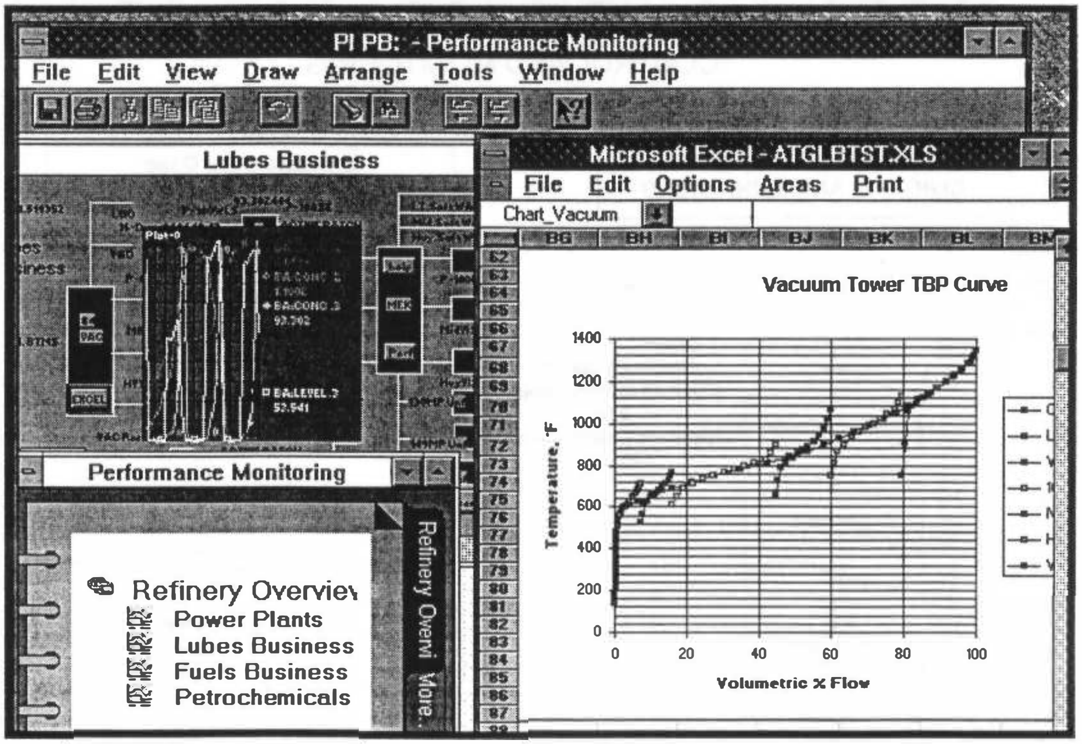

Figure 2 Integrated Process Management Workbench

Dynamic performance spreadsheets are easily constructed (using Excel as an Example) with the ProcessBook workbook. Data linking features avoid having to re-key or retrieve additional data. The user can start report runs with no manual data entry and be free for other higher value activities. Figure 2 shows an integrated process management of a complete refinery business area and a particular recalculated TBP curve for the Vacuum tower. The integration of process data with laboratory results organized by unit and blocks allows the user to configure these specialized spreadsheets for performance monitoring.

Modern spreadsheets permit automatic integration of presentation quality graphs or charts. Plant data do not have to be re-entered into a separate formatting program for crisp, professional reports and presentations. This is a major quality improvement in the added value to the data, the content of information as well as the appearance of the reports. The elegance of using a spreadsheet is that everyone in the workgroup has access to a single copy of accurate process data and can make their own analysis. Individuals may also have their own Excel spreadsheets, but they are always working with current information and from a unique data source for enhanced decision making and for continuous improvement. This added flexibility is a must in today's rapid changing environment.

The data are used by process engineers for continuous improvement of their processes, using steady state or dynamic simulators. Performance cost/benefit analysis can help resolve problems and reveal opportunities for debottleneking with minimum capital investment. Users can move closer to product constraints such as pumparounds, circulating loads, flooding, Reagent/Product ratios, product specs, reformates, RVP, and minimize product giveaway and develop cost effective recipes to improve customer satisfaction and minimize cycle time for scheduling of the integrated production plant.

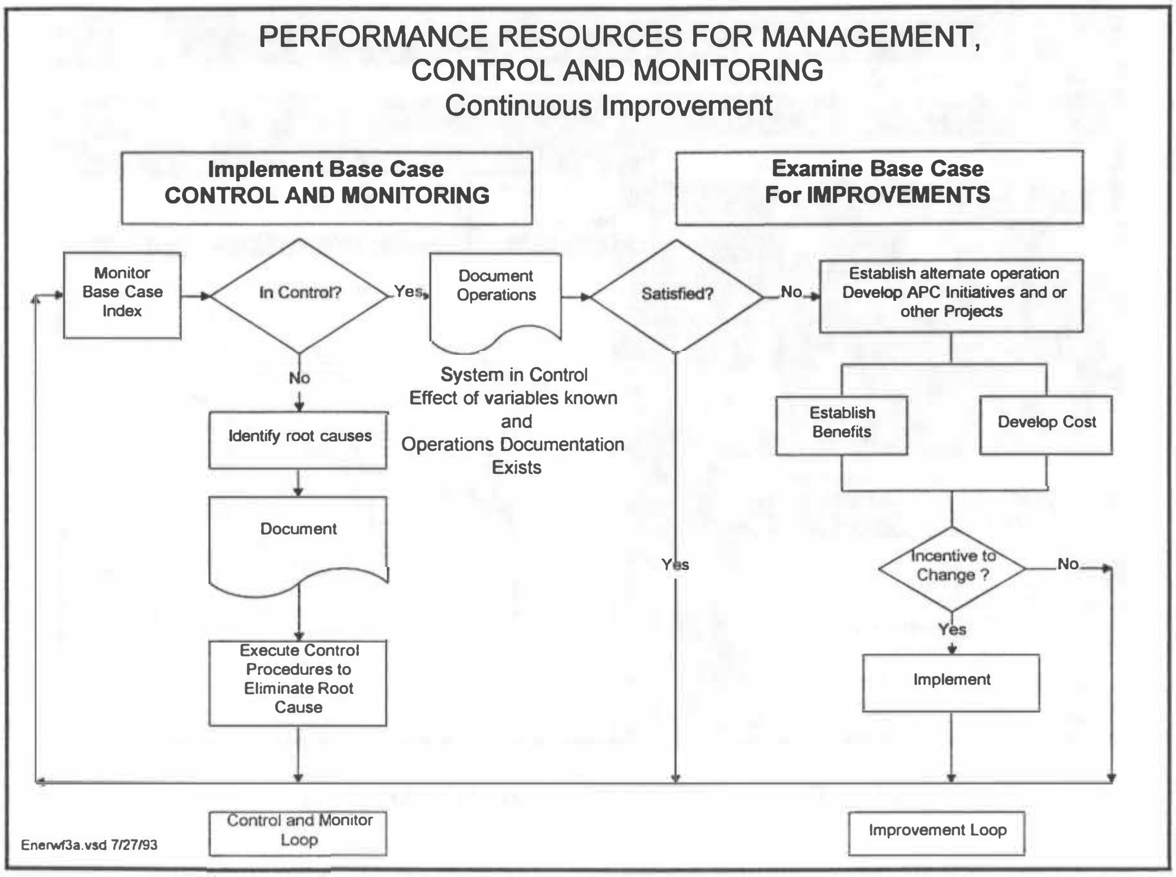

Figure 1. Continuous Improvement Loops.

Figure 1 shows the workflow process of monitoring and reviewing these indices. This figure is an extension of the one proposed by Badavas, 1993 and is based on two separate loops. One is the control and monitoring loop and the other is the improvement loop. The improvement loop is handled by the support teams (engineering, maintenance and management). This metaphor simplifies process management. Operating teams are in charge of maintaining the process at a certain degree of variability while the personnel in charge of the improvement loop must ask the question if it is cost effective to improve. There are other workflows, e.q. production, quality, cost, maintenance, safety, environmental improvement, that will use similar continuous improvement loops.

ARE WE IN CONTROL? LOOP

- Provide the operator with a cause/effect diagram with attached information for key performance indices.
- Provide assistance by linking to operating procedures models and E-mail facilities to notify staff support teams.
- Document root cause analysis for further improvement.
- Access directly to work order system for maintenance, engineering, and management attention.

ARE WE SATISFIED? LOOP

- Run unit/process model to simulate the plant and calculate alternative operating conditions, given process constrains, and product specifications.
- Automated heat and mass balance reports estimate material balanced energy efficiencies.
- Use of steady state simulator and dynamic simulators to identify and evaluate alternatives.

Process Continuous Improvement

One of the main connectivity features between a real time data historian like PI, from Oil Systems, Inc. and the desktop is a tool called PI PC Datalink. The PI PC Datalink allows easy and fast interface to the familiar MS Windows spreadsheets such as Excel and Lotus. Learning is easy, requiring minimum training time. It allows reporting and analysis without having to re-enter manually data from logsheets or other data acquisition systems.

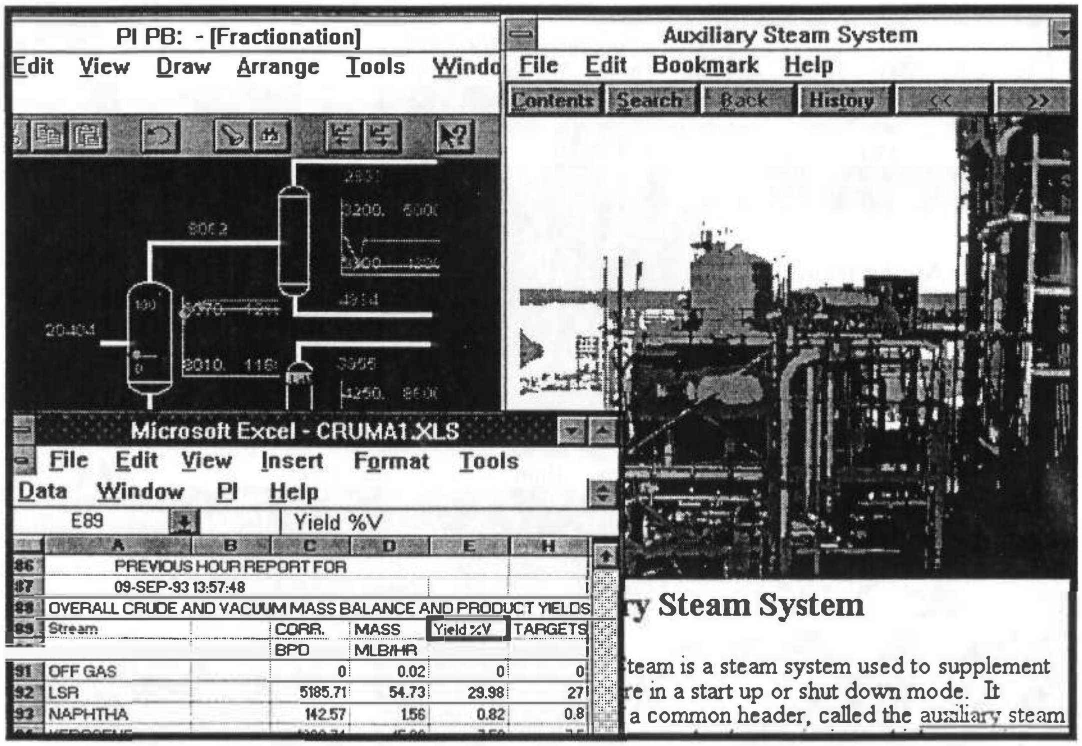

Figure 3 Live Spreadsheet and Graphics.

Historical data are used by maintenance engineers to perform enhanced preventive maintenance using statistical analysis of events of key equipment and indices for yields, fuel consumption, heat exchanger trains, oil pressure and temperature, exchanger fouling, etc.

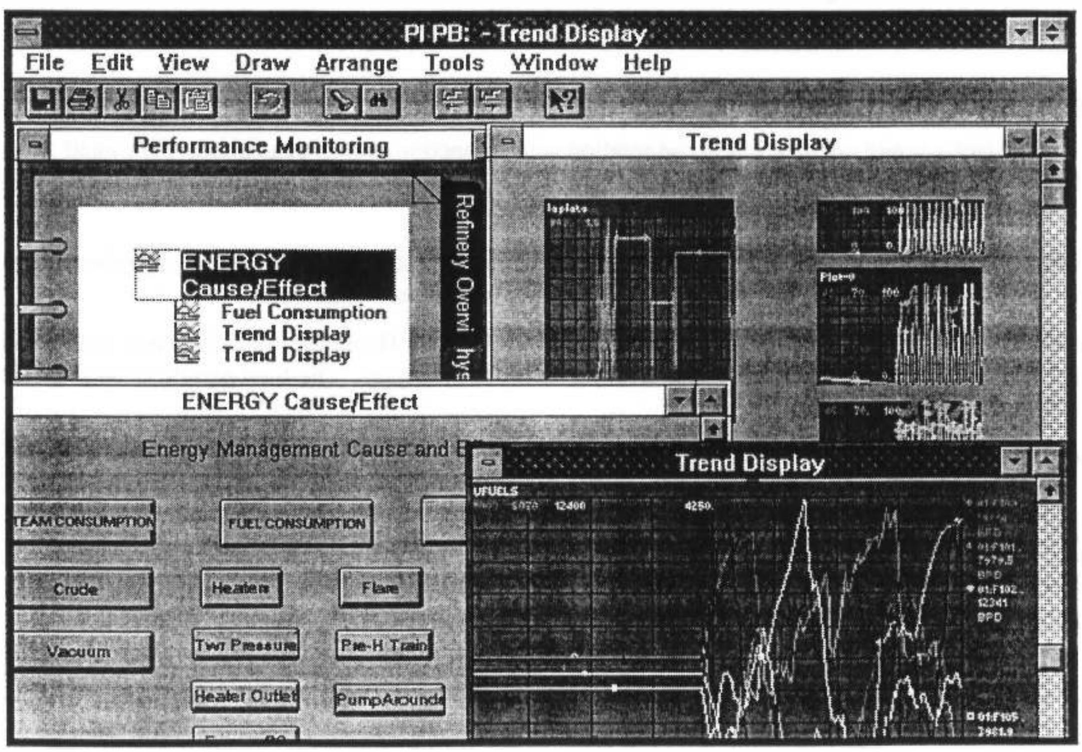

Figure 4. Energy Cause and Effect Diagrams and Dynamic trends

Improvements in throughput, product yield and efficiency can be realized with relatively small or no investments. Plant designers are often trying to foresee what will happen in the practice. Market changes require flexible production facilities which can cope with a variety of features and realize different product specifications. Modern data networks will bring cost, pricing and industry average indices to the plant floor.

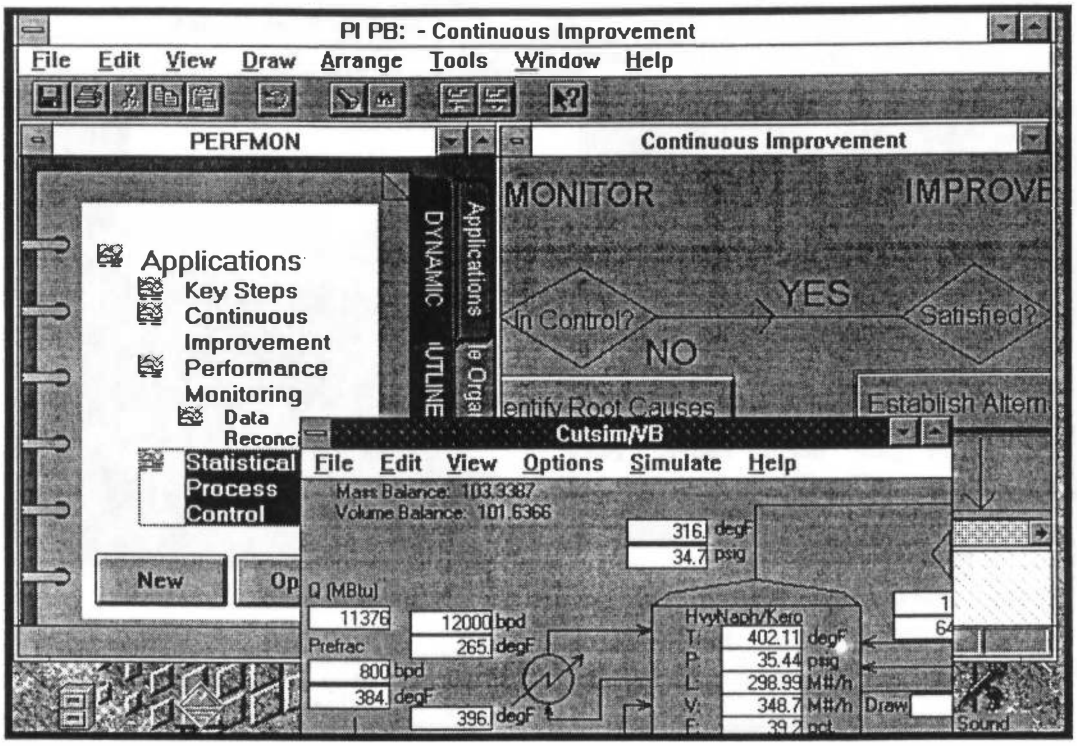

Figure 5. Continuous Improvement using an On-line Fractionation Model

There is a wide range of potential operating zones which opens the way to continuous optimization of process operation. Decisions on change are always present but not clearly recognized for what they are, improvements are often neglected. Examples above have shown individual actions. The next paragraphs will look at workgroup activities.

The Knowledge Coordinator and Repository Manager

Setting of key business objectives and goals requires cooperation across functions and organizations. We need stronger, more timely links for integrated knowledge building by application development teams within different organizations (Bascur, et. al., 1992). The information will be coming from specialized servers to clients applications.

Business information must be timely, accurate and accessible by the decision makers if the enterprise is to be successful. Applications should not be judged in isolation, they should be judged on how they provide total value added.

For this concept to work it is necessary to identify the process and its structure. The major benefits come from identifying the interrelationships and commonalties to extract the essence of the involved processes. The final benefit is an overall simplified process, communication and understanding.

The knowledge coordinator is an information filter that provides the information to the individual to conduct his/her job including the business strategies compliant with external requirements of the enterprise. The knowledge coordinator is a metaphor that allows to integrate the way that people interact together and their access to the information required to perform their activities. It is amazing that this knowledge coordinator concept is not new but in modern systems it maybe a software agent for a person. Process control engineers are familiar with how these connections are made in a control/information system. We need to develop the necessary procedures to capture these links while we configure the system.

How do we do it? We can imagine that we are configuring the display for an operator to control a process unit (Bascur, 1990). It is customary to design an overview display and a group display relating to the key control variables and indices. While we do this configuration, the system is classifying and storing the links to this display for fast access. The links and connections to the sources of the data are stored in data buffers and are handled by a communication device using exeption reporting. When we combine all the operator displays, control groups and applications we have designed an object manager that brings the required pieces of information together. What must extend this to add procedures, process safety management, training, management of change, profitability data, maintenance information and mechanical information, customer relationship with the products in hand, etc. Figure 6 captures the essence of the idea.

The data repository manager or data warehouse maintains the integrity of the information. It ensures safe, controlled sharing of the information from several sources. Some of the functions of a repository manager are: security, data access and validation, auditing, work flow, information version and status management, automated change management, and replication.

The concept of the knowledge coordinator came due to the fact that not every one is familiar with the details on how to interpret the cause and effect diagrams, or to be current with the process safety management. The knowledge coordinator is a metaphor that allows to access not only the information but the training methods and procedures available to interpret the information presented to the users. Some of our customers are using extensively Windows Help to store operating procedures using a bookshelf metaphor (Figure 3). The PI ProcessBook can be used very effectively to integrate this type of information. For instance, for a energy index, we can develop a cause and effect diagram which has the relevant areas connected to real time or historical trends and variables organized to add value to the raw data and thus simplifying the process analysis as shown in Figure 4.

Another metaphor which has been found highly successful is the supply chain management. The products from one business area to the next business area tracked graphically with their consumables. Thus, we are always defining a customer and supplier relationship in the design of the graphic interfaces and automating the analysis of the indices required to satisfy the associated customer (Internal or external) (See Figure 2, integrated production model).

Until recently engineering, operations/maintenance, management and others could access the information only in one direction. The PI ProcessBook facilitates the integration of information from different sources as well as from different programs. Figure 6 shows the integrated view of information required by an operator.

Figure 6.- Empowering the operator.

The PI ProcessBook is built on Microsoft Foundation Class Libraries, and is compatible with Microsoft programs or other compliant applications, including word processing, spreadsheets, electronic mail, mathematical and statistical analysis or modeling programs. OLE2, the capability to embed live applications into other programs, is supported. This allows full integration of the desktop with different similarly compatible packages (Excel, Word, Access, Notes, Visio,...) across several vendors. ProcessBook may be used to retrieve data from more that one PI historian running in different operating systems. Future releases will enable users to retrieve and display data from relational databases.

The user interface is based on Book View or Outline View. The Book View creates a tabbed section for primary groups, such as Business Units, Plants Areas and/or Workgroups. Each section lists all the displays assigned to it. The operation uses the works of a typical workbook.

Spreadsheets can be linked to special button objects that calculate results based on the current or predefined history. These button objects can call trends for cause and effect root cause identification or call special Troubleshooting procedures (See Figure 4). Access to other information provided by other programs is also possible. Spreadsheets such as Excel or Visual Basic are used as programmatic interfaces. Figure 5 shows a simplified fractionation model written in Visual Basic for fractionation optimization. Displays can call associated information found in electronic document databases such as Lotes Notes, or ODBC complaint databases. As such, trends can display historical process data with targets or goals defined by the planning group.

Thus, if we use Figure 6, we can inform the operator not only on the process but the interrelationships with maintenance, engineering, management and others.

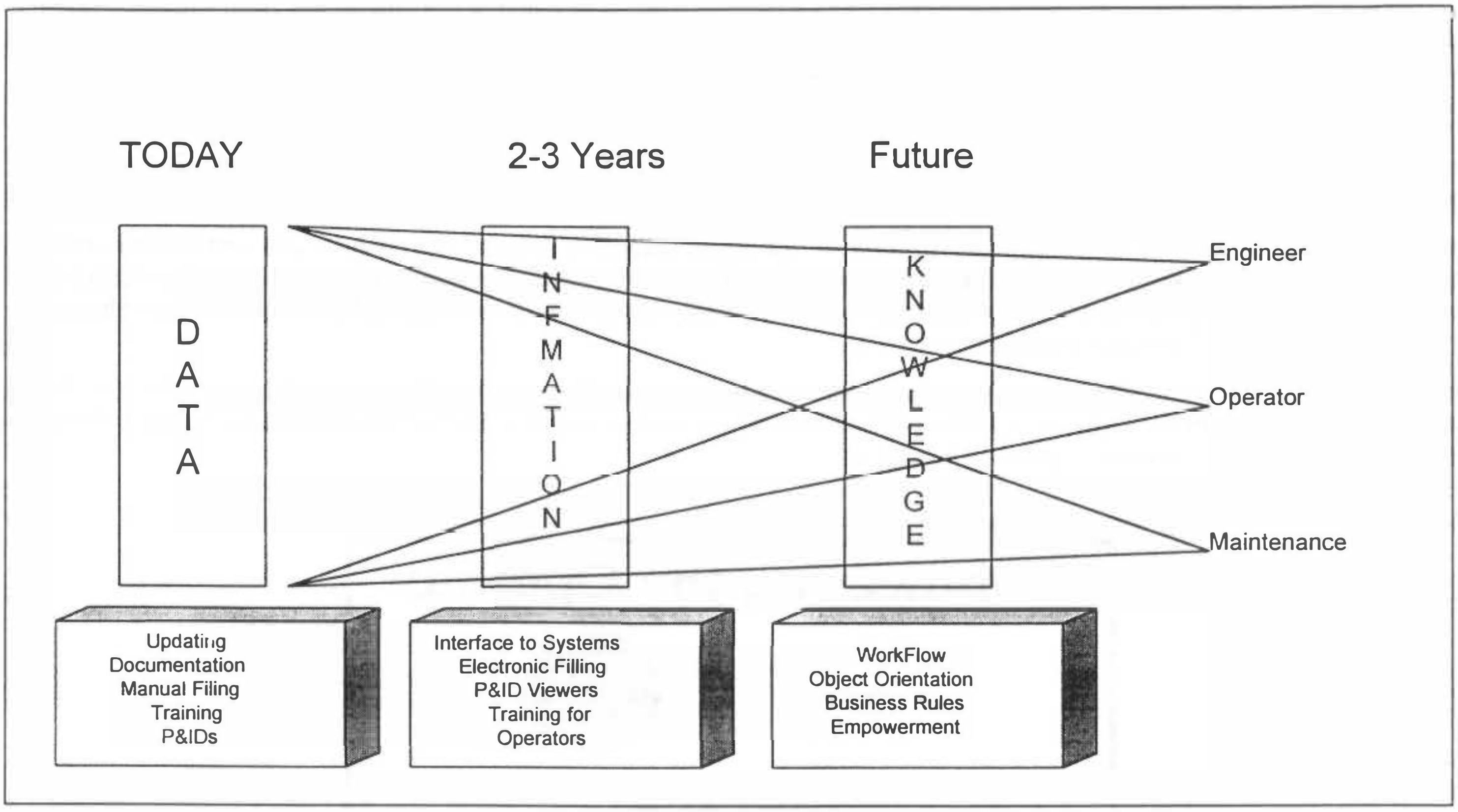

Figure 7. Long Term View for access of information

Figure 7 shows the long term view of accessing the information. Here the knowledge coordinator routes specific information from the same sources to an engineer, an operator and a maintenance engineer.

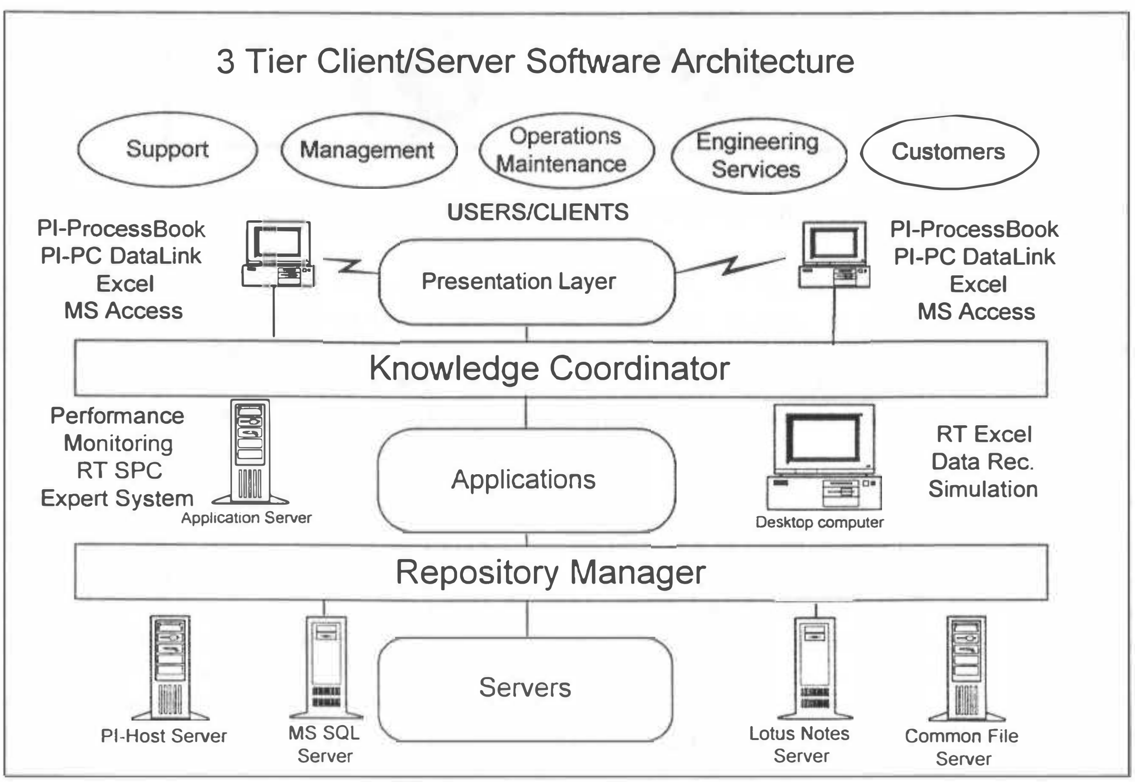

Figure 8. The Knowledge Coordinator and Repository Manager

Figure 8 is a simple schematic showing several server such as the Real Process Historian, File Server with the Refinery Production Models, Business Data, Process Safety Documentation, Product Quality, Simulators, Training Procedures, etc. Details of such computer architecture are described in Bascur and Kennedy, IMPC, San Francisco, 1994.

Example of An Integrated Plant Operations Workflow

Figure 9 shows the coordination and integration metaphor for a refinery. The operation/maintenance box shows real time performance management, just in time training, and access to process safety documentation. The planning group is connected to the information to examine the current performance and to plan the production using tools such as LP, Data reconciliation, supplier and customer data bases

The engineering is empowered by having access to the real time data to identify process control improvements as well as define benefits for capital project to enhance production. Management can visualize the work in progress from the workgroups and has access to the information for informed decision making.

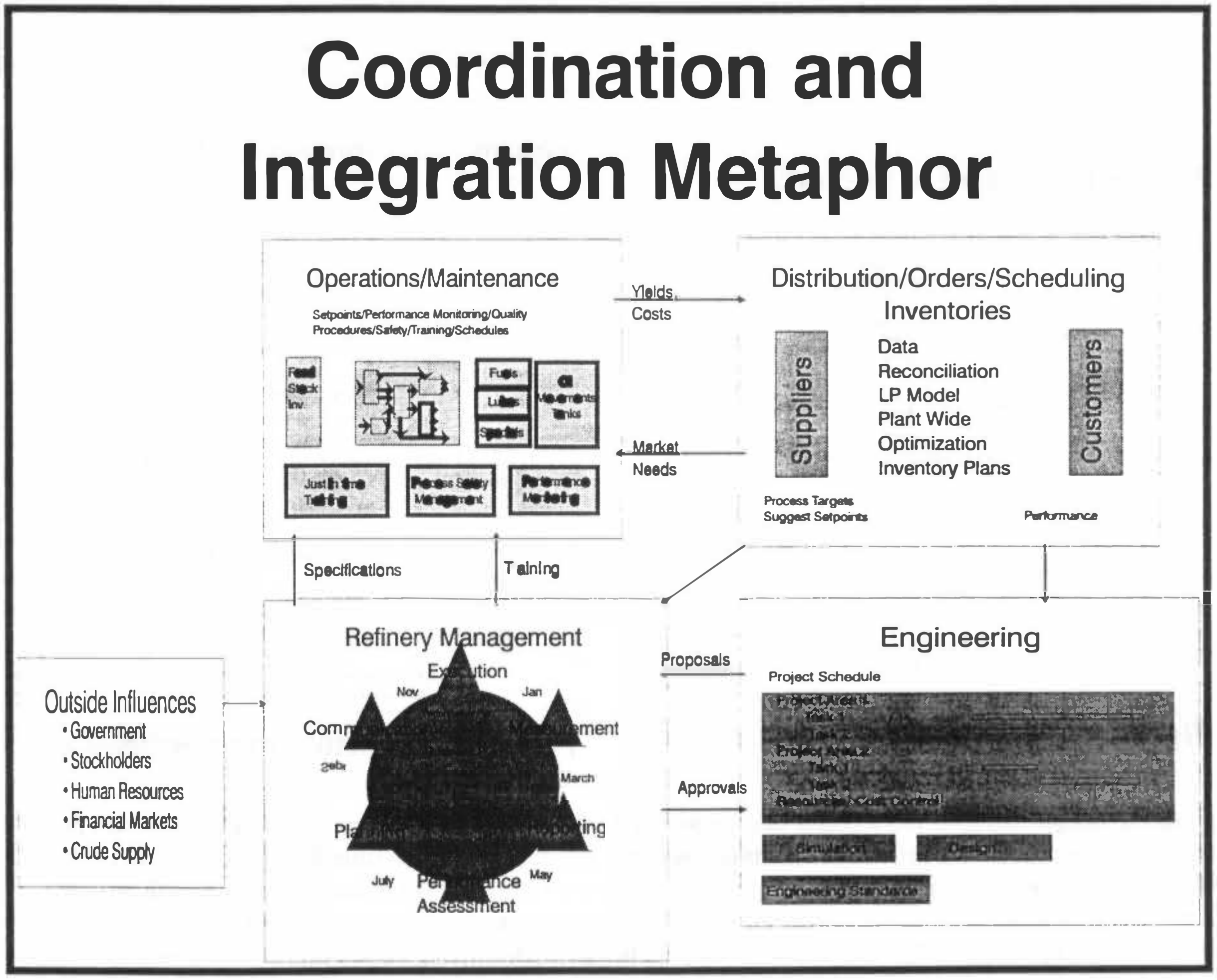

Figure 9. Refinery Coordination and Integration

The relationship between the coordination and productivity can be visualized in Figure 9. Graphical data flows for the Operator/Maintenance, Supply/Distribution, Engineering, and Management are shown. Behind each of these interfaces are the links and filters to information for the key 20% of the data for each person according to his role and responsibilities.

As these systems become widespread, the entire organization will become empowered as shown in Figure 7. In such an organization connectivity will allow the information to be focused by the knowledge coordinator. The system should contain context sensitive, just-in-time training and assist in identifying commonalties among systems and the integrated work flow in a refinery.

The following example shows as simple work group dialog between the group to enhance current operations (Bascur, et al. 1992). Here, Joe, the operator notices that pump P204 is 20% shy of the needed capacity to achieve the planned throughput next month. Joe sends a E-mail message to SAM, the maintenance man, requesting to fix the problem. Sam checks the fixed asset files for P240B vendor data and compares that with the currently installed pump via the maintenance equipment history. Noting that the pump does not meet the original vendor specifications, Sam then checks the current process design to see if there is a design change to re-size the

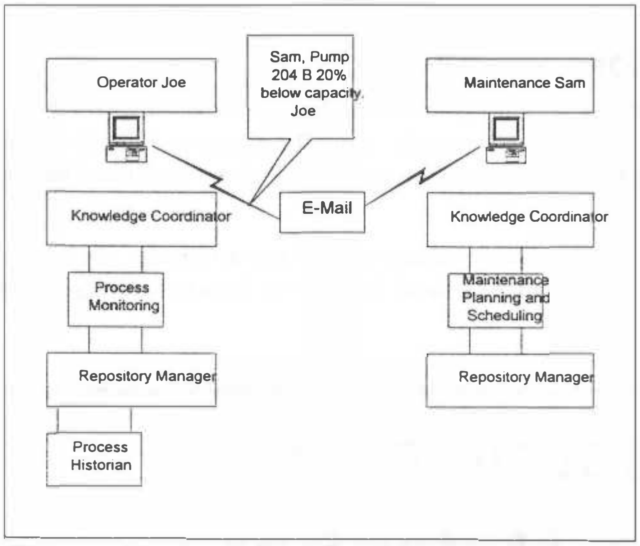

Figure 10. Operator Request

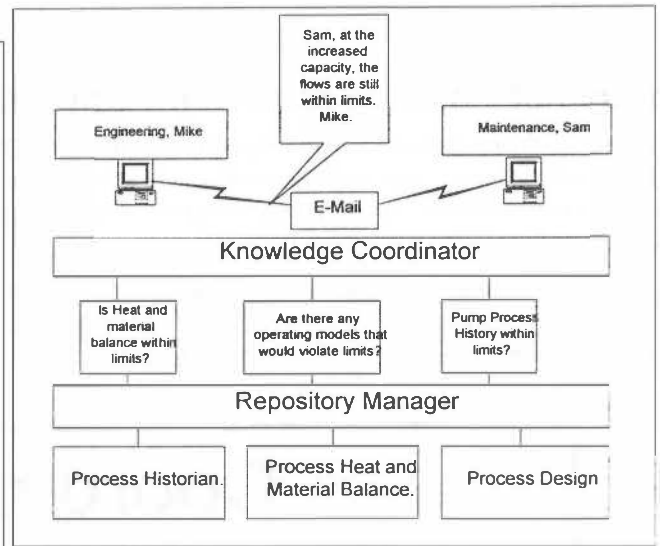

Figure 12. Engineering Decision

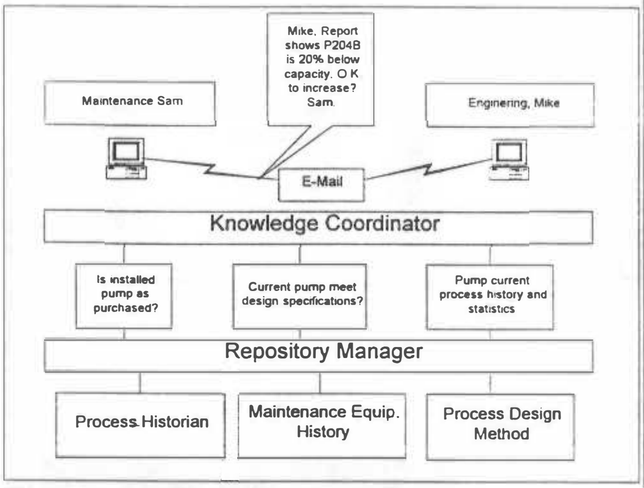

Figure 11. Maintenance Report

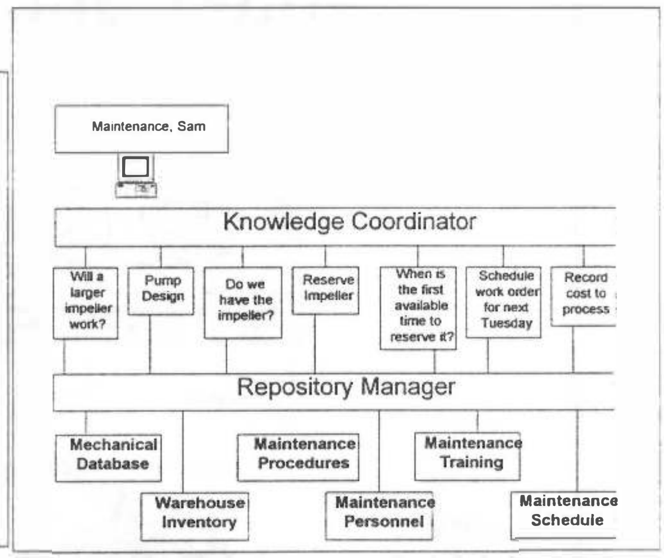

Figure 13. Maintenance Schedule.

pump. Noting that the design still specifies a pump like the one in the fixed asset file, Sam prepares a report and sends it via E-mail to Mike in Engineering. Sam asked is he can replace the pump without violating the permissible limits. Mike reviews the heat and material balances and sees that they could use a better pump to improve production. Mike then sends an E-mail message to SAM let him know that it is OK to upgrade the pump. Sam then runs a pump design pump and learns that a larger impeller would satisfy the design requirements. Sam then checks the warehouse for an impeller that meet the replacement in kind requirements of the design and reserves it.

He then run the maintenance scheduler to find the first available time to install the impeller. The program gets the total resources required via the maintenance procedures for the work from the maintenance procedures file. It checks the maintenance personnel file for the people to install the new impeller.

At Mid morning Sam calls Joe to ask if the predicted schedule would be OK. Sam confirms the work for the specified schedule.

This simple integrated work approach produces unexpected economic benefits. There are a significant reduction in maintenance costs and improved production. Both operations and maintenance work together. The maintenance personnel because they are integrated with the process management can really improve the operation. and all for a fraction of the manpower of a manual workflow.

Other enhancements in refinery integration of blocked operations is described in Figure 14. Here the production model of the refinery is the repository of the process information related to its units, streams in relationship to the refinery products.

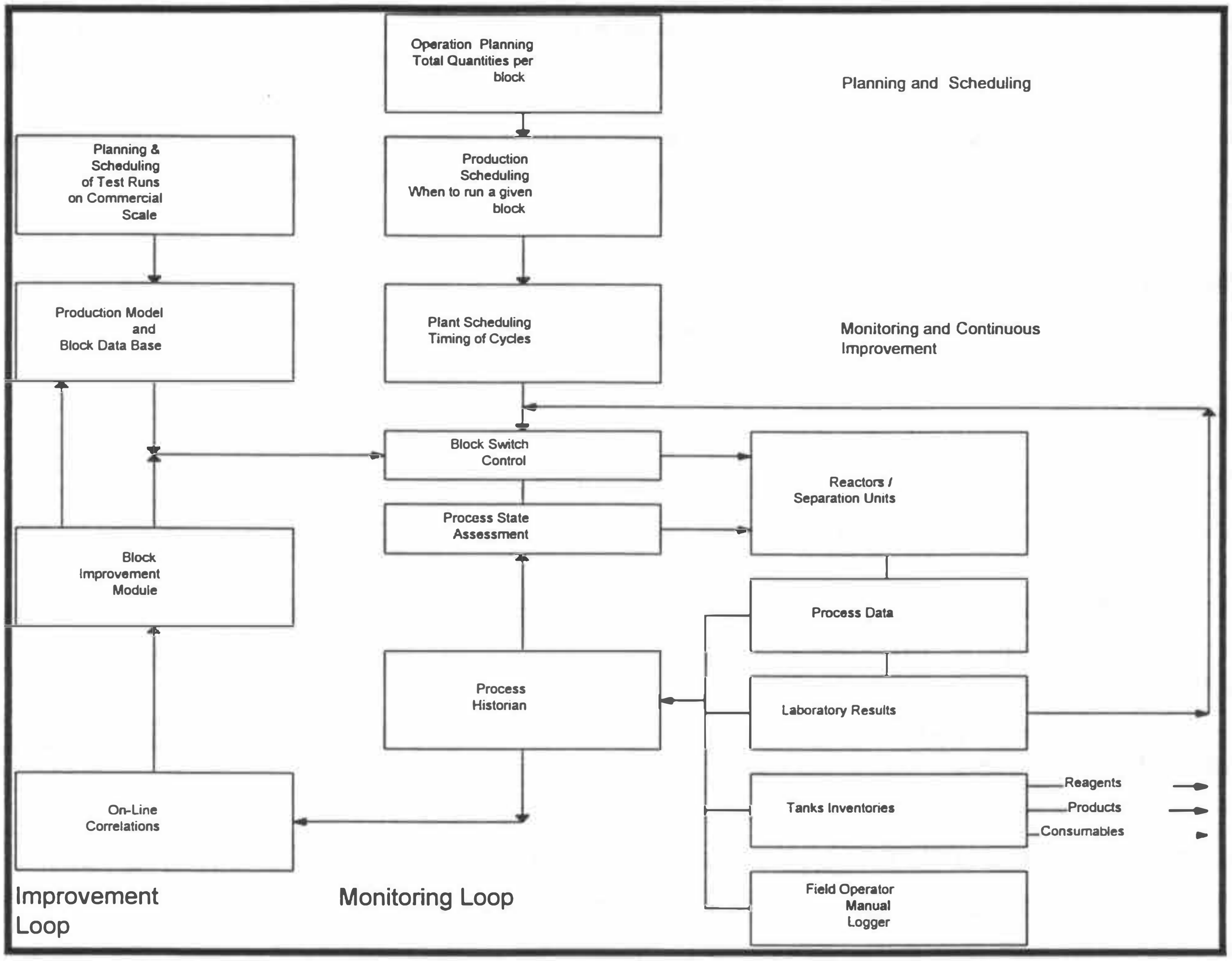

Figure 14. Block Continuous Improvement using the Process Batch Historian

The coordination between actual refinery processing and refinery planning and scheduling is being revisited as an opportunity that we called continuous recipe improvement. A production model of the refinery acts as the relationship between the control variables and the business variables organized by product or by customer. In lube refineries, these are called blocked type operations. In this case, the refinery model is decoupled into areas, blocks, each block with its own streams and product tanks. The production, quality control, planning and reconciliation tools are based on one set of relations organized accordingly. For instance, a reactor unit is used run blocked operations, each block produces different product which are intermediate or finals products. To optimize the overall profitability of the operation the associated margins for each products can be easily tracked once a production model is available. The production model is used both for planning and coordination of the dynamic operation (forecasting, dynamic performance monitoring and improving) as well as for the data reconciliation and yield accounting (past and reporting).

Conclusions

These technologies are available today to reengineer plant operation and increase the performance of current productions systems. The key is linking people workflow, business processes, strategies and the best enabling technologies. The major ingredients for a successful implementation are:

1.- An infrastructure that follows the suggested computer architecture, (Technology)

2.- The integrated Process Management Workbench using the Knowledge Coordinator such as the PI-PC ProcessBook metaphor to unify the access to information, (Business Processes)

3.- The implementation of total quality management guidelines and people empowerment (Strategies and People).

Large benefits can be obtained using current process control and information management systems, thus the incentives to implement these systems are very attractive.

The successful application should be judged on how it provides added to the overall information system, such as new ways of combining and visualizing existing data or information. Process and business information must be timely, accurate and accessible by the decision makers. This information has to have a value added to the operator, engineer, manager, otherwise the final contribution is not fully attained.

Object-oriented analysis and design engineering are emerging information tools that will enable the implementation of workgroup type of plant information systems. This paper discussed the value of integrating process data, people and work flow procedures related to the business strategies defined by the plant business needs.

Acknowledgments

We would like to thank OIL SYSTEMS, INC for permission of this paper to be published.

References

Badavas, P.C., 1993, Real-Time Statistical Process Control, Prentice Hall, New Jersey.

Bascur, O.A., 1988, "An Intelligent Control Data Framework For Process Control," Advances in Instrumentation, ISA, pp. 1153-1169.

Bascur, O.A., 1990, "Human Factors and Aspects in Process Control Use," Plant Operators, SME, 1990.

Bascur, O.A., Vogus, C.B. and Bosler, W.H., 1992 "Long Term Knowledge Integration With OSHA PSM," NPRA Computer Conference, November 16-18, 1992.

Bascur, O.A., 1993, "Bridging the Gap Between Plant Management and Process Control," Emerging Computer Techniques for the Minerals Industry, B.J. Scheiner et. al., eds., SME, Littleton, CO, pp. 73-81.

Bascur, O.A., and Kennedy, J.P., IMPC, SME, San Francisco, CA, October1995.

Covey, S.R., 1989, " The 7 Habits of Highly Effective People," Fireside Book, Publishing by Simon & Schuster Inc., N.Y.

Henderson-Sellers, B., 1992, A Book of Object-Oriented Knowledge, Prentice Hall, New York.

Kennedy, J.P., 1986, "Plant Computers and Distributed Controls Changing Strategy for the Advanced Controls", Advances in Instrumentation, ISA # 86-2504, pp. 29-33.

Kennedy, J.P., 1994," SCADA and GIS Integration", C 15 in the Rockies, Golden, CO

Shoshana Zuboff, 1991, "Human Potential in the Age of the Smart Machine," The Consultant Forum, Vol. 6, Number 1, 2-6.

Sholtes, P.R., 1988, The Team Handbook, Joiner Associates, Madison,WI.