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Author(s): D. Brayton, H. Lim, T. Long, R. Richwine and K. White

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Abstract: The technology managers will have to place increasing emphasis on the innovation of products and processes to maintain competitiveness in today's globally interdependent markets. Considerations like shorter development cycles and high quality manufacturing methods play a crucial role in the evolution of technological advancement. This report examines these concepts, and presents a model for the introduction of new processes into the manufacturing environment. This model outlines the fifteen essential steps as a structured checklist, required to introduce a new process. These steps were developed by a review of a wide variety of process areas and a literature search. Introducing a new process following each step of this model will provide the optimal process introduction program.

INTRODUCTION OF A NEW PROCESS INTO THE MANUFACTURING ENVIRONMENT

D. Brayton, H.K. Lim, T. Long,
R. Richwine, and K. White

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Dr. Dundar Kocaoglu

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Darice Brayton
Hogan Kusnadi Lim
Tom Long
Reynold Richwine
Kraig White

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EXECUTIVE SUMMARY

To maintain competitiveness in today's globally interdependent markets, the technology managers will have to place increasing emphasis on the innovation of products and processes. Considerations like decreased time to market, shorter development cycles, and high quality manufacturing methods, play a crucial role in the evolution of technological advancement. With that scenario as a backdrop, this project attempts to make a more detailed examination of one aspect: introduction of new processes into the organizational environment. The topic deliberately focuses on process rather than product introduction for several reasons:

- There is much literature available on new product introduction, and the contributions of this team to that myriad of existing resources would be minimal.
- Market trends suggest that innovation in the manufacturing arena will play a vital role in re-shaping America's competitive posture and rejuvenating our reputation as a technology leader.
- Because we found very few descriptions of techniques to perform successful new process integration in the literature, we feel that our topic will provide the audience with an effective tool which can be applied directly, or leveraged highly from, to stimulate more successes in this area.

Consequently, the focus of this paper is to develop such a tool, with supporting evidence for its accuracy derived from both empirical data and confirmation through literature searches. We offer the model we have generated as a specific set of guidelines to be used in more effectively introducing process changes to existing applications and as an aid in the development of new process introductions as a whole.

The project investigates a wide range of areas to be considered when developing processes and planning for their successful implementation. The discussion ranges from the development of a need for change, filtering that need with the goals and objectives of the organization, selecting the right equipment to support the desired change, selling upper management, training appropriate personnel, performing trial runs, documenting the new process, transferring the new process ownership, and providing recommendations for managing the process through its ongoing life.

By offering a structured concept that can be made flexible across broad segments of industry, it is our hope that lending attention to this set of issues will assist the managers of technological process innovation, and enhance the quality of their efforts.

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ABSTRACT

Continual innovation is required in the manufacturing environment to insure competitiveness in the marketplace. This paper presents a model for the introduction of a new process into a manufacturing environment. This model outlines the fifteen essential steps, as a structured checklist, required to introduce a new process. These steps were developed by reviewing a wide variety of process areas and a literature search. Introducing a new process following each step of this model will provide the optimal process introduction program.

INTRODUCTION

The marketplace for today's consumption oriented societies has become increasingly competitive over the last decade. With the advent of many small innovative firms and the consolidation of a high number of the larger corporations through leveraged buyouts, the ability of manufacturers to respond to changes in market demand has become increasingly more complex. One avenue of response has been to focus many efforts on new product introductions, in attempts to flood the market, maximize shelf space, and gain a proportionate "share of mind" from the consumers. While this strategy has offered several breakthrough products (such as those in the integrated circuit areas), the profit margins of many companies are steadily decreasing.

In an effort to capture market interest and simultaneously boost company funds, there have been many attempts at winning through process innovation, rather than product introduction. John P. McTague, Research Vice-President at Ford Motor Company, comments that "the cumulation of a large number of small improvements is the surest path, in most industries, to increasing your competitive advantage."[1] While the United States has been primarily centered on product introductions over the last decade, the Japanese have been "process" oriented, and have made significant inroads to the American consumer marketplace. "They don't beat us with cheap labor," says Ira Magaziner (a Management Consultant), "they beat us with technology and skilled labor."[2] While the foreign technologists have been steadily improving their manufacturing processes, the U.S. industry leaders are just beginning to focus effort in this direction.

Consequently, in order to remain competitive, American industry must learn to utilize manufacturing expertise as a lever to catch up and hold the dominant market positions with their products. Focusing on process innovation means making small changes and translating those efforts into larger scale economies as they prove successful. The technology manager

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[1]"Innovation in America," Business Week, Special Issue, 1989, p.16

[2]Ibid.

must learn how to introduce these changes into the organization with skillful technique and solid communication to make the changes effective, and strengthen the organization.

This project paper investigates, develops, and recommends a structured "checklist" of items that are pertinent to the introduction of a new process. The aspects that have been discussed are ones that we have identified through "real world" empirical data and through verification by literature search.

During the development of the model, we were unable to find many examples of sequential steps required for a successful process integration, although many sources agreed that individual components that we offer are vital. Thus, the primary contribution of this paper is to provide a conglomeration of the various sub-segments into a single location, and provide specific detail about the relevance of the key pieces. This project team believes that use of the model we offer will help make the engineering manager's job of dealing with process change a more tangible and manageable task. Through better execution of future process innovations due to better understanding of the issues outlined, we anticipate that managers can effect change with a more positive impact on their organizations and the domestic economy as a whole.

RESEARCH METHODOLOGY

The project team consisted of five engineers with views of process innovation stemming from different perspectives. These perspectives included the environmental engineering consulting, high tech manufacturing, construction project management, and high tech company management. These perspectives provided a good cross section of views concerning process innovation.

The project group followed a systematic investigative process during the study. This process is outlined in Figure 1. The process for developing this model was to first develop a case study of the introduction of a new process from the perspective that each team member brought to the project. From the case studies, a draft model was developed by taking the common elements from each of the case studies. Each of the elements of the model were then assigned to individuals on the project team. A literature review was performed and each model element was optimized. The optimized model was then used to review each of the case studies from which the model was originally developed. It was determined that the model was representative of each case study verifying the usefulness of the model.

CASE STUDY DEVELOPMENT

A case study outlining the major steps for process innovation in their respective fields was developed by each project team member. These case studies included:

- Introduction of Automated Manufacturing Equipment - Process Start Up/Introduction

PROJECT INVESTIGATION PROCESS

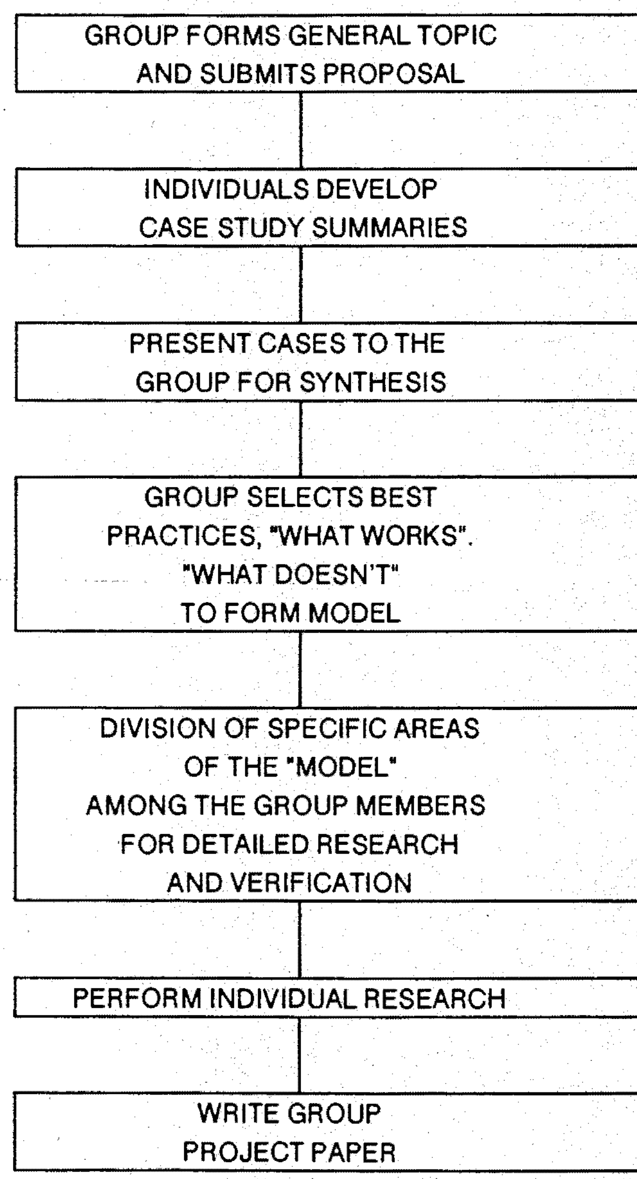

FIGURE 1 - PROJECT INVESTIGATION PROCESS

- Implementing a Paperless Repair Data Gathering Process Into The PCA Manufacturing Environment at Hewlett-Packard, Vancouver.
- Water/Wastewater Treatment Plant Process Implementation
- Introduction of a New Data Processing Process Into a Construction Company
- Semiconductor Manufacturing Problem

These case studies represent a good cross section of process environments. They represent five perspectives dealing with the introduction of a process from the engineering to the users environment. Each case study was written independently. After each case study was written, the project team met to extract the common elements and create the process model.

Each of these case studies can be found in Appendix A.

DEVELOPMENT OF PROCESS MODEL

The process model was developed by taking common elements from each of the case studies. A linear flow diagram of the model is shown in Figure 2. The order in which each model element occurs and the name given each element may differ throughout various industries, but the function performed in each of the model's steps appears to be common in each of the industries.

The order of the individual elements may not occur in the same order that the model shows them. Also, in many cases, some of the functions occur simultaneously. The model was developed in a linear fashion for the sake of simplicity. Further research is necessary and a greater number of case studies will need to be reviewed before the order of the model's elements can be optimized. This paper has identified the critical steps and has placed them in a linear order that best suits the five case studies that were evaluated.

The title given to each of the fifteen steps in the model will also differ in different industries. An example of this is that an engineering trial run in the manufacturing environment is called a pilot study in the environmental consulting environment. The similarity of this process step between the two environments is that it is a verification of the performance of the process. It is used to determine actual operating criteria which is used to optimize the process design. This example clearly demonstrates that even though the title may be different, the function is a common one.

VERIFICATION OF MODEL

The model was verified by performing an evaluation of the literature available for each of the process steps. A discussion of the review of each of these model steps is included in following sections under Discussion of Model Aspects.

PROCESS MODEL

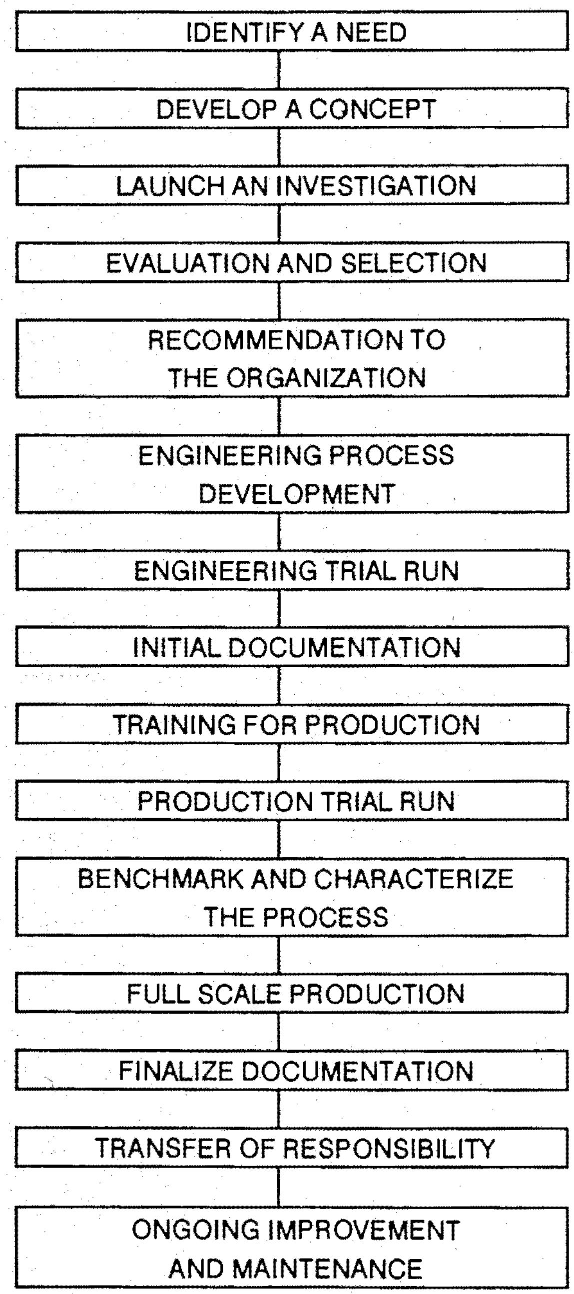

FIGURE 2 - PROCESS MODEL

Each of the process steps was reviewed and optimized during the review period. To expedite this process, each team member was assigned specific model elements. Weekly meetings were held for discussion of the findings and optimization of the model. The final verification of the model was to re-evaluate each of the five case studies to insure that the model represented the process introduction for each case. The project team concurred that the model represented each case study and froze the model.

DISCUSSION OF MODEL

The process model for introducing a new process into a manufacturing environment consists of fifteen individual and discrete steps as discussed earlier in this paper and shown in Figure 2. The following sections discuss each of the steps of the model in detail.

IDENTIFY A NEED

There are many signs that indicate the need for change[3]. They are:

- New technology developed whether inside or outside the company.
- Market demand or potential which cannot be sufficiently supplied using current processes
- Strategy of the company to stay at the competitive edge by continuing to improve the process/product.

In order to be aware of the need, the signs which can be occurring from within and outside a company must be monitored. New technology or new processes can be monitored by:

- Looking at the research and development (R&D) department and the progress of the project carried out in a department.
- Reviewing science and engineering journals
- Attending exhibition or trade shows

Market demands and/or potential can be monitored by:

- The growth/decline in the sales of the product
- The growth/decline in the market share of the product
- The growth/decline in the number of competitors in the market.

The way to monitor the need for change or the strategy of the company is to :

- Monitor the life cycle of the product
- Evaluate those signs above and make an evaluation of them.

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[3]Peter F. Drucker, "Innovation and Entrepreneurship, Practice and Principle," Copyright 1985, n. pag.

But we have to be careful in order to justify the need for change, because not all of the changes are sufficient toward a successful implementation of new process introduction. Some of the consideration to be made here are the availability of the technology to support the new process, the timing, and the budget allocation. There is a trend known as "Lure of Technology": which implies that "If the technology exists, I am missing out by not using it."[4] This can be misleading toward the justification of the need for a new process. The key is in the companies approach to planning, design, and implementation of the new process; because if a company ignores one of these, then even the best technology will most likely fail.

DEVELOP A CONCEPT

Once the potential need of a new process is validated, we can develop the engineering team that is responsible for the development of the new process, to achieve the characteristic performance needed (i.e., faster, lower cost, more reliable and more productive.

Besides the technical activities, we have to also consider the marketing activities such as market research and investigation toward the possibilities of increasing the market segment and market share of the product. And last, but not least, the management support for the new process introduction.

If one is looking only at a product line or process line for improvement, then a pareto analysis can be used to find the most significant loss in quality, yield, or time. These elements all translate to money. These loss elements can then be translated to reflect their priority. Thus, one only needs to access the capability and funding requests necessary to attack the projects in order of priority.

Several problems may occur in the development of the new process. Problems with the allocation of creative personnel, company resources and the human factor (i.e., the acceptance of the operator which will handle the operation of the new process on the daily basis).

Several aspects which have to be considered are:

- Organization

  The structure of the team can be varied[5] from Functional type to Matrix type or a combination of them (i.e., Functional Matrix, Balanced Matrix, and Project Matrix) based on the type of the company and the scale of the process involved. The authority and responsibility of the functional manager and project manager are also

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[4]William E. Bracker, Jr.,PhD and Christi Harris, "Automation: A Tool, Not A Means To An End," Printed Circuit Assembly, October 1989, p. 15.

[5]Erik W. Larson & David H. Gobeli, "Organizing for Product Development Projects," Journal of Production Innovation Management, Volume 5, Number 3, Sept. 1988, p. 181.

varied, where in functional type, the functional manager has more control over the process development and at the other end, for the project type, the project manager has more control.

- Human Factors

  In order to minimize the restraint of change by the operator of the new process, it would be helpful if their hands-on experience and opinions are included as an input for the engineer to design the new process, since the operators are the ones who would implement most of the operation routinely after the new process has been developed. And in doing so, we can possibly increase the motivation of the operator and develop the sense of belonging to the new process.

  Training can also play an important part in the success of the new process introduction, since it transfers the features and capabilities of the design by the engineers to the operator who will operate it on a routine basis. The more effective the training, the more chance of a successful introduction of the new process.

At the stage of developing a concept for a new process introduction we have to give appropriate consideration of many aspects, i.e. the commitment of management, technology availability, human factors, and marketing potential[6].

LAUNCH AN INVESTIGATION

The key aspects of developing a new process are[7]:

- Idea generation
- Concept formulation
- Screening the best alternative
- Prototype setting
- Evaluation of the performance

Those activities are ongoing activities that can be iterated many times before a solution which conforms to the performance characteristics needed for the new process is reached.

Some techniques that can be useful for stimulating the creation of ideas are[8]:

- Need Assessment
- Scenario Analysis

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[6]Roger J. Calantone & Cooper, "New Product Scenarios: Prospect for Success," Journal of Marketing, Spring 1981.

[7]C. Merle Crawford, New Products Management, 2nd edition, 1987, p. 110-111.

[8]Ibid.

- Group Creativity
- Attribute analysis
- Relationship Analysis
- Lateral Thinking

The technique chosen for stimulating the generation of ideas can be varied depending on the organization's preference and the internal situation. This can be a combination of several techniques. After the stage of idea generation, the ideas toward several alternative concepts needs to be formulated. The best alternative then needs to be determined and developed further as a prototype. The prototype is then tested and the actual performance is measured and compared to the specified performance. This is an ongoing process. Other alternatives can be prototype and compared with the desired performance. This process can be done serially or simultaneously based upon the scale of the new process involved.

At this stage, the marketing department has to do some investigation as the preparation toward the commercialization of the product based on the new process. The activities have to test and measure the analysis made before, because the accuracy of the marketing analysis play a significant role in the success of the product[9].

Some of the activities to support these activities can be in the form of a questionnaire to the customer or a survey to the market for this kind and related product. Some marketing activity that is also important is the investigation of the possibility to increase the market share and increasing the market segment, that involved Competitive and Market Intelligence which can give the information about the competitor and the trend of the market.

EVALUATION AND SELECTION

In order to evaluate and/or select a vendor it is vital that the implementor be aware of the needs of production. The problem should be outlined and detailed in order to investigate the possible solution(s) or options available.

The vendor could be an outside O.E.M., or someone contracted to design and fabricate the equipment (inside or outside of your company). Trade magazines, professional society publications, and technology articles will be of great use in determining if there is process equipment which could suit your needs currently available in the market.

If there is not process equipment currently available, you will need to determine if current market equipment can be "enhanced" or if the equipment can be developed in house or by an outside contractor.

Regardless of where the equipment comes from, there are several factors that will affect the equipment's acceptance and life span.

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[9]Robert G. Cooper, "The New Product Process: A Decision Guide for Management," Journal of Marketing Management, Spring 1989, Volume 3, Number 3, p. 238.

These include:

- Level of complexity for the operators
- Availability of training for operators, technicians, maintenance and process engineers
- Maintenance History of the supplier and of the machine itself
- Cost
- Preciseness (Accuracy) of the machine
- How easily the machine will integrate into your current operation
- Benefit analysis of what the machine is improving and to what degree

RECOMMENDATION TO THE ORGANIZATION

Once the vendors have been evaluated it then is necessary to formally communicate "the selected vendor" or discuss the options available. The primary importance of this is to insure that the goals of the organization will be met through this decision. This also creates a dialogue to insure that the process and its implementations have been thoroughly investigated. Not only will this limit the amount of surprises and turmoil but it also follows "a philosophy of long-range thinking and planning"[10].

ENGINEERING PROCESS DEVELOPMENT

The process development or design step is the step where the traditional engineering tasks are performed. The engineering team will be organized with engineers from the various disciplines: mechanical, electrical, instrumentation, software, and process. This team will work together to produce the design documents (drawings and specifications) which will be used to upgrade or change the process as well as purchase specific process equipment.

The first task in this step is the project manager to put together a project plan. This plan will:

- Define the Scope of Work and Assign Project Responsibilities
- Select Project Team
- Prepare Work Plan to Complete Each Work Package at the Lowest Possible Cost
- Prepare Detailed Schedule
- Develop and Install Project Control System
- Control Project

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[10]William E. Bracker, Jr., Ph.D. and Christi Harris," Printed Circuit Assembly, October 1989, p. 14.

To define the scope of work for a project, the project manager must precisely define the minimimum amount of work to be done to complete this project satisfactorily and the work that does not have to be done on this project.[11] Definition of scope is very critical to a projects success. This is the mission that the project team must work towards and the limits that they must work within.

After the project scope is determined, the project manager must establish and document the major work packages for completing the project. A work plan to complete each work package must then be developed. This is done by breaking each work package into lists of tasks that need to be completed. A budget outlining labor and expenses must be determined for each project task. After this work plan is completed, the project manager knows the level of effort and the personnel requirements for completing the project design.

The next step is to select and organize the project team. Team members must be selected to insure technical competence for the project and for their availablity for the project. After the team is organized, a staff organizational chart should be developed and distributed to all project members. This will establish the lines of formal communication for the project.

When a project is planned, a schedule for implementation of the new process is created that allows for the completion of the project at predetermined time. Various methods have been developed for project schedule management. These include CPM and PERT. The schedule is a tool for the project manager and the project team to be used throughout the project for monitoring the required progress to meet the project goals. In many cases, the project plan and project schedule is created at the beginning of the project and never reviewed after that. This tool is critical for monitoring the progress of the team and insuring that the project is completed on time and on budget.

ENGINEERING TRIAL RUN

The engineering trial run can also be called a pilot plant or a demonstration project. This is a specific task where the process concept is implemented on a small scale. This can be incorporation of the process concept into one of the manufacturing lines under close supervision of the design engineers in the manufacturing environment, operation of a bench scale or a pilot scale treatment plant on the actual water or wastewater that the new process is being designed for in the case of the environmental consulting engineer, or the introduction of a new software product into a construction firm by providing the software to one project and monitoring its use.

In each of these cases described above, the common element is to review the performance of the concept on a small scale. This will provide the engineer with the following:

- Verification of the process

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[11]Kenneth J. Barlow, "Effective Management of Engineering Design," Engineering Management Division's Specialty Conference, Chicago, April 1981.

- Design criteria
- Ability to optimize the process on a small scale
- Cost information

Verification of the capability of the process to perform as desired is a critical step in the introduction of a process. The engineering trial run provides the required verification of the innovation on a small scale, which minimizes the risk for implementation of the concept on a full scale.

The verification of actual values for design is extremely important. Gathering of these data must be closely monitored by the engineering staff so qualitative operational criteria can be gathered and verified. This information can then be used in the design of the actual process. Without this information the process designer would be required to use textbook values for process variables which presents a higher potential for failure. Failed assumptions are most economically proven in this step.

During the engineering trial run, the engineering staff is also provided the opportunity to optimize their assumptions used when developing the process concept. The operating system can be "played with" to determine what modifications will improve or limit process performance. They are also able to determine which variables have the greatest sensitivity, which provides the designers with critical knowledge as to where to place their effort in designing process flexibility.

Another benifit of the engineering trial run is the ability to verify assumed operating costs for the process. This information is affected by scale-up factors, but is much more accurate than the information available without performing this effort.

INITIAL DOCUMENTATION

Documenting the process thoroughly plays a key role in the future success of any new process development integration. There are several phases of the process that require adequate explanation or definition. Some of these include:

- Identifying or clarifying original design intent
- Workcell operation and functionality
- Operator interaction and procedures
- Engineering details (such as bill of materials, schematics, software program code, etc.)
- Identifying safety related issues and practices

For the initial documentation efforts, it is important that the new process development group carefully address items two and three above, namely workcell configuration and operator interaction requirements. Although at this point, statements of the design intent should have been clear, we will focus on solidifying the train of thought on that subject later in this paper.

Having completed the initial process development and the engineering trial run, the next step is to begin preparation for adequate operator training prior to characterizing the process under full production loading. To support the smooth transition from engineering development to the actual "live" scenario, several tools can be helpful aids to the documentation process. Some examples of these in the electronics industry are the use of assembly drawings depicting the locations of parts on a printed circuit board, or an overview of the steps required at a particular assembly station. Another invaluable tool can be the use of flowcharts to itemize the sequence of process steps the operator needs to take. Finally, mechanisms like piece part labeling schemes can be greatly enhanced with the addition of another dimension of information -- color. The applications for color coding part numbers, process steps, or important instructions are varied and numerous, and limited only to the creativity of the process engineer and production team.

Establishing a "procedures book" and combining it with the presence of a centralized location for future documentation reference is also a good practice. The key to documentation is to realize that you are establishing a vehicle for communication, and like any other form of information exchange, it is vital that you are specific, accurate, and anticipate any future concerns that may be generated. The production operators are often an important source for gathering information on the specific areas of the process which are most critical to document, and it is equally significant that they be included as part of the input process for the documentation efforts.

TRAINING FOR PRODUCTION

Training is of critical importance when introducing a new process into a manufacturing environment. Two companies in the United States (U.S.) that have exhibited a progressive approach to continuing improvement and quality are Hewlett-Packard and Motorola. Both companies have identified training as an essential part of their strategy. Motorola was awarded the 1988 Malcomb Baldridge Quality Award for having shown the best sustained quality improvement of any company in the U.S. Motorola attributes much of their success to training of personnel at all levels in the corporation.

For a moderately complex process, aside from the actual design of the process, nothing is more important than the training of the production workforce. Training can be relatively unsophisticated for simple processes and can be accomplished in as little time as a half hour. For the most part, this would be an exception and of course would apply only to a very simple process.

If a complex process is being installed, such as an advanced integrated circuit process, it can take up to two years. Personnel would have to be trained in specialized topics such as: basic cleanliness, material handling, safety, proper equipment usage.

Very often understanding process control has to be taught. Employees often have to be trained in basic math, basic process control charts and taught what to do when limits are approached. For example, "The Motorola Training and Education Center (MTEC) Advisory Board, calls for a minimum of 40 hours of training (2% of total working hours) per year for each employee. This policy, which will be phased in over a three-year period, will move Motorola as a global corporation one step closer to achieving a culture of continuous learning."[12]

Poor training can be surfaced during the production trial run. If the process takes substantially longer than anticipated and if the yield is lower than expected, a good place to look for problems is the adequacy of the training program.

PRODUCTION TRIAL RUN

The production trial run can also be called startup. The startup of a process will consist of the following elements:

- Functional Testing
- Startup Period
- Commissioning
- Warranty Period

Functional testing is the testing of individual equipment items and subprocess units prior to the startup of the process as a whole. This task insures that each component of the process operates to its specifications prior to the testing of the complete process. A failure of any element to perform to its specification may cause a delay in process startup.

After each element of the process has been testing and confirmed to meet specifications, the process can then enter its startup period. This is the point in time when the process is first operated as a complete system. The goal of this project phase is to have the process perform its intended task and to provide a period of time when operations staff can be trained on the actual operating equipment. Process efficiency is not a priority during this phase, operating the process is.

After a comfort level with the operation of the process has been reached, the process then enters the commissioning period. This is where process optimization occurs. The engineering and operations staff work together throughout this period to bring the operation of the process to a point where is is producing product as per the process specifications. The length of time required for the commissioning of a process is highly dependent on the complexity of the process and the quality of the engineering design.

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[12]Gary Tooker, "The Training Investment Is a Productivity Investment," IMPACT, September - October, 1989.

When new equipment has been purchased for implementation of the new process, a warrenty period of usually one year is provided by the equipment manufacturer. During this period of time, the equipment manufacturer is responsible for the support of all breakdown maintenance for the equipment item. Preventative maintenance is usually the responsibilty of the owner, but may also be incorporated in the warrenty and be the responsibility of the manufacturer. The warrenty period requires a continuing coordination by the engineer that managed the installation of the equipment and the startup ofthe process with the operations staff. Management of this effort by the engineering staff is important to insure that the warrenty service-is provided when necessary. This also will provide the engineering staff with knowledge of the capability of the equipment useed so this information can be incorporated into the design of future systems.

BENCHMARK AND CHARACTERIZE THE PROCESS

Benchmarking the process serves the purpose of establishing a base line and Statistical Process Control (SPC) establishes the process limits. If the process starts to go out of control, corrective action must be taken. One needs to discover the cause and effects, thus establishing a routine procedure for bringing the process back into specification or controlling the process in a routine manner.

Training in the Taguchi method of experimental design or a similar method is often required. When several variables are involved and the cause and effect are not readily determined, engineers are prone to make assumptions about the cause of the problem. It takes a very disciplined process to uncover the linkages or cause and effect. The Taguchi method and Kepner-Tregoe analysis provide such a vehicle.

FULL SCALE PRODUCTION

Full scale production can be quick and easy for simple processes or can take a year or two for very complex processes. The supply of material for the production process can be a very complex planning activity and lead times can be from six months to a year, thus requiring planning and commitment on the part of suppliers.

Full scale production requires yields at planned levels or better, otherwise cost can be prohibitive. It is therefore important that planned levels of output as well as yields are accomplished.

This course, is dependent upon the robustness and technical correctness of the process. The output and yield will correlate closely with the quality of the training program.

FINALIZATION OF THE DOCUMENTATION

With the new process running at full scale production, it is time to focus some resource effort on updating the documentation about the entire process. Where the initial documentation was aimed at providing the production operator with the necessary information to operate the process at a low level, the final stage involves more depth and scope of documentation for the entire process operation. Consequently, attention to areas like clearly specifying original design intent and providing a "paper trail" of drawings, material lists, and software functionality, will reduce the possibilities of future misuse of the process as well as establish a springboard for leveraging future process innovations from this attempt. "The process must be defined in detail, including the methods, materials, and tools. This is the task of Manufacturing Engineering who must have the necessary authority and manpower to carry this out. The shop floor must follow these instructions exactly ....."[13] In addition to these engineering details, another good step to take is to update the operator guidelines and workcell documentation to the current status, incorporating all the procedural changes that have taken place since the initial write-ups.

A key piece of information to include in the final documentation stage reverts back to the original benchmark of the process. The quality levels that have been established should be noted, as well as information on process control limits. This data can be monitored for conformance of the process to the desired specifications and can be used as a reference to identify when the process goes out of control. Since most of the actions that will later be undertaken to maintain or improve the process will be based on the data collected when the process operates as specified, it is valuable to document as much data on the process as practical. "The manufacturing procedure will only be correct if a proper evaluation is made, and on-the-job data are essential for making a proper evaluation."[14] Documentation will ultimately play a crucial role in the successful operation of the new process, both from a user and control perspective, and attention to detail during this phase of the process introduction will ensure that future difficulties can either be avoided or identified more efficiently.

TRANSFER OF RESPONSIBILITY

At this point in the process, the development engineering group begins to shift formal ownership for operating and maintaining the new process to the production and/or maintenance organizations. It is important to involve the appropriate key personnel in a meeting to gain consensus and document the status of the project, depending on the organizational structure in place at the time as well as the organizational and environmental culture. However, with these differences noted, there are several alternative ways to approach the "release" phase of the process introduction.

1. Effect the handoff of responsibility from the designer to the user, (i.e., engineering to manufacturing, or contractor to owner), with the designer stepping completely away from the process. The engineering team is dissolved, and begins working on another task and the ownership of the process is now with the user.

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[13]Ralph W. Woodgate, "Managing the Manufacturing Process," Printed Circuit Assembly, August, 1988, p. 19.

[14]Kaoru Ishikawa, "Guide to Quality Control," Asian Productivity Organization, January, 1984, p. 1.

This dramatic step can offer a clean break in the ownership transfer of the process, but also provides a myriad of pitfalls that will inevitably impact the organization in a negative fashion. Communication between the groups involved in the technology transfer is vital to the success of the process. Not only will information flow suffer under this scenario, but upper management will not be brought up to speed, and may lack future commitment to the operation. Meredith asserts that "... because of the significant investment required for these technologies and the life-or-death status of the competitive environment, the role of 'knowledgeable managerial commitment' has become significantly more critical and is now probably the major factor in successful implementation."[15] Consequently, gaining cross-organizational understanding through teamwork and communication is an important part of obtaining a formal release of the process under consideration.

2. Negotiate a transition period and assign several members to work with Production until the operators are competent and have more confidence in their ability to run the process.

Under this scenario, one avenue would be to select several members of the original process development team to stay with production to address process improvements, cost reduction, efficiency optimization, and other activities. In general, it is a good practice to establish parameters such as functional tests, performance tests, or a start-up period to prove that the process is stable for a specified period of time without breakdown, prior to performing the final handoff of ownership.

With this solution, however, it is important that specific objectives and timeframes are set in order to ensure that the engineering resources will be freed up at a specified future date.

3. Reach an agreement that the process will be jointly owned and maintained for an indefinite period of time by both engineering and production.

While this approach offers a "teamwork" perspective in the short term, over the long run it may result in the waste of resources, and merely delay the inevitable "buyoff" by Production. In addition, if the engineering organization charter views their role as a "forward looking" group, focused on the development of new processes, it would be detrimental to the company to weight them down with added responsibilities of also maintaining existing processes. This leads to another alternative:

4. Involve a third party under some form of contractual basis to provide process support and ongoing training and maintenance.

Obviously, this step alleviates the strain on engineering resources (assuming that the third party contains personnel with the necessary skill sets and technical knowledge), and would prevent Production from being placed in a position of "owning the process" without having

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[15]Jack Meredith, "The Role of Manufacturing Technology In Competitiveness: Peerless Laser Processors," IEEE Transactions on Engineering Management, Volume 35, Number 1, February, 1988, p. 6.

the technical expertise to correct problems as they arise. An example in this case is the use of contract operations firms to facilitate the transfer of responsibility.

5. Engineering maintains the responsibility for process support indefinitely while production uses the process for operation and meeting customer demands for product(s) produced from the process.

This solution requires deep pockets of engineering resources (as noted in #3 above) or a change in the organizational structure to facilitate the success of both the engineering and production organizations. For example, forming a sup-group of engineering containing "process technicians" who have the technical knowledge needed to support the process, but who report to the production side of the house may be one alternative here. Because the existing organization provides the ongoing maintenance function, many software projects take this alternative approach, but usually begin expansion of their personnel to accommodate the increased bandwidth of work required.

Regardless of the technique used to effect a transition in process ownership, it is important that this phase of the project be blanketed with thorough attention to quality communication among all involved parties. This will maximize the understanding and help to clearly delineate future roles and responsibilities in maintaining or improving the process under consideration.

ONGOING IMPROVEMENT AND MAINTENANCE OF PROCESS

With a heavy emphasis on worldwide competitiveness and the need for companies to leverage from the manufacturing environment in order to provide future product and process innovation, the importance of follow-up support to a new process cannot be overstated. Often, this requirement for process improvement revolves around the output quality of the product being manufactured or delivered.

One industry tool that is growing in popularity is the use of statistical process control (SPC) software, which allows the user of the process to monitor "real time" failure and defect tracking data, and provide better quality control. Baker states that "because of the vast advances in manufacturing technology, along with the present product technology, quality assurance personnel must develop an on-line/on-demand quality control system."[16] Furthermore, the use of computer integrated manufacturing (CIM) techniques to provide the computer generated reporting capabilities can often be useful sources of data for making other decisions. These considerations range from performing product enhancements, to making process improvements, or implementing cost reductions.

Hewlett-Packard, Tektronics, and Motorola are examples of companies who actively pursue SQC efforts at many levels in the organization. (See the attached case studies for an example of an HP application.) In a recent Motorola newsletter, one of the goals was to

[16]Daniel H. Baker, "Real-Time On-Line Quality Assurance Data and SPC in an SMT Production Facility," Surface Mount Technology, October 1989, p. 31.

"establish on-going controls for the process based on prevention of special cause variation using statistical process control techniques."[17] Having previously mentioned the importance of characterizing and benchmarking the process of interest (see earlier discussion), we can now employ many methods to measure the deviations that begin to occur as we exploit the production process to meet market needs. At Hewlett-Packard Company, attention to tools like SQC provide the ability to recognize process limitations, and to prepare for taking the appropriate action.

The importance of maintaining and improving existing process steps is a recognized method of promoting process innovation on a global basis. The Japanese companies began the formation of quality control (QC) circles, where the workers would use Pareto diagrams or control charts to identify possible sources of trouble in the manufacturing process and attempt to eliminate them. Other tools of this nature include: cause and effect diagrams, scatter diagrams, multivariate analysis, and process flow charts. However, as noted by Deming, "the best place to start a QC-Circle in America is with the management."[18] Without a firm commitment to quality on the part of the very highest levels in the company, it will be difficult if not impossible to integrate the responsibility and dedication to quality throughout the company. Therefore, keeping management informed and enthused about the ongoing efforts to improve processes, to increase quality levels, or to reduce costs, is paramount to the success of the process itself.

CONCLUSIONS AND RECOMMENDATIONS

The model that has been created for the introduction of a new process into a manufacturing environment has proven to be acceptable in the five case studies from which it was developed. No all encompassing model for the introduction of a process was found in the literature search. Models for the development of a **product** were found and these did contain many of the same steps that were in the new process model.[19] [20]

The model has limitations in that it documents fifteen steps for introducing a new process. It presents these steps in a linear manner. Use of this model to review the five case studies for which it was developed shows that many of these steps do occur concurrently, but that each of them do occur.

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[17] Gary Tooker, "The Training Investment Is A Productivity Investment," IMPACT, September - October 1989, p. 4-5.

[18]Edwards Deming, Quality, Productivity, and Competitive Position, (Cambridge, Ma., MIT Center of Advanced Engineering Study, 1982), p. 109.

[19]Robert G. Cooper, "The New Product Process: A Decision Guide for Management," Journal of Marketing Management, Spring 1988, Page 19-22.

[20]Motorola Inc., Semiconductor Products Sector, Product/Process Improvement Flow Diagram, Marketing Brochure BR392/D.

The model was developed to be generic so it can be used in diverse industries. It shows that there are many similarities in process engineering as well as in the implementation of processes across diverse industrial segments. The design and introduction of a process without going through one of the steps presented in this model can lead to serious omissions in the process. These omissions could lead to unnecessary delays in the introduction of the process which would lead to lost revenues to the owner.

It is the recommendation of this project team that this model be reviewed by any group when putting together their plan for introduction of a new process. Each step of the process should be incorporated into the plan to ensure that the project occurs in a logical and efficient manner.

We contend that while the individual stages of the model are each important, achieving successful process modifications will be maximized by viewing the subparts as pieces of the overall procedure, rather than ends in themselves. Our subsequent recommendation forms a powerful tool that today's technology managers should utilize to obtain the optimal benefits from effecting process changes.

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