

MANUFACTURING EXECUTION: EQUIPMENT

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Assembling PBX power distribution systems was the first application of just-in-time (JIT) and total quality control (TQC) principles at AT&T's Denver works. Integrating the power shop manufacturing process with succeeding operations—the Carrier and Cabinet Shops—was achieved by consolidating the three shops into a single equipment assembly shop. Work in process (WIP) was controlled with kanban cards that pulled inventory from the feeder shops, and production disruptions were systematically eliminated. Critical to the success of the project were coordinating good production line design, implementing kanbans for WIP and inventory control, and applying TQC by an interdisciplinary team of shop and engineering personnel. These changes required small investments of capital, personnel, and equipment. The success of JIT/TQC in the equipment shop was evidenced in higher quality, fewer manufacturing disruptions, reduced floor space needs, greater production capacity, a higher product velocity, and a more uniform production interval. The consolidated equipment shop proved JIT/TQC's feasibility as a competitive strategy for manufacturing, and was applied to other shops at the Denver Works and at other AT&T locations.

Introduction

As part of Phase Two of the Denver Works improvement cycle, a team of Denver Works and R&D personnel developed and implemented the first JIT/TQC manufacturing practices in the Power Shop. The Power Shop, where power distribution panels and cooling fan assemblies for Definity® PBX products are made, was selected as a pilot because of the relative simplicity of the operation, and because it

Panel 1. Terms and Acronyms in This Paper

CEDAC chart	problem-solving tool to promote group teamwork to formulate resolutions and ideas
FAS	final assembly sequencer
JIT	just in time
Q+	performance analysis workstation
PC	personal computer
SMS	station monitoring system
SQC	statistical quality control
TQC	total quality control
shiner	uninsulated length of wire at the end of a wire of cable placed into a terminal connector
WIP	work in process

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was the first assembly step. Similar methods were also introduced into the later assembly operations: the Carrier and Cabinet Shops. The three shops were integrated into a single Equipment Shop where complete assembly was coordinated with circuit pack production, in a build-to-customer demand environment.

This paper discusses the methods introduced and installed in 1986 and 1987 to set up a JIT/TQC system, and focuses on the operational, cultural, and physical changes that took place, including:

- Establishing appropriate product flow and production models for the JIT system
- Defining a new manufacturing layout, using kanban cards to aid in WIP control
- Encouraging changes in attitude and culture through an education program coordinated with introducing JIT/TQC
- Introducing TQC based on applied statistical process control (SQC).

Case studies show the structure, composition, and use of TQC teams to define quality goals and eliminate manufacturing defects.

JIT Pilot Programs

A pilot project was undertaken in early 1986 to develop and validate a mixed-model JIT process for System 75. Four equipment modules were selected for the assembly and test pilot: the power supply, two power distribution panels, and the fan cooling assembly.

Overview of the Power Shop. The Power Shop was selected as for pilot application of JIT/TQC. Before the line was converted to JIT, batch production met the demand for Definity PBX products. The manufacturing interval was two 8-hour shifts with eight production associates per shift, the WIP was high, and the shop was often out of work or working overtime to keep the succeeding operations supplied. The goal was to reduce the manufacturing interval and keep the downstream operations adequately supplied. The Power Shop was a chance to prove that JIT manufacturing could improve operations. Converting the line to JIT reduced the interval to under three hours with only six production associates; production capacity was increased, floor space was reduced by 30 percent, and the quality level improved nearly 10 times.

The Power Shop provided two power distribution systems, each composed of four different modules, for a total of eight different modules for the various Definity system models. Each module was assembled in batches as large 100 units and then stocked separately until needed for production. In addition, some subassemblies were manufactured off-line and brought into the main assembly line as needed. To improve operations and introduce JIT, the assembly process for all eight modules had to be re-engineered.

JIT principles call for small batches and ease of switching among products. In the Power Shop, the premises were to produce matched sets—a set of four modules for each type of Definity system—and to be able to switch easily and frequently between each type, e.g. small and large system sets. The principal technical issue was *line balancing*, i.e., assigning tasks to individual production associates consistent with the assembly sequence.

Proper line balance gives each production associate nearly equal amounts of work. The line is run at a specified rate and balance is maintained as the product is changed between small and large power systems.

Q+, a line-balancing computer program developed by the AT&T Bell Laboratories' Performance Analysis Department, was the tool used for line balance. Q+'s animation capability showed product flow and helped explain the proposed JIT operation to managers and production associates before the new line was built.

Making changeovers without interrupting product flow means the parts available to each production associate are changed sequentially, independently, and quickly, with changes in production between small and large power systems. This requires planning and organization of parts presentation, and kitting, to be successful. The parts needed for the small and large power systems are arranged in kits, and are placed in small bins back-to-back on a wheeled cart. All parts for one type of power system are stored on one side of the parts cart; parts for the other system are stored on the other side of the cart. Turning the cart around enables the production associate to change quickly from small to large system, and back again. The parts kits, for sets of four of each type, are assembled in the staging area by a material handler who also moves the kits to and from the workstations. The material handler also turns the carts around at the right moment as the changeover point passes each production associate.

It is often necessary to reconfigure the line to compensate for changes in design, available personnel, and production demands. To make these changes in real time, a computer program uses the Q+ line balance to generate parts lists for the kits, and a new set of manufacturing sequence instructions for each workstation. These tools support routine line reconfiguration in less than 30 minutes for different production rates, including generating a new line balance, kit lists, and layouts.

Coordinating parts from the storeroom and the

feeder shop is important to successful JIT operation. Kanbans, or visual signals, are used to control parts delivery to the Power Shop staging area. To organize the staging area for JIT, it was laid out supermarket style, with each part delivered and placed in its own bin. To minimize the number of parts kept in each bin, and to avoid shortages, a chart near each bin was used to plot the parts remaining in a bin after each withdrawal. Using the chart, the correct buffer stock size was quickly determined, along with high or low fluctuations, and the buffer level could be adjusted as needed. The causes of the peaks and dips in inventory were also noted on the chart, and provided a powerful aid for quality improvement efforts. The Power Shop used kanbans to impose a visible, disciplined product usage pattern on its feeder shop (the Cable Shop) and the storeroom. The kanbans also helped the Cable Shop introduce JIT to its operation shortly after the Power Shop pilot project.

The production system's design places greater demands on the production associates to be flexible and knowledgeable about more of the product. Individual production associates must assemble different parts with different line configurations and product types. But the additional variety is well within the abilities of the production associates, and enriches their jobs. Employees are more productive because of better organization, discipline, teamwork, and enhanced social climate.

Power Shop Configuration. Successful implementation of JIT requires good communication among production, engineering, and management personnel. The layout of the Power Shop JIT manufacturing line supported this requirement. To aid communications, the production line is laid out in a U-shape. Parts carts are outside the U for easy access by the material handler. Production associates work inside the U, and can move easily from station to station to help each other and discuss problems. Each workstation is connected to a roller conveyor that serves as a buffer between each workstation. The buffer is large enough for one complete power system.

The buffer serves two purposes:

- To buffer the residual variation in the line balance caused by individual differences.
- To provide visual feedback on where problems are occurring.

Problems are observed as full or empty buffers between workstations: a full workstation signals a downstream blockage, while an empty buffer highlights a problem at a prior workstation.

Production control in the Power Shop is regulated by a kanban system using carts to connect it to the Cabinet Shop. Carts, with room for four sets of either small or large-cabinet power systems, are pulled by the Cabinet Shop for final assembly. WIP is controlled by the number of carts available for each type of completed power system. Carts are pulled as required by Cabinet Shop production needs. An empty cart is returned to the Power Shop for each full cart taken. An empty cart, for either small- or large-cabinet, is considered a production order from the Cabinet Shop to the Power Shop. The material handler notes what will be needed in the Cabinet Shop, and sets up the next parts kit at the right time to make the next model.

After the JIT methods were successfully demonstrated in the Power Shop, they were adapted first to the final-assembly area, the Cabinet Shop, then to the Carrier Shop, where the holders for circuit packs, associated connectors, and back-plane wiring are assembled.

Production Control Among Shops

Production coordination among the Power, Carrier, and Cabinet shops, and the final system test, is aided by a production sequence computed for weekly Definity system orders. This places a nearly uniform load on all shops simultaneously, from hour to hour, throughout the week, as each shop executes the sequence. This computation is carried out by the final assembly sequencer (FAS).

FAS coordinates the production schedules of the shops, providing the basis for integration into a single

shop. It was later applied to control production schedules in Denver's Definity system Circuit Pack Shop.

Single Versus Multiproduct Kanban Systems. The JIT system for Definity system equipment differs from the classic kanban system in that only one inventory buffer was set up for each shop, instead of one for each product. The inventory of carriers, for example, is a collection of carriers of the type, quantity, and sequence needed for the next few hours by the cabinet assembly shop: i.e., a mixed model buffer. By contrast, the Cable Shop kanban (a classic kanban) contains one inventory bin for each cable type; each is replenished independently as its reorder quantity is reached.

This important distinction between single- and multiproduct kanban systems influences the amount of inventory needed. The single-product kanban is easier to operate, but requires more inventory. The multiproduct, synchronized kanban system has less inventory, but production sequence information must be conveyed to all shops, and the discipline to follow the agreed rate must exist. In a multiproduct kanban system, the next item to be started when a pull signal is received does not replenish the last item pulled—as in the conventional system—but the next item on the sequence list.

Equipment Integration In The Shop. As JIT/TQC was developed in the three shops, the goal was to integrate the shops into a consolidated progressive assembly shop with improved productivity and quality. Through experiences in the pilot shops, the operation of an integrated shop with a lot size of one was planned. The purpose was to consolidate responsibility for the entire equipment assembly in a single area, enabling the personnel to participate in the complete assembly rather than the carrier or power unit subassembly only. Advantages included reduced floor space, reduced inventory, less critical coordination of production schedules, and improved quality.

The pilot assembly lines were merged in the integrated shop so all consecutive processes were aligned, separated by the minimum transfer lot size as determined by the labor balance models for the pro-

gressive assembly. After installing the line, this shop ran with less than two days of scheduled WIP, an 18 percent improvement in productivity and improved quality.

Introduction of TQC

Quality control was recognized as the key to implementing JIT in a factory environment. As the JIT programs reduced inventory through reduced lot size and tightened product flow constraints, any problem in a part or process severely restricted the shop's productivity. With JIT there was no surplus inventory to assemble new items or any way to cast the defective items aside for later rework efforts. Also, there were no alternate routings or process facilities to handle the problem in other areas. The best solution for JIT is to stop the assembly line and correct the problem. Defects, therefore, could not build up, and problem prevention became a way to maintain productivity.

TQC in the Power Shop. The Power Shop was the first shop in the Denver Works to adopt a policy to stop the production line for quality problems. This was a significant commitment to quality, because any problem that shut down the Power Shop for more than one hour caused the entire Definity system line to stop. The Power Shop program taught management, engineering, and the shop that stopping the line to correct the problem was the proper procedure. Formerly, the approach was to bypass the established product flow and inventory procedures, and increase production to overcome a defect rate. Stopping the line was a new concept and the education program (discussed later) helped clarify the rationale for stopping production to correct manufacturing problems. The TQC approach is to resolve all defects *when they occur*—or better, *before* they occur—to maintain productivity.

With TQC, the production associates are responsible for quality control and inspection, and each associate inspects the work of the one preceding. When a problem is discovered, the production associate stops working, and discusses the problem with the person

concerned. If the problem can be resolved, corrective action is taken. If the problem cannot be corrected, the shop supervisor and engineering are notified. Because the shop is U-shaped, communication and corrective action are easily achieved.

Not all quality problems can be solved immediately, and all problems do not compromise quality, e.g. process improvements. To help take corrective action, several simple techniques were employed: fishbone charts, suggestion boards, and weekly quality meetings. The fishbone chart is used to find a problem's root causes. Each leg of the fishbone is assigned a probable cause of the problem, and solutions associated with each cause are listed along each leg. Personnel involved with the shop problem—e.g., production associates, supervisors, and engineers—are free to discuss the causes and to contribute to the resolutions of the problem. In addition, suggestion boards are placed in several locations around the shop so all personnel can write their ideas for improvements. The suggestions and production problems are reviewed during weekly TQC meetings where the feasibility, benefits, and solution to each issue are discussed. Useful ideas are submitted to the plant suggestion system for action, and corrective action is begun.

Because one goal of excellent manufacturing is minimizing process variability, data were collected on the duration and causes of all production disruptions. To support this activity, a personal computer (PC) controlled workstation monitoring system (SMS) was developed to record workstation activity. As a disruption occurred, the production assistant would enter a code corresponding to the type of disruption encountered (e.g., part shortage, defective part, or no work). SMS timestamped the code and lit a signal lamp above the workstation to inform shop personnel of the station's status, and to start corrective action if necessary. Because SMS provided visible status for all workstations in the shop, immediate help could be given wherever it was needed. The information obtained from the SMS was used to direct the team's problem solving activities.

The TQC Team Concept. The Western Electric Quality Control Handbook³ defines a quality control team as having three members: a product engineer, shop supervisor, and quality control engineer. In Denver, the team was augmented with process engineering, quality review, shop maintenance, and the lead production associate. The new team has a detailed understanding of the process that is the basis for eliminating quality problems.

The TQC team's goal is to promote continuous quality improvement, as measured by lower in-process defect rates, less on-line inspection, fewer disruptions, and reduced scrap. The team's responsibilities are to:

- Review how the shop meets its quality goals
- Review control charts related to each process area
- Establish priorities for problems to be solved
- Analyze problems from data collected on the line
- Assign action items for resolution
- Plan new studies as needed
- Summarize progress
- Verify corrective action.

The TQC team follows a structured, disciplined approach to problem solving, thereby allowing a group familiar with the process to identify and resolve process and product problems. Team leadership is assigned to the shop supervisor because, of all team members, he or she is most closely responsible for the total product, including meeting quality and scheduling requirements. The supervisor "owns" all shop quality issues, assigns action items, and refers to management problems that cannot be resolved by the team. The methodology for improvement, shown in Figure 1, is adapted from the scheme used by Hewlett-Packard.⁴ It shows the feedback and monitoring mechanisms that must be in place for continual improvement to occur. The Denver TQC team uses this model to close the loop on process improvement.

TQC Team Procedures for Problem Resolution

To help define and solve manufacturing problems, there must be a clear understanding of duties and

function of each member of the TQC team. The shop supervisor must lead the TQC meeting and identify the team members responsible for problem resolution. The supervisor reaches agreement with the designated member on how the problem should be described, and helps set a reasonable date for delivering a report on the action item. All team members can participate in problem discussion and resolution, but technical issues generally are handled by the product or process engineers. Maintenance representatives usually handle equipment problems, with help from the shop representative. It is important that team members recognize the shop supervisors' leadership position and work constructively to solve production problems.

The following case studies from the Denver Power Shop team illustrate how TQC teams work. A summary of the elements needed to successfully resolve problems, and some reasons for failures, are presented after the case studies.

Case Study: Power Shop Disruption Data Collection. The interval reduction in the power shop, though dramatic, at first still was less than expected. The TQC team tried to find the causes for the overly long interval. Defect and measurement data help usually identify the sources of problems, but the Power Shop had few defects and no measurement data. Its primary problems were all linked to product flow disruptions on the line.

Thus, the team's task was to establish a method to collect disruption data, i.e., the collected data that described disruptions as they occurred on the line. They analyzed the data, defined five potential causes of disruption, and used them to classify all subsequent observed disruptions to product flow. The classifications are:

- *Defective parts:* parts supplied by the storeroom or from another shop are defective in form, fit, or function.
- *Kanban congestion:* work cannot move because the output kanban space is full, or the worker is idle because the supply kanban is empty (i.e., there is no work for the workstation).
- *Workmanship:* work is delayed because of upstream

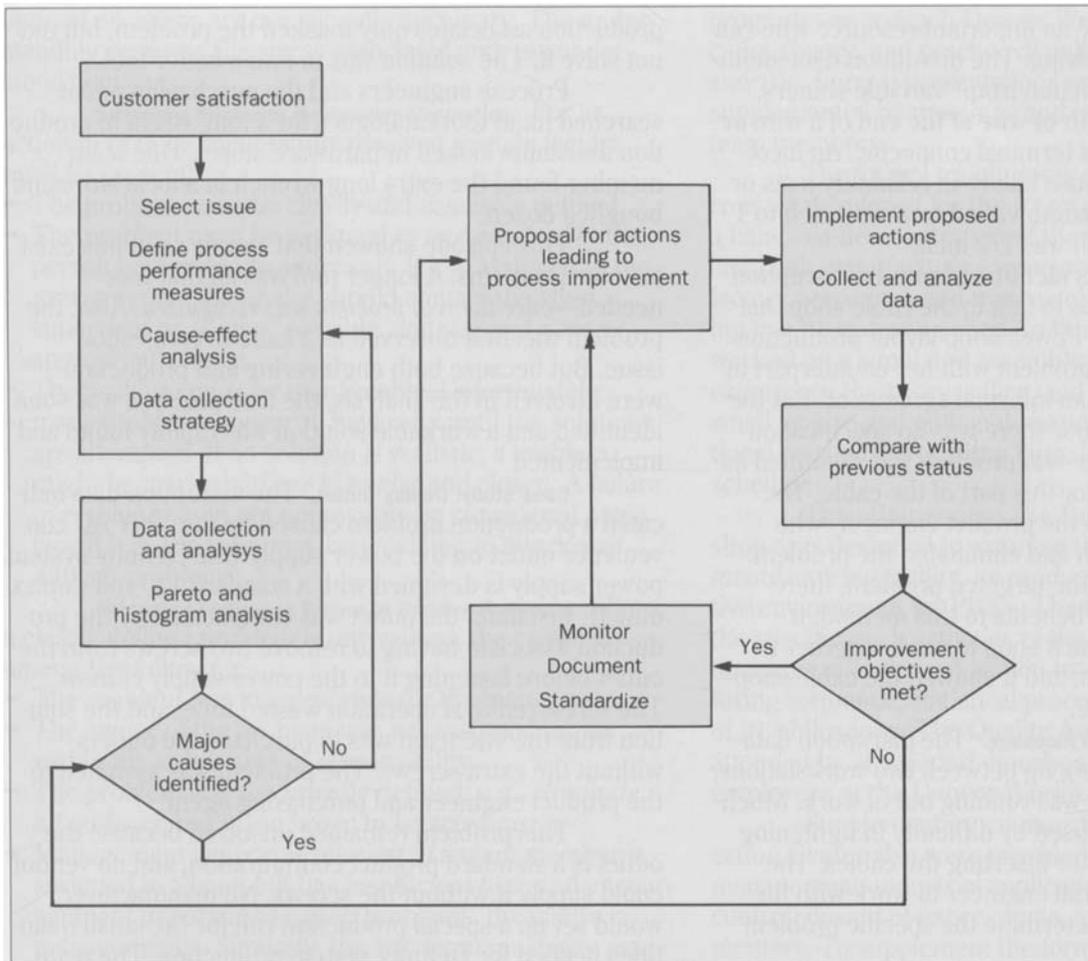


Figure 1. Schematic of TQC improvement method at use in the Denver Works.

- worker error.
- *Parts shortage*: parts are missing from the assembly kit or are unavailable from feeder shops or the storeroom.
- *Production problem*: assembly procedure, tools, or layout is poor.

The disruption data is collected daily and analyzed before the team meeting. The data gives the major disruption type; the time, duration, and workstation; and

a brief description of the problem. When disruption data collection began, the Power Shop was running at 80 percent disruption-free operating time. Because of the problem-solving activities exemplified in the following cases, after 14 months, disruption-free operation was consistently at 94 percent of operating time.

Case Study: Shiners. Engineers generally solve production problems, but the following example shows

production associates are an important resource who can contribute to problem-solving. The disruption data identified a slowdown in production from "variable shiners," i.e., the uninsulated length of wire at the end of a wire or cable that is placed into a terminal connector. An incorrect shiner length can cause failure in reliability tests or in the field. The shiner length varied from 3/8 inch to 1 inch; the preferred length was 1/2 inch.

The problem was identified from the disruption data and the first step was to talk to the cable shop that supplied the cables. The Power Shop layout production associate discussed the problem with her counterpart in the Cable Shop to reach an informal agreement. But the problem continued because there was no specification for the shiner length. The *real* problem was identified as no written specification for this part of the cable. The problem was assigned to the product engineer, who changed the specification and eliminated the problem.

Besides solving the targeted problem, there were two important side benefits to this method: it allowed the workers of each shop to work together to solve a common problem; and it showed the cable shop the advantages of JIT/TQC.

Case Study: Kanban Blockage. The disruption data showed that WIP was piling up between two workstations, but the next workstation was running out of work. Much of the congestion was caused by difficulty in tightening the terminal strip lugs after inserting the cables. The team assigned an industrial engineer to work with the production assistant to determine the specific problem and develop a solution.

The assembly procedure required cables to be placed in a terminal strip on the bottom of the power supply chassis. Two hands were needed to reach into the chassis: one held the wire, the other tightened the terminal lug. However, the hand with the wire obstructed visibility. Thus, it took several tries to fit the wrench into the terminal lug, and caused delays in the assembly process. Because some production associates were more dexterous, they had less difficulty than others; but changing

production associates only masked the problem, but did not solve it. The solution was to find a better tool.

Process engineers and the purchasing agent searched hand tool catalogues for a long wrench; production assistants looked in hardware stores. One team member found the extra long wrench in a local store and bought a dozen.

This episode showed that simple solutions exist to some problems. A longer tool was all that was needed—*once the real problem was recognized*. Also, the problem was first observed as a kanban congestion issue. But because both engineering and production were involved in the analysis, the true problem was soon identified and a workable solution was rapidly found and implemented.

Case Study: Duplex Outlet. The disruption data indicated a production problem caused by the 120V AC convenience outlet on the power supply (the Definity system power supply is designed with a standard 120-volt duplex outlet). Installing the outlet was complicated by the production associate having to remove two screws from the outlet before fastening it to the power supply chassis. The screw removal operation wasted time, and the solution from the TQC team was to purchase the outlets without the extra screws. The problem was assigned to the product engineer and purchasing agent.

This problem remained unsolved because the outlet is a standard product configuration, and no vendor could supply it without the screws. No manufacturer would set up a special production run for the small quantities needed for Definity system production. The team considered a design change to a single outlet, but the cost of the change would have exceeded any potential advantages. Consequently, the team dropped the issue.

This problem illustrates the tradeoffs made in resolving problems. Some problems cost more to fix than to accept. Here, the saving from using a standard part outweigh additional labor. Tackling unresolvable problems provides production associates, supervisors, and engineers with an understanding of why less-than-

optimal decisions are occasionally necessary. The understanding removes the stress associated with misunderstood decisions.

Summary: Elements for Problem Resolution. For an action item to be successfully resolved, certain factors must be present:

- The problem must be clearly and concisely defined.
- The problem must be assigned to *and accepted by* the person best suited to address it. If it is assigned to the wrong person, he or she should contact the shop supervisor as soon as possible, and suggest a more appropriate choice.
- The problem must be manageable. Unfortunately, many problems appear to have a fix until the solutions are attempted. If no solution is realistic, a problem might be marked *failure to resolve* and closed. A failure to resolve should not necessarily be considered negative: if it is, the team may be unwilling to attack any difficult problems.

Summary: Factors in Failure to Resolve Problems. When a clearly defined problem is unresolved, the cause is among the following:

- The problem was inappropriate for the team.
- The owner of the problem was not assigned issues within his or her area of responsibility.
- The problem was too broadly defined: e.g., *eliminate all solder crosses* is too broad to be acted on.
- Management support is missing. If a team member is assigned to a team but has insufficient time and encouragement to pursue assigned problems, the failure is management's. Similarly, the TQC team must give management a record of the accomplishments of the individuals and the team. This can be done as a monthly list of resolved problems and open action items.
- Interprocess cooperation is missing. It is not enough for an area to commit to the TQC team concept. The other related groups (Storeroom, Purchasing, other shops, etc.) must work together, or many issues will be impossible to resolve.

Education. The thrust of the JIT/TQC education

program was to teach Denver Works personnel the concepts, theory, and practice of pull manufacturing (JIT) and TQC. Formal presentations and training courses were supplemented by meetings and informal training by the team members.

The formal training was given in two specific courses developed for the JIT project. The JIT Workshop, a hands-on demonstration of the difference between pull and push manufacturing, was presented to most of the factory personnel, and was mandatory for anyone working in a JIT operating shop. In this workshop, participants worked on a simulated assembly line, and were able to experience the process flow, and compare the results of small lot-size and pull-on-demand manufacture with traditional methods of pushing large lot sizes to a shipping schedule.

The other course, the Quality Awareness Workshop, was designed to examine the Denver Works as a manufacturing facility, its product lines, and the competitive environment for PBX's. The course also examined the specific work activities of the plant shops, the relationships of each workstation to others in the manufacturing sequence, statistical process control, and a review of JIT philosophy. The Quality Awareness workshop was attended by all salaried, hourly, and management employees at the Denver Works.

Supplementary courses from the Corporate Education Center also were provided. These included project management, industrial applications of statistical quality control, design of experiments, and statistics for experimenters. To supplement the formal courses, informal workshops and seminars were given by the R&D team members to the various Total Quality teams.

As a final supplement to the education and training program, many meetings were held to show the project's goals and accomplishments. At these meetings, introductory comments and major presentations were made by members of the Denver management team.

The commitment of the Denver Work's management to JIT/TQC was evidenced in support and participa-

Table I: Pilot Shop Implementation Dates and Results

Metric	Power-4/86		Cabinet-11/86		Carrier-12/86	
	Pre-JIT	JIT	Pre-JIT	JIT	Pre-JIT	JIT
Floor space (sq. ft.)	2400.0	1700.0	4300.0	1400.0	8500.0	1500.0
Interval (shifts)	5.0	1.0	4.0	2.0	6.0	0.5
Velocity*	5.0	25.0	6.3	12.5	3.1	37.5
Time no disruption (%)	82.0	93.0	40.0	60.0	50.0	70.0
Turnover ratio	17.0	56.0	66.0	95.0	26.0	63.0

* Velocity = (Butt-to-butt time / Actual time) x 100

tion in the education program. In the quality awareness course, the introductory and closing comments at each presentation were made by the plant manager or one of his immediate subordinates. For the JIT workshop, a manager attended each session as a participant, and the plant manager and his entire immediate staff participated in a special workshop session.

Education and training in JIT manufacturing, supported by the factory management, were critical to successful implementation of JIT and TQC. Implementing, accepting, and improving manufacturing operations were found to be more easily achieved if the goals and operating philosophy of JIT/TQC were fully understood.

Results, Summary, and Conclusions

In the integrated shop, Definity system products are assembled only to meet specific customer orders, minimizing WIP levels and build intervals. The design of the integrated shop embodies the simplicity of JIT. All activities are closely coupled, and problems are quickly exposed and resolved. Management, engineering, and production assistants are committed to resolving problems and adhering to JIT/TQC disciplines in the daily operations that provide quality products to customers. This commitment has yielded the integrated shop

results summarized in Table I.

The impact of JIT/TQC developments are evidenced in increased quality, fewer disruptions, higher product velocity, reduced production interval, and fewer non-value added activities. Disruption times (Table I) significantly decreased in the three areas. Product velocity was increased by a factor of two in the cabinet shop, and by more than an order of magnitude for the carrier assembly. Both the improved velocity and reduced disruption afforded significant reductions in production interval, and provided increased responsiveness to customer needs. Improvements in as-built quality levels reduced non-value added activities by 60 percent.

An additional effect was reducing production floor space after JIT/TQC implementation. The production output remained at its pre-JIT levels, while floor space needs were reduced by more than 60 percent. Much of the reduction came from reduced inventory and staging areas, as well as more efficient production workstation layout.

Turnover ratio (TOR) is a critical metric of the Denver Works. Table I presents the TOR for the shops before and after JIT/TQC. With JIT/TQC, the shops achieved TORs from 56 to 95.

Implementing JIT manufacturing was coupled with total quality control to produce substantial

improvements the assembly of PBX telephone equipment. Coordinating the technical issues of production line layout, line balance, and kanban setup with education and management support made the successes possible. The TQC effort initiated the cultural change to continuous process improvement. In this JIT application, a multiproduct kanban was set that reduced the number of product buffers, and a system to reconfigure the manufacturing line was developed. The goal of combining three assembly shops into a single integrated shop was realized after the three shops were converted to JIT.

TQC team problem-solving techniques were applied to problems where conventional SQC methods were not applicable. Production output and quality were improved by cooperation among production, engineering, quality, and support organizations. The essential issues were *cooperation*, *education*, and *data*. These were applied to a well-engineered production line where data identified opportunities for cooperation among the organizations that implement solutions.

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Biographies (continued)

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