ETM

ENGINEERING & TECHNOLOGY MANAGEMENT

Title: Introduction of a New Technology Into Manufacturing

Course:

Year: 1988

Author(s): S. Brainerd, A. Doumani, R. Phillips, M. Sugg, R. Wise and S. Zhou

Report No: P88009

Abstract: This report examines the process of introducing a new technology into manufacturing. The process is divided into the design and transfer phases. Each phase is further broken down into components. Design is examined through design process, manufacturing cost analysis and tool analysis. Transfer is broken down to communication, test proof, documentation, staffing and training. In addition, we examine the sociological aspects of the introduction of a new technology

INTRODUCTION OF A NEW TECHNOLOGY INTO MANUFACTURING

S. Brainerd, A. Doumani, R. Phillips,
M. Sugg, R. Wise, and S. Zhou

EMP - P8809

Table of Contents

Introduction of a New Technology Into Manufacturing

EXECUTIVE SUMMARY

Brainerd, Doumani, Phillips, Sugg, Wise & Zhou

This project examines in detail the process of introducing a new technology into manufacturing. The process has been divided into two main areas: design and transfer. Each one of those areas was further broken down. The division of design is as follows: design and process,manufacturing cost analysis, and tool analysis. Transfer was broken down into communication, test proof, documentation, staffing and training. In addition, the sociological aspects of the introduction of a new technology was examined.

To collect data we interviewed managers and blue collar workers at our respective facilities. In addition, we did extensive literature searches. The paper is based on a combination of both plus our own personal experiences. The project identifies problem areas and suggests methods for handling each. The purpose of the project is to offer a set of guidelines which a perspective implementor of a new technology could follow to ease the transition and make it more effecient.

The manner in which a change is introduced into manufacturing plays a large role in determining the sucess of failure of the new technology. The process can be made very painful and expensive or it can be made fairly smooth and relatively easy. Following the guidelines presented in this paper will help the company take a major step towards a smooth transition and reduce the upheaval that the intorduction of a new technology into manufacturing can invariably cause.

The recomendations from this project emphasize getting input from all the involved parties which will help gain the support of all the personnel involved. The manufacturing people need to have some input into the design becuase if it cannot be manufactured, then it does not matter how good the idea is. The proper equipment and tooling needs to be purchased and in place prior to the introduction of the change, or the whole process will come to a complete stop. Open communication also has a major impact on the success of a change and should be emphasized. The new product needs to have a test proof and quality test completed in order to avoid any surprises which-can quickly detract from the support of a project. Careful planning can eliminate problems in all these areas and also in documenting, training and staffing.

Finally, taking into account the human aspect of the introduction of a new technology will also be quite beneficial to the implementor. All companies employ some number of workers, therefore, they should not be ignored. To do so will end up causing more problems which could have easily been avoided at a much lower cost in terms of time and money.

Introduction of a New Technology Into Manufacturing

Brainerd, Doumani, Phillips, Sugg, Wise & Zhou

1 INTRODUCTION

1.1 Problem statement

Today's rate of technology growth is resulting in a much shorter product life-cycle than has ever been experienced before. Products that used to maintain a strong market showing for ten or fifteen years, such as the electronic industry, are now being obsoleted in about three. This has resulted in the need for a much more efficient new product introduction effort than ever before.

One step in the life-cycle that is drastically affected by this change is the introduction of the new technology into manufacturing. There appears to be a lack of effective methods to efficiently and rapidly perform such an introduction. Many companies, though innovative and aggressive, have lost significant market share and in some cases gone out of business because they failed to integrate the new technology required to produce the new products into their manufacturing process. There appear to be both technological as well as sociological causes for this failure and they span all phases of the introduction from planning through transition and to post introduction follow-up.

1.2 Goal statement

The goal of this project is to develop a set of general guidelines that would be used as a tool to aid in effectively transferring a new technology from design into manufacturing. Though we will be emphasizing the introduction in a high-technology environment, the majority of the guidelines should be applicable in any manufacturing situation.

1.3 Approach

We utilized two different research tools: A literature search and interviews. We first identified the major technological and sociological aspects of introducing a new technology and divided them up among the members of the team. The technological aspects broke down into those associated with planning, such as design, process definition, manufacturing cost and tool analysis, and those associated with the transfer of the new technology, such as communication, test proof, documentation and training. The sociological aspects broke down into general issues of resistance to change in the workplace, and barriers specific to the introduction of a new technology into manufacturing, both in planning and transfer. We each then conducted a literature search in our particular area.

For the interviews, we jointly developed a set of questions spanning both the technological and sociological areas outlined above. We each then used the questions in conducting interviews in our respective work locations. We interviewed 17 people ranging from assembly people to manufacturing managers and including technicians and manufacturing engineers. The results of the interviews are compiled in Appendix A.

Using the data we collected through the interviews and literature searches, we identify the major problem areas, their causes and effects, and we offer a set of recommendations to the implementors of the new technology to provide for a smoother, more efficient introduction.

2 DESIGN AND PROCESS

2.1 Abstract

New product design and process development methodologies to improve internal corporate technology transfer to manaufacturing were investigated. Data came from availjable literature, interviews with professionals, and personal experiences of the author. Recommendations on how to effectively develop a new product to assure manufacturing success will be given.

2.2 Background

Anyone involved with manufacturing can relate to the frequent occurances or delays in new product introductions that result from design and process incompatibilities. Many of these are not publicly known, but are internal challenges for the entire corporation. A planned design and process are extremely critical to the manufacturing success of any new product. The critical nature of a good product design was described by Whitney [1] who reports that 70% of the manufacturing cost of GM truck transmissions is determined in the design stage. A study at Rolls-Royce [2] indicated a 80% manufacturing cost is related to the design. A corporations profits are so tightly coupled to their products design, that managers will require systems that assure new products are designed with manufacturability in mind while still meeting the required market demands. Whitney describes design as a strategic activity, whether by intention ordefault.

The high technology semiconductor industry is full of many examples of corporations whose failure was primarily due to major problems in mass producing a particular product. The majority of these are small startup or newly formed companies who are trying to build complex products with new designs and processes. The personnel in these new corporations are typically highly educated innovative creative engineers[3] whose main self proclaimed career goals are to create new designs or processes and to just demonstrate them as prototypes without regard to any type of "unchallenging manufacturability concerns"[4]. They typically let others worry about the act of implementation and associated problems resulting from their innovations or inventions lack of manufacturability. This lack of manufacturablity concern is a major shortcoming of the current American engineering educational system, which I believe has lead partially to our decreasing lead in the worlds manufacturing market.

Trilogy was a corporation in Santa Clara, California that in the early eigthies promised to deliver wafer scale integration (an entire computer on a silicon wafer typically 4 inches in diameter and 20 mils thick). This product was extremely complex and one which had never been produced before. The design and process were virtually untested. They were being entirely developed by research engineers without guidance from the future production group. From its inception this company had the odds stacked against it from ever being able to consistently manufacture a product. The company went out of business due to market demand, lack of investors confidence, and fundamentally a lack of manufacturability. The future product never made it out of the lab. Another recent semiconductor startup failure was Gain who's mission was to create VLSI in gallium arsenide, a silicon substitute that produces fast working electronic circuits but is very difficult to manufacture. The difficulties that plagued Trilogy led to Gains failure. This is not to say that the lack of new product manufacturability was the sole reason for the failure of these companies. There were other obvious causes such as marketing demand, lack of investor confidence in a long over budgeted project, long schedule slips for the product introduction, and judgement errors in the companies financial area.

It can be said that with a good sound design for producibility strategy [1] these corporations would of had a better chance for success. I will not discuss startup failures in this section but how high technology companies have introduced new technologies into manufacturing with emphasis on the new design and process. For the purpose of this section a new technology will be defined as a new product that requires a new design and process which offers a significant improvement in performance level over that of any other previous product. Design is defined as functonal-mechanical layout of a product which describes the way subassemblies or basic building blocks are connected. Process is defined as the set of sequenced steps necessary to produce the product. Recommendations will be given on how strategic product design and process planning can be done to assure a manufacturable product. One particular semiconductor companies execution of this will be discussed and evaluated.

2.3 Literature review

There is a lot of literature on the subject of technology transfer as it pertains to introducing a new technology from government research and development to the private sector and developing foreign nations. There is a Journal of Technology Transfer which throughly discusses these concerns, but it is very weak on information on how corporations "transfer technology" internally from the development group to their production facilities. This appears to be a very virgin area, but obviously some of the approaches used for government technology transfers can be applied to internal corporate technology transfers. Even if it's dated (1963) Quinn and Mueller's article [5] is a good source for ideas on a corporate wide plan for internal transfers. They discuss the management planning strategies neccesary for moving research results into production. Most of the articles found do not provide detailed information on specific corporate technology transfers.

Early treatment of internal corporate technology transfer was done by M.V.Sagal the engineering research director at Western Electric's engineering research center in 1977 [6]. His organization provided new processes for future new product designs and improvements to existing processes for all programs that had the widest and long range corporate impact in the Bell System (Western Electric and AT&T).The success of his organization was measured on how sucessfully their innovations were implemented into the factory. He describes a strategy his group employed, which consists of three key components. The first component is to setup a cooperative development program with the customer (production factory) and the development group for all new ideas. This improves the chances for the new innovations success in the factory, because expert manufacturing personnel contribute to the final product at its initial conception. He states that the initial exchanges are extremely important in providing answers to basic questions that are frequently overlooked such as "if this new idea works as advertised - what would be its impact on you?" The second idea is to provide the factory with a new technology "warrantee" or guarantee that assures the factory that if problems develop after its implemention the Research Center people will help. This is very important in providing trust, acceptance, and desire of the new technology by the factory which will greatly enhance its success. The center also had the unique planning concept of rotational and internship engineering programs whose goal was to improve the manufacturability of new products by educating engineers on development and production issues. In the rotational program a carefully selected factory engineer is put on a two year assignment in a Research Center after which time he returns to his home factory and serves as their key engineer in implementing all new technologies developed by the Center. In the internship program a carefully selected development engineer is put on a two year assignment in a factory where the primary goal is to become educated on "real world" routines of the factory and to also contribute to the factories day-to-day problems. The engineer then returns to the center better equipped to develop usable products for the factories. The cross-fertilization provided by these two programs provides personnel with the experience required to develop manufacturable new product designs and processes.

Similar to Sagals cooperative development program, Whitney [1] discusses multifunctional design teams that use a "simultaneous engineering" approach to effectively achieve good manufacturable designs. The teams are small and consist of design, development, manufacturing, marketing, and purchasing personnel who get involved at the new products conception. This type of team is typically able to integrate the design into the demands, requirements and limitations of the other areas. To assure new product manufacturability Whitney calls for top executive team support, involvement of manufacturing, assembly, and field repair in the design at conception, simple assembly, reduced subassemblies, ease to integrate into automation, combinational design (subassemblies that can be interchanged with other products), and jigless manufacturing (no setup for small batch sizes).

Meredith [7] in a case study of Peerless Laser Processors reports that design complexity should be avoided and simplicity of manufacturing techniques are mandatory to the successful introduction of a new technology into manufacturing. Other key items were a champion of the change at the top of the organization, a small team for implementation to avoid long responses, and operator involvement or experimentation with the new technology to evolve new more effective procedures and other potential competitive uses.

Hauser and Clausing [8] describe a design strategy, which they call the "house of quality". This is an approach known as quality function deployment (QFD) that was developed at Mitsubishi's Kode shipyard in 1972. Basically one sets up interfunctional teams consisting of marketing, design, engineering, purchasing, and manufacturing who integrate customer desires and manufacturing limitations into the new products design. The approach relies very heavily on customer attributes (CA's) which are phrases customers use to describe the product such as "system is very user friendly" or "fast execution". Engineering characteristics (EC's) describe the product in measurable terms such the coating is rated to 200C or the product requires a 15V power supply. The analysis of engineering characteristics that affect customer attributes is the main feature of this house of quality approach.The success of this approach is based on effective communication between all team members. This article cites two eye opening examples of the effectiveness of QFD. The first one showed a 60% decrease in startup and preproduction costs at Toyota Auto body after QFD had been part of their methodology for 4 years. The second example compared a Japanese automaker who used QFD and an American automaker without. The the design and process for the Japanese autos was frozen when the first auto came off the assembly line, while the U.S. company was still making changes months later. This is the classic example of a lack of an effective new product design and process strategy causing manufacturing problems. Unfortunately this occurs quite frequently in U.S. manufacturing companies.

2.4 Interview results

The results of the interview questions relating to the design and process strategies for introducing a new product into manufacturing were disappointing as they did not generate any new innovative ideas and only supported a few of the ideas found in the literature. Most of the design for manufacturablity ideas and plans are supposedly "common sense" as one manager interviewed stated, but these obivous simple approaches were overlooked by most interviewees. The results also indicate that the particular managers and employees screened may not be properly educated on technology transfer methodology . This paper should assist them in this area. A table of six key ideas for design and process planning for a manufacturable product are presented in figure 1 with the 14 interviewees responses. These key ideas came from the literature and my personnel experiences. The lack of these ideas being mentioned by the majority of the interviewees may be caused by several factors: 1. poorly developed interview questions; 2. particular interviewees were not really involved with the plans to develop and transfer a new product into manufacturing; 3.resistance to change or lack of create innovative ideas. The only two common points relating to the design and process planning expressed by more than 35% of the interviewees were: 1. the need for manufacturing to be involved with the design and development phase of a new product, and 2. it is good technically sound and devoted personnel that really make new technology transfers successful. Although they may have been assumed, there was no direct mention of a manufacturable product design, interfunctional team formation, or other planning tactics.

FIGURE 1
SUMMARY OF INTERVIEW RESPONSES RELATING TO KEY NEW PRODUCT DESIGN AND PROCESS DEVELOPMENT PLANNING IDEAS

DESIGN/PROCESS KEY IDEA	INTERVIEWEE 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.Interfunctional team formation	Y									Y	Y			
2. Design & Process Manufacturable										Y				
3. Involve manufacturing with new product at conception	Y	Y	Y	Y		Y							Y	Y
4. Operators on team		Y												
5. New product design & process warranty														
6. Personnel make transfers successful							Y	Y	Y	Y	Y			

CODE: M = manager or engineer; E = technician or operator
A Y repsonse indicates that they supported that ideas because they brought it up in the interview.

Interview questions and answers are attached in the appendix. Only a subjective comparison of answers looking for similiarities was performed. Futher analysis of the answers could be performed which might yield informative results involving current trends in successful technology transfer methodologies or systems that have been successful in the past. To do justice to the analysis the entire interview process would have to be repeated with a larger group and the format of the questions would have to be changed to quantify the answers. The questions and answers could also potentially be grouped by catagory such as design or personnel issues. The application of a Chi-Squared test [9] could be performed on the quantified answers to look for statistical relationships.

2.5 Recommendations

Innovation and change are key to the survival of all present day corporations [7]. The odds of a new innovation failing are very high due to a number of reasons [10][14]. Engineering managers must plan for success by assuring that all new products are designed and the processes required to produce them are developed with manufacturability and customer requirements in mind. The U.S. market has been badly set back by it's failure to produce quality products, which is partially a result of poor designs and "unmanufacturable" production processes. In 1987 Garvin [7] proposed eight critical quality factors that should be strategically used when designing a new product for manufacturing. Garvin's eight product quality factors are: performance, features, reliability, conformance, durability, serviceability, aesthetics, and perceived quality. The engineering manager's challenge in the current ecomonic environment is to effectively develop a new product quality strategy. This can be achieved by forming interfunctional teams whose mission is to develop manufacturable new products. This marketing, design, engineering, purchasing, and manufacturing team approach was overwhelmingly recommended as an absolute requirement for success in the literature.

The design and process development strategies for a successful new product introduction into manufacturing we recommend are:

1. Form interfunctional teams consisting of key marketing, design, engineering, purchasing, reliability, manufacturing, and assembly personnel.The teams mission is to design manufacturable products.

2. Key team members are involved with the new product at conception so all key design, reliability, manufacturing, and assembly requirements are initially considered.

3. A long term strategy would be to foster the cross-fertization of development and manufacturing personnel by careful selection of key personnel for assignments outside their normal job function. Basically the production engineers would assist in the development of new product for a specified time period to gain the required knowledge and personnel contacts which can assist them with future technogy transfers to their factory. The development engineer would work in the factory to get a good understanding of what manufacturability items one needs to consider when developing a new product.

4. The House of Quality methodology approach [8] should be employed as the basic foundation of the teams mission.This is the effective balance of customer attributes to describe the products performance from marketiing studies and engineering characteristics of the product to drive the new product design.

5. Effective project leaders who are able to develop enthusiasm within the group and with the recieving manufacturing group are required to properly achieve the desired goal of a manufacturable product. Proper project plans, monitoring, and measuring techniques should be employed [11].

6. Garvin's [12] eight quality factors should be used to organize the new products strategic quality, design and process plan. These product quality factors are: performance, features, reliability, conformance, durability, serviceability, aesthetics, and perceived quality.

7. The new product design and process should be kept simple using procedures and equipment that are familiar to manufacturing personnel or easy to use where possible. There are some who agrue for small incremental changes to existing products, instead of radial changes. Others say you continuously need to introduce new innovations, because you don't want your competitors getting to market the first with that great new idea.[13]

8. Actual production operators need to be part time members of the team to act as consultants. They should be allowed to try out all new procedures and equipment required to manufacture the new product. Their function is to provide input on the ease of using the new manufacturing procedures and equipment. They should also be encouraged to experiment with the procedures and equipment as they may find better methods for producing the product. A cooperative trusting relationship needs to be carefuly developed between them and the engineers.Their inputs should be highly valued by all team members and practical design or process changes made based on them.

9. Communicate all quality trade-offs resulting from design and manufacturing incompatibilities to top management, sales and team members so there are no unexpected unmet expectations. An example of this occurred at a new semiconductor company where 10% of a particular integrated circuit product line has to be scrapped to meet the customers requirement for speed and power. These products require a 10% resistor value tolerance control to produce the desired speed and power, while the process can only consistantly produce parts with a 20% resistor control.

10. Require that all new process and design modules be characterized for latitude. This means quantifying the effect of slightly changing a process parameter on the products specifications as might occur due to normal production variations. The key design parameters should also be changed to evaluate their impact on product specifications to optimize the products manufacturability.

11. All technical, procedural, and administrative results relating to the new product development and transfer need to be documented and properly organized for easy retrieval.

12. Setup pilot lines to demonstrate the manufacturablity of the design with clearly defined documented criteria.

13. The interfunctional team should guarantee the design and process after production begins on the product. If there are any manufacturing problems with the new product the interfunctional team will see that production is provided with the proper resources to rapidly resolve the problem.

14. Additional motivation for the interfunctional team members can be developed by rewarding them for successful transfers [5].

This all sounds so easy right? Wrong, it's easy to say how things should be, but another to effectively cause real action. The key ingredient to make all these recommendations work is a champion with authority. The desired individual is the CEO of the corporation. He or she must firmly believe in these methods to achieve success and get others to exercise them so that they become natural ways of operating within the corporation. It becomes part of the corporate culture to develop all new products using this methodology.

The effectiveness of the recommended methodologies can be measured by the length of new product introduction schedule slips and the number of design and process "tweaks" performed after production is begun.

2.6 Case example

Bipolar Integrated Technology (BIT) is a small semiconductor company with 150 employees who manufactures high speed VLSI (very large scale integrated circuits) with a proprietary process. Their process currently produces the worlds fastest bipolar ECL VLSI with the highest speed to power ratio in the industry. Their market is manufacturers of high speed work stations such as SUN Microsystems and Hewlett Packard whose computer products demand the performance offered by the BIT circuits. BIT currently has a market lead, because of their products superior performance. They compete with large corporations such as TI, Harris, and National. In this section I will discuss how BIT introduced it's first product into manufacturing, the problems incurred, and recommendations for improvements which future startup semiconductor companies can employ.

BIT began plans on its initial product in 1983 with a team of development design and process engineers. This initial team did not have a seasoned experienced manufacturing member, which later significantly impacted the operation.In 1984 an informal interfunctional team of marketing, design, process development, finance, manufacturing, and assembly was formed. This team still failed to organize itself with disciplined objectives and staff itself with seasoned manufacturing personnel experienced in technology transfer. However the basic process was designed with some manufacturability in mind as the procedures were kept simple and the equipment employed was fairly well understood at the time.Another problem resulting from not having a sound structured design, process and manufacturing plan was the lack of vital new product design and process development documentation. This docuementation deficiency resulted in an inefficient development process with many delays.

The lack of an experienced manufacturing team member at the time of conception caused some products designs to be slightly incompatible with the process. An example of this shortcoming was the fact that certain high speed and tight power specification products were designed without fully understanding the process limitations. To achieve the high speed and low power as desired by the customers the products require the resistors to be controlled to a 10% tolerance. The process can only produce resistors with a 20% tolerance . This results in 10 to 15% of the manufactured product being scrapped.

This lack of a structured interfunctional team formed at product conception with clearly defined goals and objectives and some decisions being made in a vacuum lead to some very significant manufacturing problems for BIT. There was a lack of disciplined process characterization during the development phase which has resulted in many significant process "crashes". As an example the manufacturing process relied very heavily on wet chemical etching where pre-defined amounts of specific film coatings are removed off of the silicon wafer's surface after a set immersion time in a solution. The absence of these process characterizations for the etch steps resulted in an ignorance of the process latitude. Process latitude is how much a particular independent variable such as etch time can vary and still produce a good product. The characterizations provide this information and the engineer adjusts the process to achieve maximum process latitude. This is the desired mode as maximum latitude allows the process to be reproducable day after day. This deficiency with the BIT process resulted in the fabrication of defective products which were under etched and couldn't be delivered to customers. The engineers responsible to maintain the manufacturing process frantically had to correct these problems as they arose. This is referred to as after lunch tinkering in the House of Quality article [8]. This firefighting consequently resulted in a lack of focus on future development, which caused BIT's competitive edge to slip.These problems are very typical of startup companies managed by innovators who start the enterprise but almost always fail to successfully develop an effective manufacturing implementation strategy. They appear to view it as a non-innovative simple task or they overlook its complexity because they've never done it before.

The issues defined above were so interwoven into the current design and process, that changing them would of been too costly for BIT in the critical start up phase. It spite of these problems BIT survived and became profitable. It could have been much more successful if it had formed a structured interfunctional team with clearly defined objectives.

This lack of coordination, organization, planning, and direction has resulted in serious manufacturing problems for BIT. The major shortcoming here was the lack of a farsighted and experienced champion to assure that systems were organized to assure BIT's developing product design was compatible with their manufacturing process.

To avoid these manufacturing problems future high technology start up companies should do the following as a minimum:

1. The core startup team must have experienced marketing, design, development engineering, manufacturing engineering, manufacturing operators, manufacturing managers, and assembly personnel.

2. This team must have clearly defined objectives whose goal is to produce manufacturable products.

3. Document and organize all results pertaining to the new products design and process.

4. The development phase must be devoted to determining and optimizing all process/design latitudes through characterizations. A disciplined plan must be developed and executed to achieve this. Documentation and communication is absolutely required.

5. Simplify all procedural operations which manufacturing personnel will be using to produce the product.

6. Have a strong and enthusiastic champion with authority that supports these ideas and implements them as part of the technical culture.

3 MANUFACTURING COST AND TOOL ANALYSIS

This section will discuss the methodology for tool selection and cost analysis for introducing a new product or technology into a production environment. The sources of information used were personal experience, interviews of various factory personnel and a literature search. I have 4 years experience as a sustaining engineer in a high volume manufacturing facility and have introduced automation into several segments of the production line in addition to bringing on line a new process in one segment of the manufacturing process. The interviews were conducted by members of this group and consist of inputs from people in our organizations both at the managerial and blue collar levels. The literature cited is varied and ranges from trade magazine articles and text books to case studies done by corporations and individuals who have studied this problem.

3.1 Cost Analysis

Implementation of a new technology in the manufacturing environment, whether it is a new piece of equipment, a new product or a new process can represent a significant investment of time and money. If it is done incorrectly due to poor planning, equipment selection, training or other causes the project will have a reduced rate of return on its investment due to a prolonged adaptation process. It could also result in the cancellation of the project after much money has been spent. For these reasons it is important that each project be reviewed carefully to ensure all costs are identified prior to actual implementation.

There are two basic types of cost when implementing a project. They are identified here as Relevant Costs and Non- Relevant Costs. The non-relevant costs are fixed items such as depreciation on existing materials and equipment and fixed overhead costs such as management salaries, existing facilities and etc. These affect the bottom line of the company but should not impact the implementation of a project and therefore will not be addressed here.

Relevant costs are those items that will directly affect the cost of the implementation of the new technology and its use. The major costs will vary depending on the kind of technology being implemented and the degree of complexity. A detailed list is in Table 1.

In analyzing any costs there two fundamental accounting catagories of facility improvements. They are Capital and Expense. The capital costs give tax deductions based on depreciation over a period of years. Expense dollars are typically accounted for in the current year in which they are spent. In addition there are several methods for analyzing which capital investment to make and how to account for it. Two methods for doing the analysis, Equivalent Present Amount and Equivalent Uniform Annual Amount are reviewed in Ramalinghams' book "Systems Analysis for Managerial Decisions". In addition there are many other good books addressing this and as a result accounting methods will not be addressed here. Capital expenses are those that add life or substantially increase the value of a physical asset. Equipment purchases, facility improvements, and some spare parts are capital aquisitions. The rest of the costs fall into the expense category.

Equipment purchase costs are probably the easiest to identify in any project since there is usually a limited number of options. However it is important to understand installation, facility and maintenance requirements. These could significantly impact a projects cost if there are special requirements such as a shutdown required for installation, new utilities required for operation, special skills required or new facilities needed for maintenance or use. Once the equipment is installed, jigs and/or fixtures may be required to facilitate efficient work flow or allow for analytical tools. Depending upon the complexity of the process these costs could be significant.

Table 1. Relevant Costs

Initial Investment	Material
-Purchase Price	-Reliability
-Installation costs	-Yields
-Service Contracts	-Prices
-Spares	Inventory
Direct Labor	-Thru-put
Sustaining Costs	-Quality
-Spares	-Yields
-Supplies	Equipment Utilization
-Fixtures	Utilities
Variable Overhead	Additional Revenue Generated
-Technician Salaries	Training
-Outside Services	

Spare parts, production materials, and supplies may need to be stored on site depending upon geographic location and response time by vendors. Typically equipment spares cost 2-3% of the equipment purchase cost. Material and supply costs are highly variable but keeping these to a minimum and working just in time (JIT) delivery schedules with vendors will reduce operating costs.

Equipment maintenance contracts and other support or advisory personnel should be considered if complicated machinery or processes are being instituted and resident experts do not exist in the company. These can be extremely effective in getting the new technology off to a good start and achieve early acceptance by employees. In addition equipment utilization and learning curves will be maximized early into the project achieving a greater return on the investment.

Training is probably the one thing that is most often under budgeted and under staffed. It is important to train all personnel who will be involved with the technology before it is implemented. This creates support for the project as well as anticipation of its arrival. It also allows the trainees to give feedback on perceived weaknesses in the system which could impact the implementation. Although it is hard to quantify on a general basis, the training could easily pay for itself through a faster ROI due to increased output or decreased machine reliability problems.

3.2 Tool Selection

There are many success and horror stories that detail how a firm succeeded or failed in its effort to bring in a new technology. General Motors has a well known example of how not to implement new technology. When it tried to fully automate one of its new automobile manufacturing plants, the results were robots painting each other, increased quality control issues and reduced output. This plant had to endure major redesign efforts to eliminate these problems.

A success story that was reviewed in the February 1988 issue of IEEE Transactions on Engineering Management, "The Role of Manufacturing Technology in Competitiveness: Peerless Laser Processors", is a good example of what planning and correct tool selection can do for a company. By careful analysis of its specific needs, Peerless combined two technologies, laser cutting and computerized machine control through menu driven software. By doing so they created a specialized machine at their most critical manufacturing point and reduced lead times by a third as well as increasing process flexibility and quality of the output.

Peerless achieved these results by following a systematic program which are summarized nicely by Critchlows book "Introduction to Robotics". In it he lists four major phases between conception and full operation. These phases are:

1. Investigation. Determining what the goals of the system are and educating those involved in the necessary technology and operational requirements.

2. Planning. Identifying alternative ways to to meet system goals, analyzing cost and benefits, and selecting the optimum system configuration. Planning includes hardware, software and the effects of people involved in the the system. During this stage, detailed specifications for all types of equipment, procedures, and operator training should be developed.

3. Implementation. In this stage, designing the system to meet desired specifications. Making any necessary trade offs or compromises, purchasing or building the system elements, and installing the system are done.

4. Evaluation and Follow-Up. Verifying that the system met its goals or the reasons why it did not is an important task. It is necessary to learn as much as possible about each system so that it can be improved upon and so that each new technology implementation can be made smoother (Critchlow).

The investigation process should include educating all personnel and staff to some basic level on options available. This can be done getting specialists to hold seminars on the technology involved and reading as much written information as possible on the various options. Identifying economic benefits for each option will help in the selection of the correct tools. A 5 year ROI (Critchlow) should be evaluated rather than short term ROI in order to understand the long term benefits. It is important however, that ROI not be the only selection criteria. Operational fexibility, reliability and operator friendliness will go a long way towards recovering a higher installation or purchase cost.

The planning process should include system goals, ergonomic factors, documentation requirements, acceptance testing criteria, and a multitude of other factors. A summary of these requirements is listed in Table 2. In a small system not all of these steps may be necessary, but most will be. It does not take long to decide what will need to be done, and if done correctly and thoruoghly it will be more effective and less costly in the long run.

Table 2. Equipment Selection Criteria

Tolerances	Reliablity
Thru-put	Cost
Maintenance requirements	Material requirements
Utilities	Scrap generated
Vendor Support	User friendliness
Training	Footprint
Integration into existing equipment	Fixtures
	Product flow
Flexibility	Product Quality Improvement
Working Conditions	Life Cycle Costs
Documentation	Personnel Requirements
Installation	Acceptance Tests

3.3 Summary

It is important to note that out of all the interviews conducted and books reviewed, a common theme emerges. Planning, training and careful equipment selection for high leverage areas are the keys to a successfull technology transfer. The thorough review of each of the factors listed in tables 1 and 2 by experienced, qualified personnel at various factory levels including management, engineering, finance and production operators will produce a cost effective, user friendly working environment that will produce higher quality goods with increased yields and/or thru-put. By focusing on good equipment design, layout and integration to existing operations you will provide an environment that will allow the most cost effective operation. A well trained production staff that feels it is a part of the project will contribute considerably to the success of the transfer. And in that way assist in meeting the companies goals of increased profits or output.

4 DOCUMENTATION, TRAINING, AND STAFFING

4.1 Introduction

Documenting, training, and staffing play critical roles in the success or failure of implementing a new technology into manufacturing. All three require preplanning and deserve serious consideration. By thoroughly completing each one, the impact and confusion caused by the change can be reduced. This is the goal of the company in this situation.

In these sections we consider the importance of and suggested methods for handling documenting, training, and staffing for a major change in technology. At the end of the sections, we will recommend actions to take which will ease the problems encountered during a period of transition.

4.2 Documentation

Documentation plays a critical role in technology transfer because it ties the development of a technology together with the actual implementation. Without good documentation, there is no continuity between the design and the manufacturing people. Documentation has become a major part of the development costs and often costs more than the project itself. Often, however, technological documentation is most useful only when the author is available to explain its contents. [15] Therefore, it is important that the time be taken to prepare clear and complete documents which give all the pertainate information.

Technology transfer planning consists of three phases:

1. preplanning
2. development
3. implementation

The package of required documents consists of several items. First is the preliminary design or feasibility study. After deciding that it is feasible to continue with development, all new projects should have a project description and a project plan. These are examples of several documents made during the preplanning stage. Others include: drawings, production procedures, specifications, test reports, and operating instructions. [16]

Most of these documents are self explanatory, but we would like to define project description and project plan due to their importance. The project description details the required resources and technical aspects of the project. While, the plan explains the timing of the activities and dates of significant deadlines. Often the plan will include milestones and should consist of three parts: the abstract, the rationale/protocol, and a transfer plan. The abstract and protocol should contain the title of the project, an indication if the project is new or a continuing one, an objective, a business rationale, a technical rationale, and resource needs. Required manning levels and expenses should be in the abstract which is about one page in length. It is important to remember that the abstract will be reviewed with top management for final approval. The plan itself can be detailed or just an outline of major dates depending on the level of needed resources and complexity.

A several page, detailed rationale/protocol is especially important for major projects. Why the project is needed, how it will benefit the company, and a brief description of competing products or processes should be contained in the business rationale section. On the other hand, the technical rationale should detail the approach for the project and why it will succeed. Detailed in the resource needs will be the expenses and manning requirements broken down for each year over the life of the project. [17] An activity list may also be included, which will show the major tasks broken down into subactivities. Flow diagrams, Gantt charts, or Pert Diagrams are effective for long term projects.

A technology transfer plan is the third part of project plan to be generated. Initially when presented to upper management in the preplanning phase it will have to be rather sketchy, but when the project is in the development stage it must be fully completed and detailed. It is a response to the recognized need to involve large numbers of people and is important for the overall success of a project. It is important that it be carefully planned out and consider timing, publicity, equipment, staffing, funding, and alternative actions. The implementation of a written technology transfer plan is the first step in obtaining a measure of the plan's sucess or failure. [18] The importance of the whole project plan is that it is used as a reference for management in making decisions regarding which project to fund. Therefore, the plan needs to be well thought out and prepared.

There are three important training documents to be written during the project development phase. First is the training specifications which contain a detailed statement of what the trainee needs to learn. Second, the training program which is really an interpretation of the training specifications in terms of units of instruction or learning. Each item needs to be set out in a chronological sequence and time allotments. Finally is the training manual, which is a guide for the use of the training staff or trainee and shows the details of the training. It includes such details as the points to be covered,standards which must be achieved,methods, equipment and materials, and forms of records. [19]

4.2.1 Recommendations

A complete document package should be prepared for the introduction of a new technology into manufacturing. The package should contain the following: a project description, project plan, and training documents. The project plan is made up of an abstract, rationale/protocol, and a technology transfer plan. To neglect any of these items could jeopardize the success of a smooth implementation and quite possibly the project itself.

4.3 Training

Businesses are constantly faced with new production processes and product lines and must respond by training their people so they can move them from one set of conditions to another efficiently and at low cost. The need to train for new product lines is not unusual or new. Both Kohler and Ilg Electric Ventilating during the 1930's were able to move employees to new product lines even though the new line were specialized. In the case of Kohler, they started making lighting units and radiators in addition to the current line of bath equipment. Ilg Electric on the other hand began making refrigerators in addition to fans.[20]

Training is important to a company because it is the major process which can alter the composition of the labor force. Because training is expensive, not enough of it is being done. Justifying the cost in production is relatively easy to do by using information about production time, costs, scrap, absenteeism, and labor turnover. The time has come for managers to make decisions about the need for training. Employees will learn even if they are not trained, which creates an even more expensive problem. Companies need to review their training policies and plans for the future so they can take care to try and prepare the personnel for changes and plan for those events.[21]

A company's manpower should be treated as a resource and taken into account during the overall planning activity. Training needs to be viewed as an investment just like other types of investments. Sometimes it will be on a small scale and at other times it will be on a large scale. It may have a small or a high risk. Training will have a pay back period as most investments do. Training is one of the few investments which is directed toward an asset that is capable of appreciating rather than depreciating. The situation which most often requires additional training occurs when a company decides to change a process or to diversify its product line. Thus, technological changes often dictate a need for shop floor retraining program.

When a change has been decided upon there are several managerial decisions which must be made relative to training. These are[22]:

1. defining the training objectives
2. what level to train to
3. what training methods to use
4. which jobs and positions selected for training
5. the value of training as compared to other investments

Having a well-trained staff is one of the most important responsibilities of a supervisor. This includes every manager from a top executive to a line supervisor. Studies have shown that production, cost, quality, safety, moral, and good working habits are proportional to the quality of training that employees receive. [23] Unfortunately, most supervisors have a negative attitude about training because it requires so much of their time. It is important that these attitudes be changed. The introduction of new equipment or a new product offers the opportunity to reestablish the importance of quality, cost, and safety to the employees. It also allows time for further emphasis on job pride and create a more versatile workforce. The combination of all these items will improve the attitudes, gripes, turnover, tardiness, and absenteeism. Supervisors should be aware of the usefulness of training.

There are endless ways to train people. Different types of instruction are: general, job training, apprentice training, vestibule training, and on the job training. General training is usually for going over the company's policies and some academic work. Job training teaches a skill to the trainees. Learning while working and getting formal instruction over a period of years is apprentice training. Vestibule training incorporates the use of an actual training department wich is less production oriented,but is also very expensive. Finally, there is on-the- job training which is quicker than the other methods and has the employee actively engaged in making the product. Some methods are more successful than others. Because the need to get the employees retrained is in a rather short time period in a manufacturing situation, we will assume that the employee will be trained on-the-job andconcetrate on improving that method.

Studies have show that an instructor who has had some training is usually more effective than one without.[24] A good instructor will find a variety of methods of presenting a job to an employee to maintain interest. Things which improve learning are competition, enthusiasm, and a feeling of accomplishment. Characteristics which will slow learning are insensitivity on the part of the instructor, fatigue, monotony, distractions, and anxiety. Training will be more effective if supplemented with information to show the trainee how they fit into the process and what happens before and after they see the product. This was shown in General Electric's Columbia Experiment where welders were trained. GE saw a large change in quality after retraining their welders. Broken welds weredown from 6.5 to 2.8%. Rework decreased from 22 to 17%. Overall, the weld defects were cut in half. The training cost the company $1,000, but the increased quality saved them $50,000. There was also an increase in job satisfaction as a result of the training.[25]

The most sucessful retraining programs operate on the assumption that workers can be equipped to meet the demands of a changing labor market and that secure jobs await them upon completion of training. Training needs to be approached systematically to make sure all the important items are stressed. Training is a support service which needs to be clearly identified and organized to suit the needs of a particular situation. It can be broken down into six steps:

1. Prepare the instructor

2. Orient the operator
3. Explain the operation
4. Test performance
5. Release the operator
6. Follow up performance

Preparing the instructor involves first deciding who is going to train the employees. The instructor needs to know how much time he has to train the people. Trainer has four questions to keep in mind. First is what must the trainee learn? Second, what order should the elements be taught? Next, how will it be clear that the employee has learned? Finally, what training methods and materials will be best suited to this situation.[26] To answer these questions a training plan needs to be prepared from the project's training documentation to inform the instructor what the goals are and how they will be obtained. The job needs to be broken down step by step. Time and motion studies can be used to determine the most effective method of work so that the method that people are being train to do a processes is efficient. The instructor also needs to be aware of the needed supplies.

The second step is to orient the operator. It is important the trainee is not anxious. As stated earlier this is something which can impede learning. A goal of the instructor is to relax the employee but at the same time make him interested in what he is learning. Next, the operation should be explained in detail. The instructor should use the training plan and go through each step slowly. A good way to see if the employee is understanding the steps is to have him explain the job back to the instructor.

The fourth step is to test the performance of the trainee. In this step the employee actually tries to do the operation. The instructor will considerately correct the errors and encourage the employee. This will help the learning process. The next training step is to release the operator. It is important that the trainee be encouraged to ask questions and should never have a doubt if they are doing something correctly. Some companies such as SAAB actually have a work station just for training.[27]

The instructor will designate a fellow employee that the trainee can go to for help. The final step in the training is to follow up the performance of the trainee. The instructor will check several times a day on his progress for the first week. The instructor needs to encourage and make suggestions to the trainee. He can check on the employee less and less often. This is the step which is most frequently forgotten even though it is important.

4.3.1 Recommendations

Training is one of the most important aspects to be considered when planing to implement a change in technology. A small investment in the training or retraining of employees canquickly pay for itself many times over. A six step plan should be followed to make sure all the important information is covered and the employee really learns his job the correct way. This is where the training documents become very important and can drastically help or retard the technology's implementation.

4.4 Staffing

A definition of manpower planning is trying to have the right number, and the right kind of people at the right places at the right times, doing things that result in both the organization and the individual receiving maximum long term benefits.[25] Manpower planning brings together the business and manpower resources of a company. Planning is a systematic analysis of the company's resources and is used to construct a forecast of future manpower requirements. Its' purpose is to find the most efficient use for people and is tied to the organizational goals. Planning is future oriented. Manpower planning is often the number one or two priority of a company. Sometimes it is just behind research and development. The primary objective of manpower planning is to incorporate planning and control of manpower resources into the company's overall plan. This allows all resources to be used together in the best possible manner. A secondary objective is to coordinate all the company's manpower policies.

A sharp departure from the existing work systems and practices in a company triggers major organizational restructuring in the internal occupational and skills mixtures. Technological developments require a manpower review relative to personnel type, number of people, eduaction and experience needed, and emphasize the need for organizational planning and new educational plans. By planning ahead there is a better possibility that you will be able to retrain and transfer the personnel. Therefore, the emphasis on formal manpower planning must increase. There are two types of data used in manpower planning: internal and external sources. Types of internal sources include marketing to see about the possibility of expanding a product line, production relative to capacity or menthods, and financial to see if there is funding. Two other internal soures are research and development for product and process improvements, and personnel to see if the company has enough people with the right skills.

Sources for external data are political or relative to the government, social pertaining to peoples values and rights, econimic areas concerning competative trends, and technological areas involving innovations and new developments.[29] It is ctirical that the company takes all these sources of information into account because they can have an impact in the decision that a company may make in respect to manpower planning and staffing for a change in technology or products.

Stages of Manpower Planning

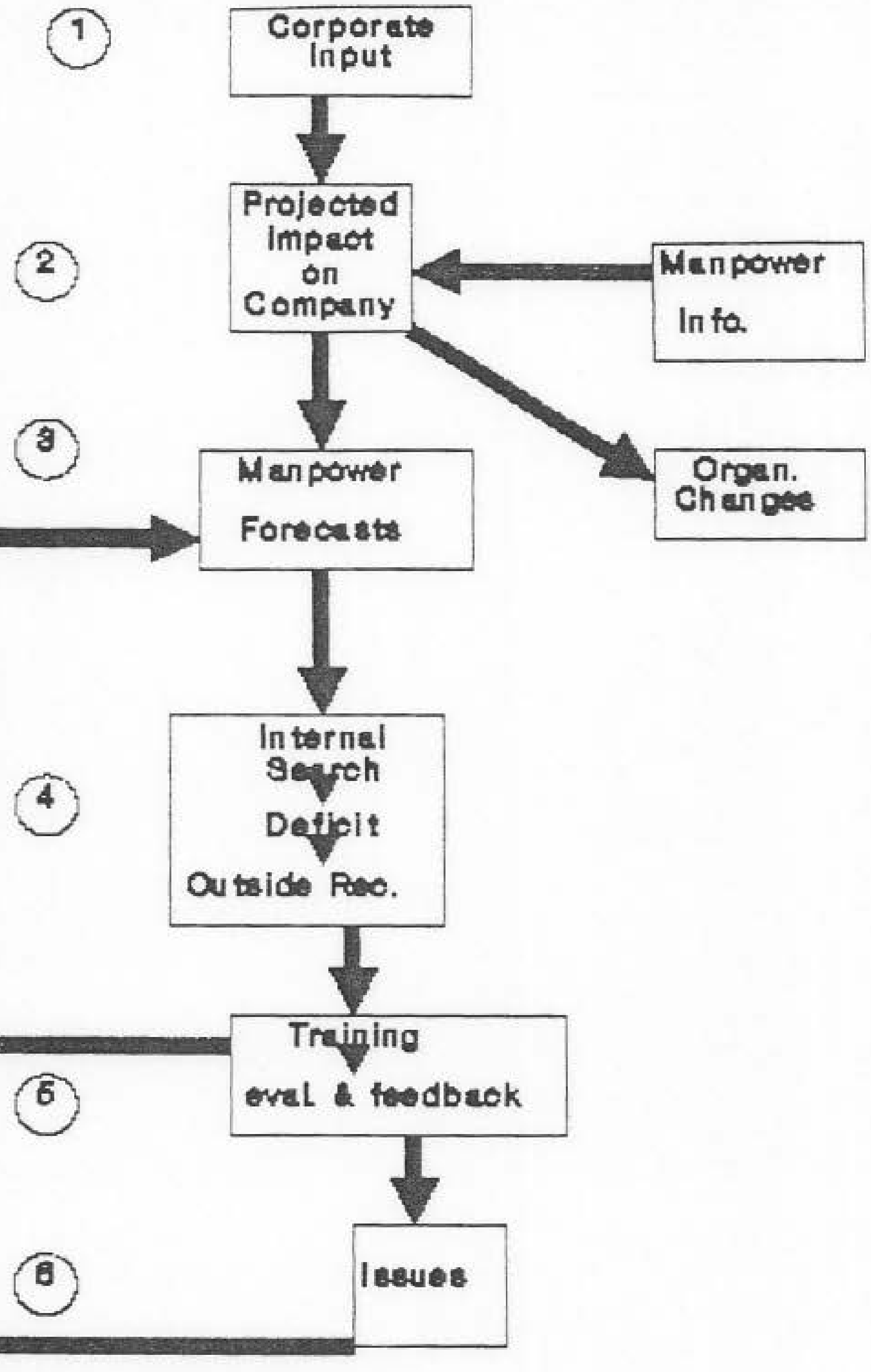

FIGURE 2

There are five features of an effective manpower planning program[30]:

1. Systematic manpower forecasting with enough detail to forecast demand and supply.

2. A complete analysis of change to include proposed programs to prevent obsolescence and updating of individual's knowledge, skills, and expertise.

3. Integrating into policy the effects of a change relative to financial, physical plant, product and service plans. Constraints must also be considered.

4. Audits of performance, talent pools, and moral assessments.

5. Continuing staff attention in research, expertness, and programming and plans for actions.

There are also five stages to manpower planning. Stage 1 is getting corporate input (see figure 2). This is where the decision to implement new technologies or a new product line originates. This means a set of organizational commitments are made which will affect and structure the process of manpower planning. At stage two the impact of the change is considered. This is where the projections are made. Basically the company has modified its position and eliminated the old. Manpower information must be collected, analyzed , and interpreted. The data on the organization's manpower reserves also need to be reviewed. Depending on the size of the company, some of this information may be in a computerized form.

Stage 3 is a parallel process if organizational changes and manpower forcasting. The manpower aspect of this stage is a continuation of stage two. It is an attempt to gauge what changes will do to an organization's structure. Some methods of forecasting include regression, multiregression, and productivity analysis. At this point it may be worthwhile to state the difference between manpower planning and the traditional "personnel management". Manpower planning is intrinsic to and triggers organizational change. Personnel management is reactive and adjusting to organizational environment as it exists.

In stage 4 the manpower planner gets a clear understanding of the implications of an organizational change and the manpower forecast. This reviews the types of manpower deficits by position when compared with the future needs. The needs must be met by internal sources, interorganizational search, or outside recruiting. Use of a manpower information system is important because it gives quantitative data which can be used with the employee behavior and compare them with the skills, knowledge, and experience needed. If internal sources are going to be the primary source of employees it is at this point that you need to identify the training, retraining, and development needs.

Stage 5 is the implimentation of the manpower research results. At this point if additional people are needed, the gradual ramping- up should begin. This will allow time to begin the training process and avoid flooding the system with new employees. It is important to go back and evaluate the implimentation because changes will always occur and hopefully you can learn something that you can apply next time to make the adjustment to the change in technology smoother. Stage 6 is used in meeting the emerging manpower trends in society and face the challenges. Because this is such a dynamic model, feedback is critical.

4.4.1 Recommendations

Manpower planning and staffing needs to be at the top of a company's priority list especially when implementing a change in technology. It needs to be constantly updated and should be kept in touch with the other factors, both internal and external, which can effect decisions made by the company. It is important that the company has the five features of an effective manpower planning program to handle the staffing needs. Companies will always implement new technologies and products, therefore, if the manpower planning program is a permanent feature, the transitions periods can be handled much easier and more smoothly.

5 COMMUNICATION AND TEST PROOF

Transferring technology from development to manufacturing is very important for a company, for a successful transfer will strengthen the company's competitiveness. The complexity and rate of change associated with today's technologies make it difficult to predict the results of the transfer, and existence of the product in the laboratory does not ensure success as a mass-produced item. Here we conduct some research works about communication and test proof as they relate to the introduction of a new technology into manufacturing within a company.

5.1 Communication

Organizational communication is a system with purposes, operational procedures and structure. A primary purpose of communication within an organization is to facilitate technology transfer within a company----from research group to manufacturing group. The purpose of communication are to link these two groups and allow technical information flow from one group to the other, in order to insure the successfulness and good performance of technology transfer. We refer to this kind of communication as technical communication.

5.1.1 Communication between research and manufacturing

a) Technical document: This is a formal and major communication channel, the research group passes the technical information to the manufacturing group, which is necessary for manufacturing group to begin production. Our interviews indicated, though, that the people on the floor tend not to take the time to read it , so documentation is probably not very helpful when introducing a new product. Our interviews also pointed out that maintaining the documentation is very important.

b) Formal training: The engineers in the research group offer formal classes the production group to introduce the new product to the people on floor. Because the production of new product may bring some new process and new tools into manufacturing, so the classes allow people on the floor not only to know the new product but also to know how to deal with the new process and new tools, this is a very benefitial form of communication when introducing a new product.

c) Technical services: Necessary after the start of production, because the technical documentation is insufficient to describe everything in details. Some unpredictable problems may occur during the manufacturing process, so the engineers in the research group provide technical services to the manufacturing group. This is very important for achieveing good performance of technology transfer. Articals indicate that this direct information exchange between the two groups is key to achieveing good R&d performance. During the technical services the engineers in the research group will find ways to solve the problems which arise in manufacturing, so that the new product will be improved.

5.1.2 Communication within each group

a) Technical communication within the research group: A new product always constits of several parts. After starting manufacturing, some of the problems concerning these parts may occur on the floor. These problems are then passed back to the research group to solve. A good communication environment in the group will make some of these problems easy to solve, such as if a problem occurs in one part, and is difficult to solve, some adjustements may be made to another part which will allow the problem to be solved more easily, and can also result in achieving a better total quality of the new product.

b) Technical communication within the manufacturing group: New product often brings a new process and new tools into the manufacturing group. Learning to deal with the new process and use the new tools will encourage communication within the group.

5.1.3 Technical communication with the other groups.

Mangers in both the research and manufacturing groups should encourge communication with the other group. In his article on R&D performance as a function of internal communication, Thomas Allen points out: "as would be expected, development projects are strongly benefited by communication with other parts of firm". Table VIII in this article gives out the evidence. There is also other evidence to confirm the importance of good communication with marketing and production for all the development engineers within the project.

5.2 Test Proof

Test proof is very important in achieving good performance of technology transfer. The following three types of test approach are needed and critial when introducing the new product into manafucturing.

5.2.1 Market testing

Market testing requires the accomplishment of a number of important functions. Most of these functions should aim at insuring the continuing viability of the company. Many of the functions are concerned with determining perceptions of the new product. These perceptions include many aspects of the new product such as:

Reliability: which includes considerations of whether the new product will function correctly over its expected lifetime.

Maintainability: which is concerned with what is required to insure that the new product remains operable within certain specification for fixed periods of time, and considerations of the levels of skills required by the staff involved in performing manitenance and the frequency with which maintenance is required.

Usability: which is concerned with how easy or difficult it is for users to understand and use the new product successfully.

Installability: which deals with how much infrastructure and skill will be required to install the new product, how much specialized training will be required by installers, and how many pieces of auxiliary equipment will be required for the installation to work properly.

Applicability: which concerns the suitability of a new product for satisfying a particular need or a class of needs.

Another important function of market testing is assessing the trends in the existing markets for the new product, and in identifying or conceiving of new markets for the company's new product and in testing those markets as to their size and potential receptivity to the new product.

5.2.2 Quality testing

The quality testing is another important aspect during manufacturing. In order to achieve a high quality technology transfer, an effective system for integrating the quality-development, quality-maintenance and quality-improvement efforts of the various groups in an organization is most important, so as to enable production and service at the most economical levels which allow for full customer satisfaction. The goal is to achieve a continuous quality improvement effort that permeates every process, every product and every service in the organization.

When we define or introduce a system to assure the quality of a new product, we should follow the steps below:

- Achieve coordination of the entire quality function.
- Define the work to be done and which departments are responsible for doing it.
- Set out measurable goals and provide for review of progress against goals.

Necessary tools for achieving quality control are based in three areas:

a) Statistical tools include use of quality information systems, control charts, cause and effect diagrams and pareto analysis to diagnose problems, find causes and learn from processes.

b) Classical industrial engineering tools such as method studies, flow charting, data analysis and economic evaluation can serve well in meeting customer needs and achieving integration of groups necessary to be the top and low cost provider of products and services.

c) Behavioral science issues are beginning to be effectively and systematically applied in business to improve performance. Given technology and the ability to produce, the missing element is desire----desire to use the technology and desire to apply, day after day, one's ability to its fullest extent. The challenge of all management is to create the desire to use the quality tools as well as to seek continual improvement of processes and the operations.

5.2.3 Product qualification and operational testing

The purpose of product qualification and efficacy testing is to verify that the component and system designs are adequate to meet the product specification and goals. This phase is necessary to ensure that the product will continue to function satisfactorily as designed in any environment it may likely encounter.

The operational test is concerned with whether the new product will have any unplanned consequences, beneficial or detrimental. The consequences may affect individuals or groups, or environment, and the consequences may have economic and/or political effects. In all cases where there are significant effects the new product needs to be assessed for their potential implications, and some modifications to the original design may be required.

5.3 Summary

Above we have discussed the two aspects----communication and test proof----in introducing a new product into manufacturing. We can clearly see that these two aspects form a feedback control system, the test proof identifies where problems are in the new product and these are passed on to the research group through the communication channels. Also, through the same communication channels the research group will create a much more effective new product.

6 SOCIOLOGICAL ASPECTS

> It must be considered that there is nothing more difficult to carry out, nor more doubtful of success, nor dangerous to handle, than to initiate a new order of things. For the reformer has enemies in all those who profit by the older order, and only lukewarm defenders in all those who would profit by the new order.
>
> Machiavelli

A great deal of investigation and research has been conducted on the sociological phenomena that occur in the workplace. A brief glance through the card catalog at any library will bear this out. Yet for all the efforts devoted to the understanding of this subject, it remains the area of greatest opportunity for improvement in the way we manage our organizations. For organizations are nothing more than people interacting to reach common goals. It sounds pretty straightforward, why then is it so difficult to achieve? One reason is that the goals of the organization may not be the goals of the individual. And if there are hundreds or thousands of individuals that comprise the organization, the dilution of the goals becomes pronounced.

Introducing a new technology into manufacturing significantly impacts the lives of many people on the manufacturing floor. In fact, it is suggested that the success or failure of the new introduction often hinges on the social impact of that change and how it is handled by the manufacturing personnel.

In this section we address the sociological aspect of introducing a new technology into manufacturing. We identify a number of the major barriers to change, clarifying their causes and their effects on the introduction process. We then present a set of guidelines which if followed, would remove, or at least weaken these barriers to change, through creative action.

6.1 Inherent resistance to change

There are many reasons why people resist change in general. At a most basic level we are conditioned throughout our lives to strive for stability. From the dawn of a baby's consciousness most things are repeated with precise regularity day in and day out: feeding, sleeping, school and even play. It is no wonder that as we mature we tend to cling to consistency and stability in everything we do. As a result, when a major technological change is introduced on the job, the immediate subconscious reaction is a negative one. Even before the merits or drawbacks of the change can begin to be discussed, there is already a major cultural barrier to overcome.

To overcome this barrier a strong organizational culture promoting change is required. The organization as a whole must provide an ambience that promotes the advantages of change and dispels the myth of stability. This is a continuous process that does not start or end with the introduction of a new technology into manufacturing, but more of a way of life for the organization. Overcoming the cultural block to change takes time especially since as Donald Schon puts it, "the loss of the myth of stability is frightening. It carries with it the fear of being in the Red Sea with no Promised Land in sight."[31]

6.2 Fear of failure

Closely related to the subconscious need for stability is the fear of failure. The existing technology and process are well understood by the people on the floor, and regardless of how many problems exist the limitations are known. Change involves risk and there is no guarantee that the proposed system would function as well as the current one. This generally translates to failure in the minds of the people involved and failure is another major taboo in our culture. Throughout our development we are conditioned to fear failure and avoid it at all costs. As a result change is automatically resisted regardless of the potential value, since with any change there is the risk of failure.

Two techniques go a long way in alleviating the fear of failure. The first is reconditioning through the corporate culture, again. This is achieved by being involved in or merely witnessing failed organizational experiences where the employees involved did not adversely suffer as a result. As one of our interviewees indicated, knowing that one would be allowed to fail and not "have their head chopped off" is extremely important to the willingness to take the risks involved with technological change.

The second and equally important requirement for alleviating fear of failure is information. "Too often little or no explanation is given to the workers, sometimes with the attitude that this is none of their business."[32] The more the employees know about the details of the new technology before its implementation begins the more confident they will feel about dealing with it and consequently, about their chances of success. This information can be disseminated informally through discussions and question-answer sessions with management, as well as more formally through training. "Training programs to teach employees necessary skills should be started well before the change."[33] When the new technology is introduced the employees will have had enough time to become comfortable with the new knowledge and skills.

6.3 Ethical considerations

Some consideration should be given to character attributes of people and how they influence change in the workplace. Because cooperation and interaction are so essential for good management-labor relations, intangibles such as integrity and honesty are major forces that heavily impact the way people approach their jobs. Increasing competition in all sectors of business has tended to focus attention on bottom line performance. In today's world, financial considerations are a source of great temptation to cut corners in ethical and moral conduct. While this practice may never be encouraged, it is sometimes condoned as necessary for maintaining a competitive edge. However, the harm such conduct can cause to morale within an organization should be enough of a deterrent to preclude its use. This is actually one of the few areas of organizational management where no change is desired! Establishment of standards beyond reproach and ensuring the continued adherence to such standards demonstrates management's commitment to principles important to employees at all levels in an organization. In his classic book "General and Industrial Management", Henri Fayol states the importance of moral qualities "increases with position, and they may be set at the head of the list of higher managers'attributes". Management's uncompromising support of these supremely important sociological issues will help demonstrate to employees that it can be trusted, an element essential to acceptance of change in the workplace.

6.4 Change in relationships

In a detailed case study on administering technological change in a factory, Harriet Ronken and Paul Lawrence of Harvard University concluded that "the phenomenon popularly called 'resistance to change' was resistance not to the technical aspects of the change, but to the consequent modifications in interpersonal relationships."[34] Though many researchers do not agree that change in relationships is the only cause for resistance, it is believed to be a very significant one.

Introducing a new technology into manufacturing often brings new people from various areas onto the scene. People already familiar with the technology are hired to augment the manufacturing organization, and people from the development side of the organization get involved at least in the early stages of the introduction. Existing relationships within the manufacturing organization are often also modified. This change in relationships further complicates the introduction since smooth communication channels have not been established and the people involved had not yet learned to work with one another.

One of the manufacturing managers we interviewed suggested that the most effective solution to this problem is to create a project team that includes all the key manufacturing personnel early in the development process. As a result, when the new technology is ready to be introduced into manufacturing, the relationships among the manufacturing personnel as well as between manufacturing and design are well established.

6.5 Management barriers

In an article dealing with technological change, David C. Mowery points out that managers charged with implementing new technologies "may feel threatened by policies that give greater responsibilities to workers". In light of reductions to the levels of employment of middle management in recent years, this is not surprising.

Additionally, Mowery feels many managers are poorly trained for the effective evaluation and adoption of new technologies. This can create a reluctance to take risks on new and unproven innovations, impeding the process of technological change. Managers must work to improve their skills and upper management should actively support and provide for training to all employees, as this is perhaps the surest way for any organization to enhance its own capabilities.

6.6 Job obsolescence

Whenever the new technology being introduced is of significance, certain jobs in manufacturing may become obsoleted. This job obsolescence plays a major sociological role in the introduction process, whether it is real or simply perceived by the personnel.

There has been a number of significant innovations in recent history which when implemented have resulted in certain job categories and skill sets being obsoleted. A case in point is the introduction of automation. This has resulted in an almost indiscriminate fear of obsolescence whenever a new technology is introduced into manufacturing. Even if the new technology will not displace any skills or obsolete jobs the belief by the workers involved in the change that it will, is more than enough to disrupt or at least delay the new introduction.

Once again the most effective way to deal with this is through communication and information dissemination. This information flow must start right form the time when management formulates its plans to introduce the new technology and must continue throughout the development and technology transfer phases. In fact, in one case where computer aided technology was very successfully introduced, management went as far as meeting informally with employees simply "to survey the latest technical developments in the field."[35] This gave the employees a lot of confidence that management is including them in their planning and will let them know whenever a new change will affect their jobs. This touches on a major general solution which one of the manager we interviewed strongly subscribed to, and that is trust. By creating a strong relationship of trust between management and the employees, unwarranted fear of job obsolescence will disappear since the employees will know that management would never conceal such a possibility from them.

There are cases however where introducing a new technology will result in skill sets and job categories being obsoleted. In such cases management has a major responsibility towards its employees. First and most important is the responsibility to retrain. In the same case mentioned above,

> "[m]anagement set up a voluntary, but grueling, 22-week formal course, with 4 hours of classwork and 8 hours of homework per week, and a tough final examination. All training was after work and unpaid; the trainee carried on his regular job during the day."[36]

Also, when the transistor replaced the tube in Tektronix' products, personnel throughout the company were enrolled in a 4-week long intensive course on the new technology. In this case though, the course was offered on company time which is believed to have encouraged more employees to participate.

Along with retraining, the organization can provide opportunities for lateral as well as vertical mobility for the employees whose jobs have been obsoleted. By giving transfer priority for other open positions throughout the organization it is usually possible to relocate a large majority of the affected employees. It is also important to be aware that job obsolescence is usually not the fault of the employee who may have been very knowledgeable and effective in his or her position. Therefore this may be the perfect opportunity for a promotion to a position of increased responsibility.

6.7 The older workforce

One important dimension to the issue of job obsolescence is employee age. As Robert Zager put it in his River Works plant case study,

> "old workers will feel the impact most. Although they have the strongest hold on employment, they are least amenable to change and have the least hope of finding traditional jobs elsewhere. To management, they represent an unattractive investment for retraining."[37]

Nontheless, special care should be taken in ensuring the placement of these older members of the workforce when their jobs are obsoleted. This reinforces the organization's commitment to all its employees especially at times of change and turmoil. Ironically, the major cause of job obsolescence today, namely technology, is also making it easier to accommodate the older workforce in certain job functions which were not accessible to them in the past. In their AMA management briefing Carol Segrave Humple and Morgan Lyons present two such technological contributions: force-transmitting machines and the microprocessor.[38] With force-transmitting machines or robotics older people can now perform many tasks that traditionally required significant amounts of physical strength. Similarly the microprocessor can compensate the older worker for decline in intellectual speed.

6.8 Phasing the introduction

From the perspective of its sociological impact, the introduction of a new technology naturally breaks down into three distinct phases: The planning phase, the transition phase and the follow-up phase. In this section we address each of these three phases, pointing out their major sociological milestones, and recommending some more specific guidelines that should aid in a successful completion of each phase.

6.8.1 The planning phase

The overall success of any major project significantly hinges on proper planning. Introducing a new technology into manufacturing is no exception. Earlier in this paper we presented the technological aspects of planning; here we discuss planning for people.

The first step in the planning process is identifying a change agent. This is the one person who plays the most significant role throughout all phases of the introduction. This person has the overall responsibility to take the new technology from the development environment and implement it in manufacturing. Selecting this person is usually the most significant decision management makes in the whole introduction process. The change agent must be familiar enough with the technology being introduced to inspire confidence in the manufacturing personnel as well as the development personnel parting with the technology. Enthusiasm and strong belief in the merits of the new technology also go a long way in promoting its acceptance on the floor.

These attributes tend to indicate that the ideal person for the role of change agent is the original innovator who conceived of or championed the new concept on the development side of the organization. One overriding factor though, is that person's ability to work well with the manufacturing personnel. If the people on the manufacturing floor have any preconceived negative notions towards the change agent, a successful transition through that person is all but doomed. The ideal change agent is a person who is well-liked by the workers and who inspires confidence and trust.

It is worth noting here that much of the classical literature strongly recommended the use of experts from outside the corporation for the role of change agent. As a result of the preceding arguments we believe that in the case of a new technology transfer, the advantages of having the right person from within the organization far outweigh the theoretical knowledge of organizational development specialists. One major study conducted by Paul Nutt of Ohio State University tends to substantiate this belief. In this research he profiled 91 case studies where managers implemented planned changes in their organizations. He concluded that 100 percent success rate was observed in cases where "change agents were manager-sponsors who took control of planned change processes. Consultants were never observed."[39]

The next step in the planning process is the assembly of a transition team. Headed by the change agent, this team is composed of key personnel from both development and production and has the responsibility of coordinating the details of the technology transfer. In his book, Managing Technological Innovation and Entrepreneurship [40], Martin identifies three requirements for this team. First, the team must not be dominated by people from either side. This is "so that the differences in attitudes and approaches that create the barriers to the transfer process may be discussed openly, and a cohesive team spirit develops."

Second, all production functions are represented through people with the right level of expertise; and third, the team should include people senior enough to give organizational credibility. We believe that both requirements two and three are of special significance to the acceptance of the new technology. By being involved in the planning, the key manufacturing people will readily accept the change and are more willing to champion it throughout their organization. Similarly, when manufacturing personnel realize that their interests and needs are represented during planning through their recognized experts, many of the barriers to change discussed in previous sections disappear, and a much smoother transition becomes eminent.

One common trap to be wary of when selecting the members of the transition team is the tendency to select the people who simply happen to be available at the time. Though these people may be at the appropriate seniority level they are not necessarily the right people. Special care must be taken in ensuring that priorities are balanced and the right people are selected. This presents a significant management challenge since the best people for such a team are usually already very busy with current production needs.

Finally, it is in the planning phase that the most concentrated information dissemination effort must take place. At the initial stages of planning, most manufacturing personnel know that a major change is coming their way and that is all they know. Unless substantial information starts flowing from management, ignorance driven resistance immediately sets in. Management must clearly describe the reasons for the technology change and lay down its approach for implementing it including identification of the members of the transition team and their roles. Soliciting feedback at this stage is valuable only if management has a serious intention of utilizing the data and acting upon it, as opposed to collecting it simply as a means for pacifying people.

A potentially very valuable tool for information transfer available to management is the informal social network in the organization, better known as "The Grapevine". As Paul Lawrence put it,"By working with this network instead of against it, management's staff representatives can give new technological ideas a better chance of acceptance."[41]

6.8.2 The transition phase

Once the detailed plans have been completed and everyone involved has been fully informed of all known aspects of the introduction, the implementation of the technology is started. During this phase, as the mechanics of the new technology are put in place and the manufacturing personnel are being trained on the new process, a new set of sociological challenges emerges.

First among the transition challenges is the Not Invented Here (NIH) syndrome. The new technology being introduced into manufacturing usually originates from the development side of the house. Thus, during transition it is often threatening to the production side since it is perceived as reflecting negatively on their own abilities and skills. A potential solution suggested by Martin [42] is the concept of people-transfer. This is simply having those members of the transfer team who originated from the development area remain with the new technology as it transitions into manufacturing and at least through the early stages of production. This has the added benefit of more efficiently transferring the technical know-how into manufacturing, since a purely "paper" transfer is never as effective as a people transfer.

A related concern going in the opposite direction is the resistance by the development personnel to changes proposed by the manufacturing personnel, during transition. This phenomenon is better known as "pride of ownership". The development personnel who were heavily involved in the definition and development of the new technology are often very reluctant to accept the technical compromises that may be required to effectively produce a salable product. This type of response will be interpreted as a lack of respect for the manufacturing personnel and must be dealt with by management. Having the person who championed the new technology during development act as the change agent, as proposed earlier, is a good first step. In addition, a development engineer "can be led to see that winning acceptance of his idea through better understanding and handling of human beings is just as challenging and rewarding as giving birth to an idea."[43]

Yet another common barrier to a smooth transition is the one affectionately called "myopis specialitis". This is very well exemplified in a case study of a Milwaukee manufacturing plant, where an engineer was assigned to develop a modification to the existing manufacturing process:

> Ed Seith didn't present his system to the maintenance crew; he virtually rammed it down their throats with no if's but's or maybe's. He also totally sold himself on the setup that he took it for granted that no one in his right mind could question it. [44]

6.8.3 The follow-up phase

In most introductions of new technology some amount of effort is devoted to both the planning and transition phases. This may consist of a formal elaborate process or a general informal recognition of the major issues and requirements. In either case, some steps are usually taken in an attempt to execute a smooth and painless introduction. Unfortunately, the introduction is pronounced complete at the end of the transition phase, and the follow-up phase is completely neglected.

Once the new technology is in place, special care must be taken to ensure that it functions properly and smoothly. The new production lines must be monitored closely and minor adjustments to the new technology and process are introduced to optimize their efficiency and product quality. This is the primary role of the subset of the transfer charged with completing the implementation, as discussed earlier. Once again, feedback from the manufacturing personnel is of vital importance in this phase. There are two major reasons for this. First, the people on the floor have the best experience base to recognize these implementation problems as well as to suggest possible solutions which have often already been tried and proven successful in previous introductions. Second, by being asked and having their experience appreciated and their opinions taken seriously the manufacturing personnel continue to build a feeling of pride and commitment to the new technology as well as a strong desire to make it successful.

In an earlier section we strongly emphasized the importance of having an organizational ambience that encourages change and rewards the successful introduction and implementation of changes that are perceived to be of value to the success of the organization. The follow-up phase is the ideal time to emphasize the organizations commitment to those beliefs and to leave a positive memory in people's minds, for future changes. Johnson and Fredian suggest a number of actions that management can take which will help in achieving these goals:

> Hold a celebration or kick-off dinner: a meeting signalling the end of the "old" and beginning of the "new" program or structure. Such an event can dramatize the new way of doing things... Mete out plenty of rewards and recognition to those who assisted and cooperated in the change. Explicit connections between their efforts and the successful implementation of the program should be identified, publicized and rewarded... Make a formal evaluation of the change. Did it accomplish what it was supposed to accomplish? What couldn't be accomplished and why?[45]

References

ENDNOTES

1. D.E.Whitney, "Manufacturing by Design", Harvard Bus. Rev., no. 4, pp83-91, July-August 1988

2. J.Corbett, "Design for Economic Manufacture", Annals of C.I.R.P., vol.35, no.1, p93, 1986

3. Robert Shannon, Engineering Management, John Wiley & Sons, New York, 1980, pp 164-167 & 186

4. W.Skinner, Manufacturing - "Missing Link in Corporate Strategy", A Harvard Business Review Reprint Series Manufacturing Strategy no.31350, p.6, 1979 (reprint of HBR May-June 1969 no.69312)

5. J.B.Quinn & J.A.Mueller, "Transferring Research Results to Operations", Harvard Bus. Rev. Jan-Feb. 1963

6. M.V.Sagal, "Effective Technology Transfer - From Laboratory to Production Line", Journal of Technology Transfer, vol. 1, no.2, pp7-15, 1977

7. J.Meredith, "The Role of Manufacturing Technology in Competitiveness: Peerless Laser Processors", IEEE Tranactions of Engineering Management, vol.35, no.1, pp3-10, Feb. 1988

8. J.R.Hauser & D.Clausing, "The House of Quality", Harvard Bus. Rev., no.3 , pp63-73, May-June 1988

9. O. C. Davies and P.L. Goldsmith, Statistical Methods in Research and Prodcution, (England: Longman Group Limited, 1971), pp 265-268

10. S.Lowell, "Managers Misconceptions About Technology", Harvard Bus. Rev., no. 6 , pp133-140, Nov. - Dec. 1983

11. Robert Shannon, Engineering Management, John Wiley & Sons, New York, 1980, pp 233-326 (chap 8,9,10)

12. David A. Garvin, "Competing on the Eight Dimensions of Quality", Harvard Bus. Rev., no.6 , pp101-109, November-December 1987

13. A.E.Pearson, "Tough-Minded Ways to Get Innovative" Harvard Bus. Rev., no.3, pp99-106, May-June 1988

14. M.C. Particelli and C.S. Killips, Successful New Product Development, Handbook of Modern Marketing 2nd. Ed., (New York: Victor Buell Ed. McGraw Hill, 1986), pp. 19.1 - 19.11.

15. Thomas J. Allen, Managing The Flow of Technology Transfer and Dissemination of Technological Information Within the R&D Organization, (The Massachusetts Institute of Technology, 1977), p.65.

16. Hyman Olken, Technology Transfer: How to Make it Work, (Livermore, Cal.: Olken Publications, 1972), p. 74.

17. John H. Dumbleton, Management of High-Technology Research and Development, (New York: Elsevier, 1976), pp. 248- 256.

18. Timothy G. O'Keefe and Harold Marx, "An Applied Technology Transfer Process", Journal of Technology Transfer, 11(1), (1986), p. 87.

19. D. J. Bell, Planning Corporate Manpower, (London: Longmant Group Limited, 1974), p. 45.

20. C. Canby Balderston, Executive Guidance of Industrial Relations, (Philadelphia: University of Pennsylvania Press, 1935), p. 275.

21. David Bell, Alexander Center, David Coleman, and Gareth Jones, Perspectives in Manpower Planning, (The Edinburgh Group, 1967), p.22.

22. Robert G. Bauman, "Establishing Broad Training Objectives", Programmed Instruction in Industry, (American Management Association, 1962), p.7

23. Bradford B. Boyd, Management- Minded Supervision, Management Institute University of Wisconsin, (New York: McGraw-Hill Book Co., 1976), p. 178.

24. Alton W. Baker, Personnel Management in Small Plants, Bureau of Business Research College of Commerce and Administration, (Columbus, Ohio: The Ohio State University, 1955), p. 78.

25. Dickson, pp. 181.

26. J Finnigan, Industrial Training Management, (London Business Books Limited, 1970).

27. Paul Dickson, Future of the Workplace, (New York: Weybright and Talley, 1975), p. 178.

28. Elmer H. Burack, Strategies for Manpower Planning and Programing, (Morristown, NJ: Adh. Mark Publication Of General Learning Press, 1972), p. 58.

29. Burack, p 76.

30. Burack, p.63.

31. Donald A. Schon, Technology and Change: The New Heraclitus (New York: Delacorte Press, 1967), p. 201.

32. Joseph and Bettie Stanislao, "Dealing With Resistance to change," Business Horizons, July-August 1983, p. 76.

33. Ibid.

34. Harriet O. Ronken and Paul R. Lawrence, Administering Change: A Case Study of Human Relations in a Factory (Harvard University, 1952), p. 293.

35. Robert Zager, "The Problem of Job Obsolescence: Working It Out At River Works," Monthly Labor Review, July 1978, p. 31.

36. Ibid., p. 30.

37. Ibid., p. 32.

38. Carol Segrave Humple and Morgans Lyons, Management and the Older Workforce: Policies and Programs (American Management Association, 1983), p. 24.

39. Paul C. Nutt, "Tactics and Implementation," Academy of Management Journal, 1986, Vol. 29, No. 2, p. 255.

40. Michael Martin, Managing Technological Innovation and Entrepreneurship (Virginia: Reston Publishing Company, Inc., 1984), p. 240.

41. Paul R. Lawrence, "How to Deal With Resistance to Change," Harvard Business Review, January-February 1969, p. 168.

42. Martin, p. 235.

43. Lawrence, p. 172.

44. Raymond Dreyfack, "Selling Change Is As Important As the Change Itself," Plant Engineering, September 1984, p. 66.

45. Homer H. Johnson and Alan J. Fredian, "Simple Rules for Complex Change," Training and Development Journal, August 1986, p. 49.

BIBLIOGRAPHY

Abita, J.L., "Technology: Development to Production", IEEE, Vol EM-32, No. 3, August 1985.

Allen, Thomas J., Managing the Flow of Technlogy: Transfer and Dissemination of Technological Information Within the R&D Organization. Massachusetts Institute of Technology, 1977.

Allen, Thomas J., "R&D Performance as a function of internal Communication, Project Management, and the Nature of the Work", IEEE on Engineering Management, Vol. EM-27, No. 1, February 1980

Apple, James M., Plant Layout and Material Handling. New York: John Wiley & Sons Inc., 1977.

Baker, Alton W., Personnel Management in Small Plants. Bureau of Business Research College of Commerce and Administration. Columbus, Ohio: The Ohio State University. 1955.

Balderston, C. Canby. Executive Guidance of Industrial Relations. Philadelphia: University of Pennsylvania Press. 1935.

Bauman, Robert G.. "Establishing Broad Training Objectives". Programed Instruction in Industry. American Management Association. 1962. p. 6-9.

Bell, David, Alexander Center, David Coleman, and Gareth Jones. Perspectives in Manpower Planning. The Edinburgh Group. 1967.

Bell, D. J.. Planning Corporate Manpower. London: Longmat Group Limited. 1974.

Bittel, Lester R.. What Every Supervisor Should Know. Fourth Edition. New York: McGraw- Hill Book Co.1980.

Brown, J. Douglas. The Human Nature of Organizations. New York: American Management Associations. 1973.

Boyd, Bradford B.. Management- Minded Supervision, Management Institute University of Wisconsin. New York: McGraw - Hill Book Co.. 1976.

Burack, Elmer H. Strategies for Manpower Planning and Programming. Morristown, NJ: Adh. Mark Publication of General Learning Press. 1972.

Critchlow, Arthur J., Introduction to Robotics. New York: Macmillan Publishing Co., 1985.

Cook, Donald A.. "Problems of Training and Retraining". Programed Instruction in Industry. American Management Association. 1962. pp. 1-6.

Dickson, Paul. Future of the Workplace. New York: Weybright and Talley. 1975.

Dingus, Victor R., "Quality is Exceeding Customer Expectations", Vol.20, Feb. 1988, IEEE EM.

Dumbleton, John H.. Management of High-Technology Research and Development. New York: Elsevier. 1976.

Fayol, Henri, General and Industrial Management, Sir Isaac Pitman and Sons, Ltd., London, 1949

Finnigan, J.. Industrial Training Management. London: Business Books Limited. 1970.

Gruber, William H., and Donald G. Marquis, "Research on the Human Factor in the Transfer of Technology", M.I.T. Conference on the Human Factor in the Transfer of Technology.

Haberstroh, Charles, ed.-in-chief, "Engineers and Automation: working for change when change is slow to come"(editorial), Food Engineering, Chilton Co., Oct.,1988.

House, Robert W., Considerations for Managing Technology From a Corporate Viewpoint, Handbook of Technology Management (to be published)

Maslow, A. H., Motivation and Personality, New York: Harper and Row, 1954.

Meredith,Jack, "Role of Manufacturing Technology in ompetitiveness: Peerles Laser Processors". IEEE Transactions on Engineering Management, vol 35, no.1, pp. 3-10, February 1988.

Mowery, David C., "Technological Change: Helping Workers Adjust", Issues in Science and Technology, Fall, 1987.

McGregor, Douglas, The Human Side of Enterprise,New York: McGraw-Hill Book Co., Inc., 1960.

Muther, R. and Haganas, Knut, Systematic Handling Analysis. Kansas City, Missouri: Management and Industrial Research Publications, 1975.

O'Keefe, Timothy G., and Marx, Harold. "An Applied Technology Transfer Process". Journal of Technology Transfer. 11(1). 1986.

Olken, Hyman. Technology Transfer: How to Make it Work. Livermore, Cal.: Olken Publications. 1972.

Ramalingham, P., Systems Analysis for Managerial Decisions. New York: John Wiley & Sons Inc., 1976.

Riggs, James L., Essentials of Engineering Economics. New York: McGraw-Hill Book Company, 1982.

Rochell, Carlton. Dreams Betrayed. Lexington, MA: Lexington Books. 1987.

Sato, Toshio. "View of the Highly Automated Factory in the Future". Robotics and Computer Integrated Manufacturing. Vol. 1. #2. New York: Pergamon Press. 1984. pp. 153-.157.

Schuler, Randalls S., & Blank, Logan F., "Relationships Among Types of Communication, Organizational Level, and Employee Statisfaction and Performance", IEEE EM-23, No. 3, August 1976

Siddall, James N., Optimal Engineering Design. New York: Marcel Dekker Inc., 1982.

Suh, Nam P.. "A Perspective on Manufacturing". Robotics and Computer Integrated Manufacturing. Manufacturing Systems and Technology of Futeue, Proceedings of International C onference. Vol 4. No. 3/4. New York: Pergamon Press. 1988.

Taylor, Robert L., "A longitudinal Analysis of Technical Communication In Research And Development", Journal of Technology Transfer,1(2), 1977.

Walton, Richard E., "From Control to Commitment in the Workplace", Harvard Business Review, March-April, 1985.

include the previous authors also in this list

APPENDIX A

This appendix contains all the interviews we conducted. We interviewed a cross section of employees in five different manufacturing organizations. Interviewees included managers, foremen, engineers and technicians. Not all interviewees answered the same set of questions but rather a subset relevant to their area of expertise.

Manager Interview:

1. How do you see your involvement in the design process improving or simplifying the introduction of a new product into manufacturing?

Manufacturing must be involved in the definition of the product right from the start of the development process. Once the product definition is finalized and the detailed design starts, it is too late to involve manufacturing. there are two reasons for this:

It will delay the design cycle.

The manufacturing team will be perceived in a negative policing role.

As for the traditional answer that manufacturing should come in and advise engineering on the design relative to manufacturing cost - I do not support this position. I believe that value engineering should be fed in at the product concept and not in the design process. Most manufacturability issues are common sense. You do not need an intimate knowledge of the manufacturing process to deal with them. The knowledge to make these decisions must be had before you even start the design.

2. Describe the major differences between managing bringing a new technology into manufacturing versus the management of sustaining a current product.

Manufacturing strives for a repetitive predictable outcome. You do not want changes at all. Developing a new process is very involved and often painful, and once it is in place and working well you do not want to mess with it. Nevertheless, rapid change is becoming required due to decreasing product life-cycles. The life-cycle of certain products, oscilloscopes say, used to be around 15 years. This luxury is going away. Look at the auto industry: model changes used to occur once every four to five years, now it is annual and may be getting even shorter. The manufacturing floor is becoming more and more of a prototype shop. So, before long there will be no difference between managing a new technology and sustaining.

3. Describe the best technology transfer you were involved in and why it was successful and describe the worst technology transfer you were involved in and why it had failed.

I do not know of any outright failures. Sometimes a significant cause of inefficiency and delay in introduction is that people get enamored with the equipment and methods of the new technology to the exclusion of really looking at the task that needs to be accomplished. A good example of this is the introduction of surface mount technology into electronic circuit board design. There has been millions of dollars spent on surface mount "pick-and-place" machines in many environments where a pick-and-place was not needed at all to implement that technology. Losing sight of the job to be accomplished may be the biggest cause of failure.

4. What was the methodology you used to introduce a new process into the manufacturing floor; how did you introduce any new equipment; what level of training did you offer; what people did you involve; and how did you justify the cost?

At this company there used to be a very serialized process known as NPI (New Product Introduction). This was a slow process but did the job of producing high quality results very well. As time-to-market pressures kept increasing this process became inadequate and it died, and nothing has replaced it yet. The approach today is very much seat of the pants.

As for training, it depends on the significance and impact of the change being implemented. Take for example the technology shift from the tube to the transistor. This is a technology change that affected everyone across the board in very significant ways, so there was a full corporate education program to help people shift to the new technology. I remember going to a four week long full time class on the new technology. On a product by product basis though, this does not typically happen.

5. How do you handle staffing needs for a new product introduction (gradually ramping up or all at once, etc...)?

The overall needs must be defined at the front-end of the project. An initial balanced development team including manufacturing engineers, technicians, evaluators and procurement personnel must be put together from the start of the project. As for staffing up to do the physical labor in manufacturing, that should occur in a ramp-up step function approach.

6. Do you feel that time needs to be set aside to train personnel before you introduce a new technology into manufacturing, and if so how do handle adding that to the normal workload of the personnel? How much time do you actually set aside in such a situation?

Training is a joint obligation of both the company and the employee. Management has the responsibility to get the employee trained and educated and the employee has the responsibility to learn. So the ideal solution is a combination of classes during work as well as company paid classes after work. This leans on the aggressiveness and ambition of people who are willing to put their own time and effort into learning and growing.

A very important driving force is how fast you need to train. If it is something that must happen quickly the company must carry the full burden.

7. What is the methodology you use for testing the product before you approve it for manufacture?

The company does not have a standard way of testing the product before acceptance into manufacturing. It is done in different ways. It could be done by either the design team or the manufacturing team, and there is no preference organizationally. There are disadvantages with both approaches. For example, if done by the design team, there is a tendency to pull the people off to do design instead of testing right in the middle of the testing phase. And if done in manufacturing, it often is more difficult to get the right level of qualified people to join manufacturing and perform this task.

8. When introducing a new technology, how have you attempted to deal with resistance to change by people on the floor? Were you successful?

The best way to deal with resistance to change is to be proactive. Develop trust between you and your employees as well as promoting trust between the employees themselves. Lack of trust must be one of the biggest reasons for reasons for resisting change. If I trust my manager I do not feel threatened by the change and I believe that my boss will do what it takes to make it successful.

We all have a certain tolerance to change. We change so much and then we cannot do it any more. People in general, especially in high technology have embraced the need to change, but not the need for continuous change. In other words you often here: "I needed to change and I did and that's enough". This is not so, we must always thrive for change and believe that whatever we have done is not enough. This is a very difficult concept to come to terms with.

9. Have you had to deal with employees being threatened by obsolescence?

This is a serious issue at our company, but I believe trust is the way to solve this one too. If I am threatened by layoffs and termination I will not trust my manager and my corporation to insure my technological growth and continued employment and this will make me very conservative.

Employee Interview:

1. How do you see your involvement in the design process improving or simplifying the introduction of a new product into manufacturing?

Operator - I don't

2. Describe the best technology transfer you were involved in and why it was successful.

Operator- Automation of work station. A large step forward due to new technology.

Tech A- 427 project (process). The reason it was successful was due to good knowledge base and lots of work put into troubleshooting process. Followed methodical path continuously working to get job done.

Tech B- Auto loader installation- Good vendor support.

3. Describe the worst technology transfer you were involved in and why it failed.

Operator- New process introduction. There was poor documentation and direction.

Tech A- New process introduction. Poor communication and research data as to why change was implemented.

Tech B- Machine upgrade. Original project owner left company during transfer of technology. Caused numerous problems.

4. How did a change in the in the manufacturing process affect you and what were the positive and negative aspects of it?

Operator- The negative aspects were poor direction and the process was not ready when transferred in. The positive aspects were the experience and change of pace it offered.

Tech A- Negative: Inconsistent communications making it harder to work on equipment when problems arise and no knowledge of how it works. Positive: long run equipment ran better and reduced work load.

Tech B- Negative aspects are initial learning curve and training that goes with it. Also becomming comfortable with change. Positive side is that systems are more managable.

5. Did you feel threatened by the introduction of a new technology why (or why not)?

Operator- Yes! I Feel that automation threatens my job but I know that it is necessary, and I enjoy working with it.

Tech A- No, improvement is good for the company and for us.

Tech B- No, as long as it is beneficial.

6. Do you feel that new technology is good or bad for a corporation and why?

Operator- Good. We need it to stay competetive in market place.

Tech A/B- Good, main reason is corporate survival.

7. What form of communication works best when introducing a new technology (documents, classes, hands-on, etc...)?

Operator- One-on-One training on the system, work with it then review weak areas with trainer.

Tech A- Q & A meetings to discuss issues, then OJT long enough to learn then class.

Tech B- Meetings for introduction, then combination of class and OJT with a follow-up.

8. Have you ever been involved in a change of technology on the floor, and if so how do you feel you handled it?

Operator- It varies, some I handle well and others, I don't.

Tech A- Yes, very good to very bad. I handle it good when I know whats going on.

Tech B- Yes, when presenting new technology I do well. When forced I handle it poorly.

9. What do you feel mangement could do to make the transition easier?

Operator- Letting people know ahead of time what is going on. Explain machine tasks and listen to inputs from operators.

Tech A- Be more involved with transition and education of employees.

Tech B- Stay on top of progress to understand and communicate changes. Be involved every day for questions and support.

10. How important is it for you to be involved in the introduction of new technology, as opposed to having it imposed upon you?

Operator- Very important. I want to feel part of it and have my view points heard.

Tech A- Important to be involved up front in decision making to ensure my needs are met and understand why certain decisions are made. To give input on those decisions.

Tech B- Important to have understanding.

11. Have you ever been in a situation where a technology change displaced some of your skills, and how did you deal with that?

Operator- No.

Tech A/B- No.

Management Interview:

12. How do you see your involvement in the design process improving or simplifying the introduction of a new product into manufacturing?

Manager 1: Introduce processes that will yield and is suitable for the way the fab runs. Comprehend equipment and manufacturing and process needs.

Manager 2: No involvement in design process. Give feedback to development group to improve process. They give feedback to the design group.

13. Describe the major differemces between managing bringing in a new technology versus the management of sustaining a current process.

Manager 1: New technology has lots of unknowns so research and cooperation are important. Must use engineering judgements, copy techniques of existing processes. Sustaining has day to day problems but lots of experience and data. Most problems have already been fixed.

Manager 2: New Technology has lots of characterization work that must be managed. Broader scope needed to obtain information. Sustaining is more routine, short term crises situations versus unclear long term problems in new technology.

14. Describe the best technology transfer you were involved in and why it was successful.

Manager 1: Using a core team concept of different disciplines to bring bring in a new process. Group meets to discuss problems and resolutions. Composed of experienced members that are considered experts in their area and are good organizers. Team had clear plan and goals.

Manager 2: 424 best to date because people involved have hands on experience and are managing their own section. (All have 5 yrs experience).

15. Describe the worst technology transfer you were involved in and why it failed.

Manager 2: Transfer of 3" to 4" wafers in fab. Was bad due to low technical experience of managers involved.

What was the methodology you used to introduce a new process into the manufacturing floor; how did you introduce any new equipment ; what level of training did you offer; what people did you involve ; and how did you justify the cost?

Manager 1: Equipment need based on process requirements and capacity. Process was brought in from other fab. told not to make changes unless would not impact process. Had to prove change was absolutely necessary and low risk.

Manager 2: Get ownership of changes to people who own the area and then protect these people from distracting problems. New equipment training was done on existing equipment in corporation but not in the fab. People had operation and maintenance experience before new equipment arrived. Brought vendor techs on site for start-up. Would not let process run on stations unless people were trained.

16. How do you handle staffing needs for a new product?

Manager 1: Did not hire new people but did transfer all at once while off loading other work.

Manager 2: Gradually ramped staffing needs.

17. Do you feel that time needs to set aside to train personnel before you introduce a new technology into manufacturing, and if so how do you handle adding that to the existing work load of the personnel. How much time do you actually set aside for such a situation?

Manager 1: Yes, we prioritized the new process as the number one requirement and offloaded other work as required. There was some overtime required. We tried to keep it to a minimum but still do a good job.

Manager 2: Yes, set time aside for training. Have to schedule and prioritize training.

17. How do you approach documenting each step of the development and transfer of the new technology into manufacturing?

Manager 1: Document as much as possible any changes. Used process specs as initial criteria, weekly meetings, review boards. Process came with "Blue Book" which has history of problems, qualifications of every step and every piece of equipment.

Manager 2: Core project team documents changes that are done. Blue books, specs, notes and documented test results are passed along with the process.

18. What is the methodology you use for testing a product before you approve it for manufacture?

Manager 1: Yields must be at same level as existing fab running process. Standard tests for reliability, sort and etc.

Manager 2: Follow testing requirements set by reliability group.

19. When introducing new technology, how have you dealt with resistance to change by people on the floor? Were you successful?

Manager 1: Was successful by showing them this was the only option or it was the best known method (BKM).

Manager 2: Published weekly summaries to explain process changes and why. People saw change as job security.

20. What have you done to prepare people for change?

Manager 1: Planning ahead, work load responsibility changes, and training. Identifying who is best for what jobs.

Manager 2: Not an issue.

21. Have you ever had to deal with people being threatened by obsolescence?

Manager 1: Reassure them that job is not threatened and at same time find new jobs when required.

Manager 2: Absolutely, Be open to let them understand general direction of technology trends but also address their fears.

22. Are there any more people issues that are difficult to overcome in a successful technology transfer?

Manager 1: Communication between team members critical. Need to understand and relate to problems in both directions. People need maturity both technically and ethically. Need people that care.

Three Interviewees:

A = Development Manager

B = Technology Consultant

C = Manufacturing V.P.

1. DEFINE PROCESS:

A: A set of sequenced steps and procedures necessary to achieve or produce repetatively a desired result.

B: A sequence of well defined steps such as the photolithographic, etch, thin films, implant and oxidation steps required in a semicoductor manufacturing facility to fabricate integrated circuits.

C: A documented method of building some particular widget. In most cases an intial desirable objective has been defined.

2. DEFINE DESIGN:

A: The conceptual act of defining the desired end result based on a given process or processes.

B: A way of connecting a well defined set of devices (basic building blocks or subassemblies) on a silicon wafer, resulting in a functional electrical circuit.

C: In the semiconductor world, a design is the layout of particular devices, which give a desired electrical result.

3. DESCRIBE THE DIFFERNCES IN MANAGEMENT STYLE REQUIRED TO BRING A NEW TECHNOLOGY INTO MANUFACTURING AS COMPARED TO MANAGING A SUSTAINING ENGINEERING GROUP?

A: Sustaining engineering is priority driven, while new technology introductions are nearly always schedule driven.

B: New technology introduction requires a problem solving mentality, a focus on schedule instead of priority, and the management of orderly change instead of maintaining the status quo.

C: Managing a sustaining group goes through phases. Phase one is constantly fighting fires of the day and fixing variances. This is crisis management with an eye to pahse two. In phase two the group is directed to prioritize the fires, then characterize and fix the top issues. In both phases stress levels tend to be high. Managing a new technology group is setting aggressive time line goals and assuring the group doesn't get stuck on one issue. Motivational sense of urgency is paramount.

4. WHAT PEOPLE ISSUES ARE THE MOST DIFFICULT IN A SUCCESSFUL TECHNOLOGY TRANSFER?

A: Egos and the NIH mentality corner in the US. Reluctance to change procedures or do something new and not understood. training in view of the first two items.

B: Hiring competent and self-motivated people to perform the tasks is difficult. Trying to develop an effective team with a bunch of "prima donnas", many highly educated engineers tend to be is tough.

C: Many times a strong sense of urgency is not understood within the group so that schedules slip. The time lines appear to be so long thatis sometimes good enough.

5. WHAT ARE THE KEY ITEMS AND ISSUES ONE HAS TO CONCENTRATE ON TO ASSURE A SUCCESSFUL TECHNOLOGY TRANSFER?

A: 1. Documentation and change control; 2. Clearly defined responsibilities and responsibilty transfer; 3. Reproducibility of the new technology.

B: 1. Good planning; 2. Ability and willingness to improvise; 3. Routine day to day attend to details (all small issues need to get full attention)

C: 1. Strong methodology; 2. A strong understanding of present manufacturing process limitations to make sure it is just not a "hot house" environment project; 3. Is it production worthy? i.e. if it is too complex the yields may be too low to be profitable.

6. DESCRIBE THE MOST SUCCESSFUL TECHNOLOGY TRANSFER YOU'VE BEEN INVLOVED WITH AND WHY IT WAS?

A: The first technology transfer at Intel was the most successful for me, largely because I was able to introduce the methodology for transfer with minimal problems. This was due to the fact that the manufacturing facility was staffed with new personnel whose procedures and methodologies were not yet ingrained. A second major *reason for its success was the strong personal cooperative relationships between the senior development and manufacturing personnel.*

B: The most successful technology transfer I've been involved with was Intel's introduction of the 256K DRAM chips in manufacturing. The major reasons for this was that the players were very experienced and the manufacturing personnel supported the entire program.

C: Motorola's introduction of a one million BIT MOSFET into production. The process was not transferred into manufacturing until the yields were grater than 50%. By doing this it was known to be aviable product and was futher fine tuned to 80% yields. The development people knew the existing process well and understood in advance equipement and process characteristics.

7. DESCRIBE THE WORST TECHNOLOGY TRANSFER YOU'VE BEEN INVOLVED WITH AND WHY IT FAILED TO MEET EXPECTATIONS?

A: The cuurent BIT situation is the worst technology transfer I've been involved with for the following reasons: 1. Manufacturing is largely out of control (now it is improving); 2. Lack of development methodology and direction from product through to process.; 3. Poor organization and charters which set priority decsions at the wrong management level; 4. No long range company plan.

B: The development of the ATEQ CORE 200 reticle engraver for the following reasons: 1. Weak manufacturing oraganization to transfer technology to; 2. Poor communications and team effort between manufacturing and design.

C: At Motorola a process was put into manufacturing that had a very poor yield (only one die per wafer). This had been deemed goood enough by the developmemt group. It took the manufacturing engineering group over one year to understand the new product and achieve reasonable yields. The reasons for this were the following: 1. The development group didn't coordinate their efforts with the manufacturing group. and 2. They didn't define a real "manufacturability" criteria for their new product prior to giving it to the production group.

8. LIST THE KEY DOCUMENTS REQUIRED FOR A SUCCESSFUL TECHNOLOGY TRANSFER.

A: General Spec which is above the process flow, process files, lead product spec., and the design rule documents.

B: Process spec., module spec., design report, design characterization report, process characterization report, and reliablity report

C: 1. a process travler that is modeled after the existing process one; 2. operating instructions; 3. full process documents, signed off by Q.A. and production control.

9. HAVE YOU HAD TO DEAL WITH EMPLOYEE OBSOLSCENCE AND HOW DID YOU DEAL WITH IT?

A: Centrate totally on doing what is best for individual employee, but do not fool yourself into thinking people will change.

B: no

C: Haven't really had to deal with this issue in the semicoductor industry. When it has occurred at all in the past I had the luxury of sending these people through extensive training classes and seminars at Motorola.

10. HOW DO YOU CONTROL THE DESIGN PLANS TO ASSURE A SUCCESSFUL NEW PRODUCT INTRODUCTION?

A: The process development manager must control design rules, lead product, design schedules, and all process/product tradeoffs.

B: Minimize changes and pay close attantion to details. " Better is the enemy of good enough."

C: never been invlved with design

11. WHAT ARE SOME OF YOUR IDEAS ON CURRENT MANUFACTURING IN AMERICA AND HOW DO YOU PERSONALLY FEEL IT CAN BE IMPROVED?

A: A better understanding of statistical process control and reproducibility in a manufacturing environment.

B: Manufactruing in America needs to think long term and the capitalization structure needs to change.

C: Driving for statistical process control needs to be carefully understood. It took the Japanese 10 years to really get a handle on how to do it. It should be more of an osmosis process starting with the equipment and process designed experimentation (Taguchi and multivariant analysis). After characterization is fully begun start training production in control chart methodologies (SPC). Too many American companies are trying to wave a magic SPC wand and it doesn't work. It takes many long dedicated years to achieve any significant benefits.

Three Interviewees:

A = Technician

B = Clerk

C = Manager

1. How do you see your involvement in the design process improving or simplifying the introduction of a new product into manufacturing.

A. I am directly involved in the design and implementation of in house technical projects, but I have virtually no input into outside generated technology transfers. For the projects that I am invovled in, cost, reliablility, and ease of operation are prime concerns.

B. During the planning process of the installation of our new computerized maintenance control system (MCS), I was asked for my input as to which features of various work station layout were most important to me. Since I was to be one of the primary users of the system, this was important to me and as a result of my participation, I now have a work environment with which I am quite comfortable.

C. I am not very involved in the design of new products, but I am involved in the design of or modifications to the processes we use to make our products. I try to ensure that corporate as well as plant engineering guidelines are followed wherever possible. Standardization is one theme that we stress, maintainability is another. Safety and ease of operation are two other factors that are very important considerations that must be addressed during the design phase.

2. Describe the best technology transfer you were involved in and why it was successful.

A. One of the most successful technology transfers into this plant has been the Ishida statistical weigher project. These microprocessor controlled weighers have proven to be extremely reliable and accurate, reducing per bag "give away" from 1/8 ounce (3.5 grams) to 4/10 of a gram, a reduction of nearly 90%. The project took place during the winter months, our slow time of the year, and was well coordinated. Most of the training occurred prior to completion of the installation, hence very little time was required to get up and running once the project was completed.

B. The best technology transfer I have been involved in is our new computerized maintenance control system (MCS). It was easy to learn, saves me time, makes my scheduling tasks much easier to do. The system if reasonably flexible, multi-faceted, expandable, and can be utilized as an analysis tool to track equipment repair and breakdown history. It really has been a big improvement over our old manual system.

C. The best technology transfer I was associated with was converting our corn cooking process to a microprocessor controlled system (Automatic Batch Controlled Cooking- ABCC). While the system was a corporate directed transfer, we were able to get our processing operators involved very early in the planning stages, demonstrating, I believe, that their input was valued and management was committed to providing a process that would make their work less strenuous, safer, and more reliable. I think we accomplished those objectives.

3. Describe the worst technology transfer you were involved in and why it had failed.

A. The worst technology introduction would have to be the starch recovery project. While the concept makes sense from a cost savings standpoint, the design of the system leaves much to be desired. Because of some fundamental design errors, this system has been a constant source of problems for the operators as well as the maintenance department. A recent upgrading of the system has still not corrected the basic flaws, and now a third upgrading is being initiated to try to make the system more reliable.

4. How did a change in the manufacturing process affect you and what were the positive and negative aspects of it?

A. The introduction of microprocessor controlled equipment has been the most obvious change in some of our manufacturing processes. While this has led to increased reliablity, it has created problems for a large percentage of our maintenance mechanics who do not have electronic skills when problems have developed. While I personally believe that is type of equipment is necessary for the plant to remain competitive, the withholding of proprietary knowledge by the manufacturers makes troubleshooting and diagnosis all the more difficult for mechanics like myself who do have a good understanding of electronic systems.

C. The change to an Automatic Batch Controlled Cooking (ABCC) process illustrated that with good planning and employee involvement, the negative aspects of technology transfer can be minimized, leaving the positive features to dominate the change process. Because this project was so successful, I will try to use similar methods of implementation in future projects in which I am involved.

5. From an individual standpoint, do you feel threatened by new technology and why or why not?

A. No, I do not feel threatened by the introduction of new technologies, in fact, I welcome it. From past history, I have seen what new processes have done for our manufacturing capabilities, and I realize that we need to use new technologies if we are to remain competitive. However, I feel the company could be more thorough in its efforts to provide adequate training for those who operate the equipment and those who must be able to repair it.

B. I do not feel threatened by new technology, especially after I have seen how MCS has made my job easier and allowed me to be more productive. My skills have improved, new technology introduction has been positive for me.

C. Through my involvement with projects here, new technology transfer into our plant seems a natural process, so I have no fear of it. I have see how new systems have improved our productivity, reduced costs, made people's jobs safer and easier, hence, I am in favor of making changes for the better.

6. Do you feel new technology is good or bad for the corporation and why?

A. As I just stated in the previous answer, this company as well as most other companies need to incorporate new technologies into their manufacturing processes. The reasons are increased reliability, reduced operating costs, ease of operation, extended useful life, increased safety, improved quality, to name a few. However, it is also imperative that adequate training be provided along with the new technologies so that employees are comfortable in using them.

B. I feel new technology is good for our company. We have improved our quality, increased productivity, and lowered our costs through the introduction of new technologies. I feel that we are a more competitive company by looking for and utilizing new and better ways to make our products.

C. As I just stated, there are so many positive things about new technologies, there is no question that they are good for the corporation. This company is committed to making the best quality product available, and has shown to all who care to see that it is willing to make the investments in new and improved equipment and programs that will allow it to achieve that goal.

7. What form of communication works best when introducing a new product (documentation, classes, hands-on experience, etc...)?

A. From a maintenance standpoint, documentation is very important since we will be called upon to effect repairs should there be a breakdown. Classes for both operators and maintenance support allow for discussion of theory that will help in the understanding of the technology and why it is being implemented, which in turn will help in the acceptance of the new process. Of course, hands-on experience is also extremely important in order to become totally familiar with the attributes and idiosyncrasies of any new equipment or process.

B. With MCS, we had hands-on training and classroom instruction simultaneously, so I was able to get comfortable with the new system right away. Additionally, expert help was readily available via telephone after we were up and running in case we had any problems that we couldn't solve ourselves.

C. Documentation is important, but oral communication in the initial phases of new product introduction is most vital. This gets employees involved and promotes buy in. Advanced training of operators and service technicians needs to take place, if possible, prior to the actual installation of the system. That way, the equipment can be up and running as quickly as possible.

8. What do you feel management could do to make that transition easier?

A. As previously stated, documentation and training are obvious necessities. Additionally, any performance problems with the new technology or process that are identified after the system is on line must be dealt with quickly and effectively. Debugging will help ensure that maximum return is obtained from the investment and will also promote continued support from those that interact with the new process.

C. Employee involvement, adequate training, follow up on "punchlist" items demonstrates management's commitment to doing the things necessary for successful change and evolution in the way we conduct our business. Being as open with labor as possible about new strategies helps reduce resistance that often accompanies the uncertainty brought about by change.

9. How important is it for you to be involved in the introduction of new technology, as opposed to the technology being imposed upon you?

A. A large majority of the improvements made to this plant are directed by our headquarters group in Dallas, Texas, and as a result, very little input can be provided by my department. Since there are over 35 plants in our company, and many of them make the same products and thus have the same type of equipment, it makes sense to have our corporate engineering group direct these improvement projects. However, there is a lot of in plant knowledge concerning our various processes that may be of value in the designing and introduction of new technology into the manufacturing facility, but we do not currently have a mechanism in place that allows for much input into this process. We have very little choice then but to accept that which is imposed upon us.

B. I believe my involvement and input into the MCS planning process helped make the system more user friendly and certainly helped gain my acceptance of it. We were able to identify and address some potential problems prior to installation that I feel made the transition smoother, easier, and actually enhanced the performance of the system.

10. Have you ever been in a situation where the technology change displaced some of your skills, and how did you deal with that?

A. The modular design of some electronic equipment has supplanted some of my troubleshooting skills, but I do not feel that this has reduced my ablility to do my job effectively. In fact, changing out a circuit board is generally easier that replacing com-

ponents, so it has actually made my job easier to perform. As long as there is adequate documentation that deals with diagnosis of equipment problems, the technology changes that have occurred have not caused me any serious problems.

Employee interview:

10. How do you see your involvement in the design process improving or simplifying the introduction of a new product into manufacturing?

Critical. It helps the transfer process by having people from manufacturing knowledgeable in the new product before it gets transferred. It also helps the design team focus better on issues that are important for manufacturing of the product such as ease of manufacturability, etc...

11. Describe the best technology transfer you were involved in and why it was successful and describe the worst technology transfer you were involved in and why it had failed.

This corporation may be atypical regrading technology transfer. I have never come across any major problems when new technology is being introduced. We have always had a manufacturing engineering group that tremendously smoothes the introduction. So there really is no clear distinction between different introductions.

12. How did a change in the manufacturing process affect you and what were the positive and negative aspects of it?

Introduction of JIT (Just In Time) Manufacturing was the most significant change I went through. It was mostly the challenge of changing your mind set towards the manufacturing process itself and that takes time.

At times you run into situations - you are used t doing things a certain way and suddenly has to change. This is a concern to people because we have to maintain the same production levels with a completely new approach for which we have no prior experience or knowledge base. In essence it is being afraid of the unknown. In these situations having skilled technical people on hand to simplify the transition was very helpful.

For the manufacturing engineer, it changed the whole approach to problem solving: you could not afford the esoteric solution any more, spending time contemplating it and optimizing it. You now have a production line depending on your solution and by the definition of Just In Time, it cannot wait. It changed our whole lifestyle.

13. From an individual standpoint, do you feel threatened by new technology and why (or why not)?

No, because I was involved in working on the new technology directly even before its introduction but I know of others who perceived the new technology (the introduction of the computer on the manufacturing line) as a serious threat to them. This was especially so because a new group was brought in to handle the automation of part *of their job. So, even though the original group did not lose their jobs they were made to feel much less effective.*

There was no management effort at all to deal with the situation, and many employees simply never adjusted to the new technology at all.

14. What form of communication works best when introducing a new product (documents, classes, hands-on experience, etc...)?

Documentation is probably NOT very helpful when introducing a new product. The people on the floor tend not to take the time to read it. Formal classes such as technician training classes are more effective.

The best thing to do is to actively involve them in the process. In the past, I had taken engineering circuit boards and showed them to the people that would be assembling them and asked their opinion on the broads, since they are the ones that knew this task better than myself or the designers and they would know of things that are problems or potential problems. This makes them really feel that they are part of the process.

The amount of classes given and when they were given depended on whether you were behind on current production schedules or not. The goal these days is not to have people so fully booked as a matter of course that they cannot take such classes.

15. What is the methodology you use for testing the product before it is approved for manufacture?

Traditionally we had what was called the 200 hour test in manufacturing. A pilot build of around 20 units is assembled and each unit is tested for its operating characteristics. The units then gets cycled at high temperature for 200 hours and during that time they get tested for the same parameters. If they pass the tests, then the Product Release Milestone is officially granted.

This has been changing lately, though, and manufacturing is getting more dependent on engineering evaluation for acceptance. This is primarily due to the increase in the complexity of the instruments to the point where simple cycle tests do not tell you much any more.

16. What do you feel management could do to make that transition easier?

Management should look more at training issues and make sure that people are better prepared for the new technology. For example, in the case where there is displacement of former activities it could be handled in such a way that the existing personnel could be trained to perform the new activities rather than being replaced by others.

People are also often afraid that the introduction of automation, say, will result in their losing their job. So by clearly detailing to these people why that is not the case and why their contributions are still needed, the transition would be much easier.

17. How important is it for you to be involved in the introduction of new technology, as opposed to the technology being imposed upon you?

Being involved is absolutely critical. There is nothing you can do to make up for involvement. With any change there is a buy-in or ownership aspect and without involvement it would be very tough to come by. The transition is usually not a clean thing. You have had a clean technology and process that you have been comfortable with for a very long time and now you are changing it for something new that is usually still quite fragile and suffers from its own set of birthing problems, so it is easy to look negatively at it and to resist it. They need to know ahead of time that they will be afforded the support and tools to deal with these difficulties.

18. Have you ever been in a situation where the technology change displaced some of your skills, and how did you deal with that?

I have had to deal with this when instrument programming has shifted from assembly languages to high level languages. It took some time for my resistance to weaken and for me to start looking at the potential advantages of this new technology. I finally ended up taking a number of classes, 3 in all. Note though, that I consider myself to like new technology and am very interested in learning new tools.

Interviews of two engineers, a production manager, and a foreman.

1. HOW DO YOU APPROACH DOCUMENTING EACH STEP OF DEVELOPMENT AND TRANSFER TO PRODUCTION?

ENGINEER 1 - I make files that detail exactly what things I have tried and why. For each action item, there needs to be some type of a write up explaining why I reached certain decisions. The file also needs to contain the results of each step taken.

ENGINEER 2 - It is important that there is a part plan written up during development so that if there is a change in personnel, or if production needs to find some information, there is one place that all of the past part history is held. In this file there also needs to be a justification for making the change and a detailed explination for each step.

2. WHAT STEPS MUST BE TAKEN TO GIVE MANUFACTURING WARNING ABOUT THE ACTUAL IMPLEMENTATION DATES OF A NEW TECHNOLGY?

ENGINEER 1 - Manufacturing needs to be involved in the desions which are going to have a direct effect upon them. They need to have some imput to feel that they have some equity in a decision or policy. Updated memoes need to be sent to manufacturing to keep them abreast of the development of a new technology. Right before the implementation of a new technology, meetings should be held to make sure that everyone is in touch with the current situation.

ENGINEER 2 - Manufacturing needs to get advanced notification that a change is going to be made. The amount of time needed for the notification depends on how drastic the change is and how many people it will effect.

MAN. MANAGER - Manufacturing needs two weeks notice at a minimum. The minute the new parts are started, it is important that engineering be there to offer their support.

FOREMAN - It is important that the idea for the change be tested out on the manufacturing personnel. Often they may make suggestions or come up with ideas that you hadn't thought of. Next, there needs to be advanced notification to the manufacturing people when a decision has been made to make a change. Finally, when the change is actually implemented they need personal help from engineering. This is very possitive because it shows that you are personally involved.

3. WHAT FORMS OF COMMUNICATION OR PROCEDURES WORK BEST FOR YOU RELATIVE TO NEW PRODUCTS?

ENGINEER 1 - After the decision to implement a new technology has been made, there should be written notification to manufacturing. Immediately following should be an outline of the plans for implementation.

ENGINEER 2 - The best communication is a written implementation plan. Immediately before the actual change an oral review needs to be made with the manufacturing personnel.

MAN. MANAGER - The best way to inform manufacturing of a change in the part or proces in to first have a meeting with all the manufacturing managers to make sure that they understand why the changes are being made and how they will improve the product and the process. Later on, a complete outline of the changes and the steps which need to be done to complete the change should be sent to the managers.

FOREMAN - A written explination should first come out when the change has been decided upon. When it is time to actually implement the change, there needs to be an oral explination of the new steps.

4. HOW MUCH TIME BEFORE A NEW TECHNOLOGY IS IN PRODUCTION DO YOU NEED TO BEGIN TRAINING PERSONNEL?

ENGINEER 1 - A month before a new technology is introduced, at a minimum , you should begin training new personnel. You should show them exactly what is going to change and what the new procedure is going to be. Within a week before the new product is put into production, a quick refersher course should be given.

ENGINEER 2 - About 60-90 days before the new technology is introduced you need to begin training the employees. The employees will learn the changes by actually doing them. They will learn best by having hands on experience.

MAN. MANAGER - Training of the new personnel needs to begin two weeks in advance of the implementation of the changes.

FOREMAN - It depends on the change, but often the employees can immediately adapt. They just need aa clear explanation of the change.

5. HOW DO YOU HANDLE THE STAFFING NEEDS FOR A NEW PRODUCT? DO YOU HIRE PEOPLE GRADUALLY?

ENGINEER 2 - You want to gradually start ramping up for a new technology. It is important that you don't flood a department with new employees. If you hire them gradually you will have them in different phases of training. This will keep things running smooth.

MAN. MANAGER - The new emplyees need to be hired gradually. It is important that it is done this way so that they can all be adequately trained.

FOREMAN - The new employees need to be hired gradually. If they are all hired at once the training is poor. As a result, the quality of the work drops. Gradual hiring helps both the people and the company.

6. WHAT PEOPLE ISSUE IS MOST DIFFICULT TO OVERCOME IN TECHNOLOGY TRANSFER?

ENGINEER 1 - People do not like change. They want to stay with the known. The most important thing you must do is justify the change and convince the workers that the change is for the best and will improve the product and thus the company.

ENGINEER 2 - The most difficult thing to overcome is to maintain some type of continuity and to help the employees overcome their fear of changes. You need to convince them that the change is in their best interest.

MAN. MANAGER- Reluctance to make a change is the hardest to overcome. People do not want to have change in their routine. It is handled by explaining the rational to the workers. They need to understand that the change is really for their best interest and will make their job better.

FOREMAN - The people tend to complain about the change. They don't want to do it. If I know why the change is being made, I can convince them that is for the best.

7. WHAT IS THE DIFFERENCE IN THE MANAGING STYLE WHEN BRINGING IN A NEW TECHNOLOGY VERSUS SUSTAINING MANAGING?

ENGINEER 1 - When a change is implemented, you must provide more support to the operators. The workers are almost child-like in trying to protect their position and skills. They must be convinced to accept the changes.

ENGINEER 2 - The employees must be continuously reassured. They are very nervous about a change to the way they are used to operating. It is important to make sure that the employees are learning the new changes and can do them as well as they could do the old methods.

MAN. MANAGER- When a change is being implemented on the floor, my position is really one of being a public relations person. I reassure the employees that the change is a good one. I am not really in the directive mode as I am usually.

8. WHAT ARE THE KEY ITEMS TO CONCENTRATE ON TO INSURE A SUCCESSFUL TRANSFER OF TECHNOLOGY?

ENGINEER 1 - The single most important item to concentrate on is to insure that manufacturing has all the information and instructions that they need. It is terribly important that all questions be answered and all fears put to rest.

MAN. MANAGER- The most important item to concentrate on is that you don't want to surprise manufacturing with a change. You need to keep them informed. It is also important to involve them in the decision to make changes. This way they doe't feel that the change is forced on them.

9. WHAT WAS THE METHODOLOGY TO INTRODUCE NEW PROCESSES? IE EQUIPMENT, TRAINING, PROCESS REQUIREMENTS. HOW WAS THE COST JUSTIFIED?

ENGINEER 1 - The government does not worry about cost. When a change is needed, they just implement it without a cost justification.

ENGINEER 2 - For new equipment the ways used to justify them include: cost studies, flow analysis, and time analysis. They must also meet a company established payback period.

MAN. MANAGER- The justification methods include man hours savings and material savings. For new equipment each item has to be itemized out.

10. HOW DOES CHANGE EFFECT YOU? POS. AND NEG.

ENGINEER 1 - The possitive effect is that the change will increase efficiency or improve the product. This will be good for the company. The negative aspect is that it creates more work for me. I also have to repeatedly justify the change to the employees. This puts me in the position of being the bad guy.

MAN. MANAGER- Changes are possitive in that they will hopefully increase profits, efficiency, and productivity. They are negative in that the workers have a strong resis-

tance to change. They are afraid of the unknown and uncertainty. Their confidence is shaken.

FOREMAN- The change is positive in that it will improve quality. It is negative because people are set in their ways. If the change can be justified, they will not resist as much.

11. ARE YOU AFRAID OF CHANGES?

ENGINEER 2 - The long term employees are worried because they feel threatened. Their confidence in their skills has been shaken. They will be the hardest ones to convince that the change is necessary and will really be an improvement.

FOREMAN - Workers are often afraid of change because they fear being laid off. Once they get past that, they are glad that things will improve.

12. ARE CHANGES GOOD FOR THE COMPANY?

ENGINEER 1 - The changes are usually made to improve the product. If the changes are successful, this will be better for the company, and as a result for the employees.

MAN. MANAGER- Change is good for both the company and the employees. It moves them forward.

13. HOW IMPORTANT IS IT TO BE INVOLVED IN THE INTRODUCTION OF A NEW TECHNOLOGY INSTEAD OF HAVING IT FORCED ON YOU?

ENGINEER 1 - It is very important that all phases of the operation be involved it the decision to make a change. This allows sugestions to be made and to tailor the changes to the department.

ENGINEER 2 - It is very important that manufacturing be involved in making the decisions relative to the change in technology. If they do not have any equity in the decision to implement the change, then they do not feel as compelled to make the change a success.

MAN. MANAGER- By being involved in the introduction rather than having it forced on me, I am much more willing to put out the extra effort to make sure it succeeds. Because I was involved in the decision, it is very important to me that the change improves the part or quality.

FOREMAN - If the change is not forced on us, it is much easier to overcome the resistance. The employees feel that they have something to gain by making the change a success.

14. HOW DO YOU DEAL WITH RESISTANCE TO CHANGE?

ENGINEER 1 - The best way to deal with the resistance is to carefully justify the change. It has to be done in such a way as to convince all the employees.

ENGINEER 2 - You need to convince the manufacturing personnel that the change will make their job easier and also improve the quality of the product. This will make them look better. Basically, you need to sell the change to the employees and make them believe that it is important that it be successful.

15. WHAT IS DONE TO PREPARE PEOPLE FOR CHANGE?

ENGINEER 1 - The workers need to be kept well informed. This will help relieve their fears. If any further training is required, it needs to be completed before the implementation of the new technology. A final effort must be made to justify the changes according to the employees value system. They need to be convinced that the changes will make their job easier and more efficient.

MAN. MANAGER- The best way to deal with the resistance is to educate and train the workers. They will come to realize that the change is for the best and will help their future.

16. HOW DO YOU DEAL WITH OBSOLETION?

ENGINEER 1 - The company will train the displaced employee for a different position.

ENGINEER 2 - It is important that the company retrains the employee. The training will help the worker to advance

MAN. MANAGER- The people who are no longer needed are trained for a new position. This way they are not really dispaced.

17. HAVE YOU BEEN INVOLVED IN A MAJOR CHANGE? HOW WAS IT HANDLED?

ENGINEER 2 - A robot was brought into investing to dip the parts in the ceramic slurry. It would replace the worker who dipped the parts by hand. There was a big fear that the robot would replace all the people. It was important that the manager put the workers fears to rest.

18. HAVE YOU BEEN INVOLVED IN A SITUATION WHERE TECHNOLOGY DISPLACED SKILLS OF WORKERS? HOW WAS IT HANDLED?

ENGINEER 2 - A robot was brought into investing to dip the parts in the ceramic slurry. It replaced the workers who had dipped the parts by hand. The workers who were displaced were trained for other positions. Someone has to run the robot.

19. WHAT IS THE METHOD FOR QUALIFYING A NEW PRODUCT?

ENGINEER 1 - Trial runs need to be made to prove out the new technology. At the beginning the new method can be run side by side with the current method for a comparison.

ENGINEER 2 - There needs to several feasibility studies run to make sure that the change is for the best. It needs to be proven before it is actually implemented.

MAN. MANAGER- Trial pieces must be run to show that the change actually works. They must meet all the requirements.