SECTION 24
JOB SHOP INDUSTRIES

Leonard A. Seder

WHAT IS A JOB SHOP?

The terms “job shop” and “mass production shop,” though widely used, are loosely defined. Managers who use these terms are well aware that industrial life as lived in the job shop differs considerably from that prevailing in the mass production shop. This difference extends to the problems of creating, controlling, and improving quality. This section undertakes to define the nature of the job shop and to explain the methods in use for dealing with job shop quality.

There is no single parameter which distinguishes the job shop from the mass production shop. Job shops vary in size from very small to very large. Some are captive; others are independent. Some serve sophisticated industrial customers; others serve relatively naive consumers. Their products range from one-of-a-kind nonrepeating items to large lots of frequently reordered stock items. Some make proprietary products of their own design. Others develop designs jointly with customers’ designers. Many cannot even be classified neatly in the foregoing terms, since their product mix spreads across the whole spectrum of customer sophistication, design responsibility, lot sizes, repeat rate, etc.

Despite this difficulty of classification, it is possible to identify certain basic common types of job shops and to recognize among them differences and commonality that affect the fashioning of a quality control program to suit their individual needs. Table 24.1 identifies four common types of job shop, and shows some typical products or operations which exemplify each type.

Percent Repeat Jobs. The term “percent repeat jobs,” which appears in the headings of Table 24.1, is one of the universal parameters of job shop operation. Percent repeat jobs is defined as the

TABLE 24.1 Types of Job Shops

		Typical products—or operations	
Type	Description	Percent repeat jobs low to moderate	Percent repeat jobs moderate to high
I	Large complex equipment	Locomotives Chemical plants Buildings Automated production equipment Radar sets	Farm equipment Aircraft Machine tools Printing presses
II	Small, simple end products and components	Fashion fabrics Industrial adhesives Circuit boards Fabricated metals Books	Tires Shoes Garments Wall covering Small appliances Metal shapes Automotive components Electronic components Private-label foods Furniture
III	Custom parts	Machined parts Forgings Weldments	Stampings Castings Molded plastics Screw-machine parts Molded rubber parts Extruded parts Containers
IV	Subcontracted services	Toolmaking Diemaking Moldmaking Printing Machining Testing	Heat treating Welding Plating Packaging Electropolishing

percentage of the total number of jobs in the factory in any one month that are identical repeats of job orders run previously.

The classification of low, moderate, and high percent repeat jobs have the following approximate values: “low” = under 35 percent; “moderate” = 35 to 80 percent; “high” = over 80 percent.

Large Complex Equipment. Companies in Type I (Table 24.1) produce large complex units, each made up of thousands of different parts and components, each of these in turn being defined by its own “drawing number.” These companies call themselves job shops because an individual job order or contract usually calls for a very small number of such large units, often only one. Only if the percent repeat jobs is moderate to high are they able to justify manufacturing these units as stock items and making (or buying) the input parts in economic quantities. Lacking a stock of finished units or components, it is necessary to produce from “scratch,” and the time pressure becomes severe.

Small End Products and Components. The Type II companies usually produce large quantities on any one order. However, they regard themselves as job shops because of the endless variations of size, shape, color, style, or configuration typically involved in their product lines. Even those with “standard” product lines frequently show hundreds of different "model numbers" in their catalogs. Those who make "specials" for the various customers' unique requirements have thousands of drawing numbers in their engineering files.

Custom Parts. These Type III companies are mainly in business as suppliers to Type I and II companies. They specialize in one or more of the processes listed and fill their shops with customer-designed parts of thousands of different configurations and compositions. Often they can satisfy a customer's annual requirements for a particular part number in just a few hours of production running time. The nature of the problems of such a job shop has been well portrayed by Furukawa, Kogure, and Ishizu (1981), as shown in Figure 24.1.

Subcontracted Services. Type IV companies differ from Type III only in that they tend to be small, independent shops specializing in particular operations, often working on customer-furnished material. Captive shops of this type are often in-house departments within a large Type I, II, or III company. Variety of jobs is again the rule, each job usually requiring only a few hours of production time.

Jobs per Worker per Week. All four types of job shops exhibit two recurring themes of commonality:

1. *Wide variety of designs* (due to a myriad of different configurations, options, colors, sizes, shapes, models)
2. *Short production time* for any individual production task on any one "job"

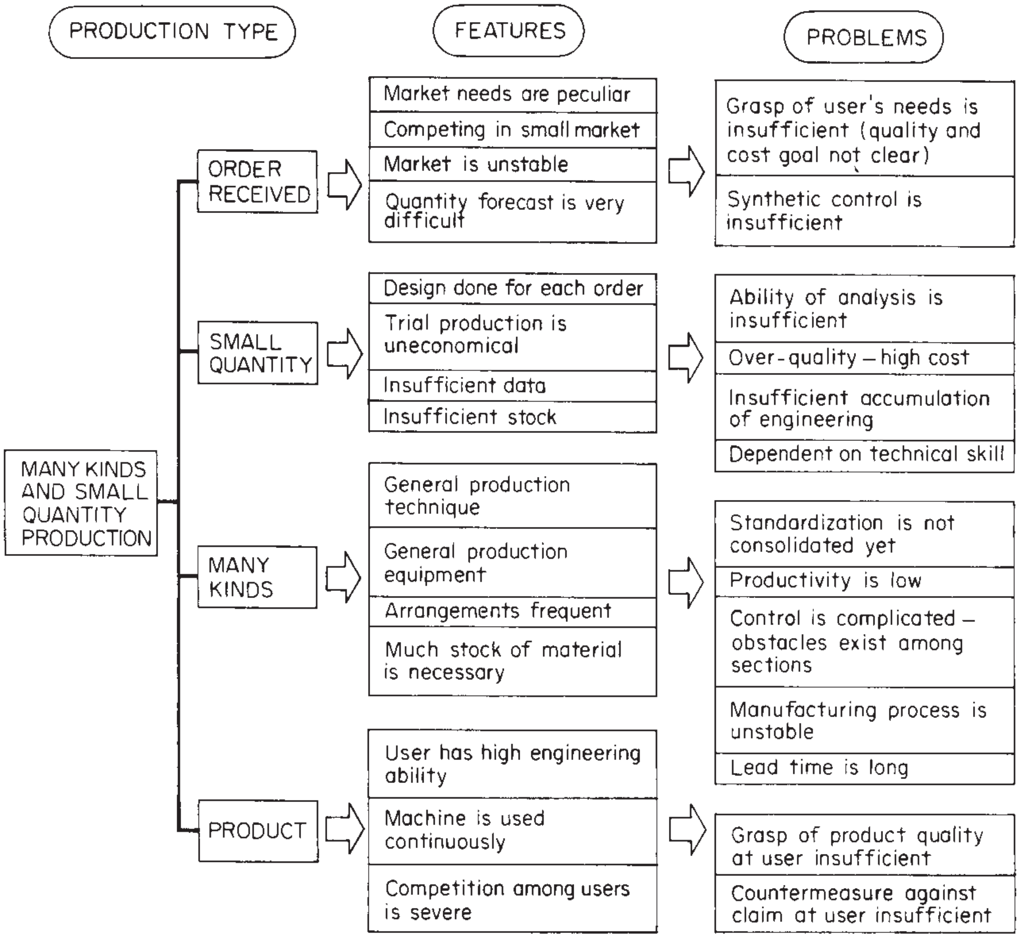


FIGURE 24.1 Problems of quality control at a plant producing to customer order.

These two factors may be conveniently combined into a single parameter of "jobs per worker per week," reflecting the average number of different orders, or different setups, or setup changes that will be handled by each worker over a week's time. (As more and more of the worker skills, memories, and decisions associated with setup changes are replaced by computers and automated setup changers, the name of this parameter will necessarily change to "jobs per machine per week.") Whatever the type of job shop, this number is generally much higher in the job shop than in the mass production shop. This fact has a direct bearing on the nature of the job shop quality program.

The percent repeat jobs (defined above) also varies in size among job shop types and within types. However, the percent repeat jobs is generally much lower for job shops as a class than for mass production shops. As implied in Table 24.1, the percent repeat jobs tends to be higher for some job shop types than others, e.g., Type II versus Type I. However, the rate varies over the whole range and for individual shops within one type.

Job Shop Grid. When the two parameters of jobs per worker per week and percent repeat jobs are related to each other on the same diagram, there emerges a convenient way to quantify the distinction between the production shop and the job shop. The "job shop grid" in Figure 24.2 is designed to show this relationship.

The job shop grid opens the way to design and apply quality control methods which are keyed to the quantified parameters. At the outset it is evident that production shops are generally those with a small number of jobs per worker per week and a high percentage of repeat jobs. Above the level of 20 jobs per worker per week, we consider it a job shop regardless of the percentage of repeat jobs. Also, below a 50 percent repeat job rate, we consider it a job shop even though the number of jobs per worker per week is low.

THE JOB SHOP QUALITY PROGRAM

In a broad sense, the problems of job shop quality management are the same as for any other shop:

1. Planning of quality for new or modified products and processes
2. Controlling the quality during manufacture
3. Improving quality levels to reduce quality losses

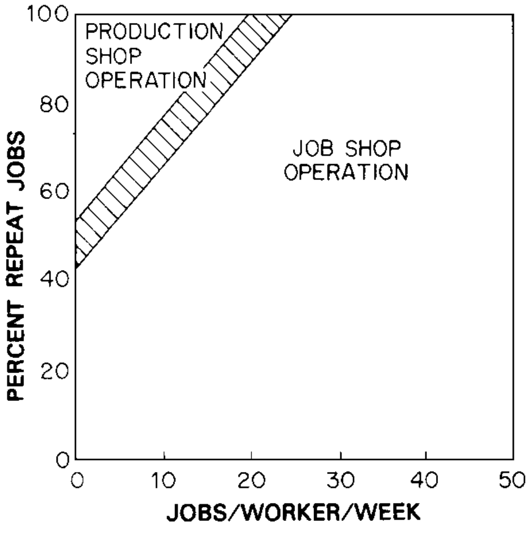


FIGURE 24.2 The job shop grid.

Similarly, the concepts and principles of solution of quality problems are those presented in Sections 3, 4, and 5, and related application sections. However, the numerous job orders (which create a high number of jobs per worker per week and a low percentage of repeat jobs) greatly influence the details of the job shop approach to quality.

The impact of these numerous job orders is not on the materials, processes, or people; these generally remain common to all jobs. Neither is the impact on the systems, practices, and procedures; these likewise remain common to all jobs. (These common "ingredients" may, however, contain the root cause of chronic quality problems.) Rather, the impact is similar to that involved in launching many "new products" every week. For each of these "new products" there is need to discover (1) what is "new," (2) how this affects product design, plan of manufacture, special tools, quality requirements, etc., and (3) what needs to be done to assure that the "newness" is correctly identified and complied with by all departments.

Stated another way, the impact of the numerous job orders is primarily on preproduction planning, and especially on *manufacturing planning.* This planning creates a considerable problem of communicating to all concerned what is "different" about each order so that responsive action can be taken. The amount of such communication can rise to enormous proportions because of the multiplying effect of (1) the number of job orders, (2) the number of ways in which each order is different, and (3) the number of processes, tools, etc., affected by each of these differences. A consequence of this great volume of communication is that the problem of quality control is a problem in *quality of communication* as much as a problem in conventional process and product quality control. As a corollary, when product nonconformance is detected, the correction to be made is very frequently in some detail of the job plan rather than in the product or manufacturing process.

In the light of the foregoing, the quality program for the job shop must include special provisions for:

Planning to communicate essential quality information to all concerned

Controlling the errors and inadequacies in this communication

Improving not merely the processes and products but also the planning and communication

THE JOB NUMERICS

As noted, preproduction planning is a major job shop activity, and involves every job. Since each job differs from all others in *design,* each requires its own *product specifications,* spelling out in detail the materials, formulation, configuration, end-product physical properties, quality and reliability requirements, and the rest. (Simplification is often possible in instances in which a single specification can be used to specify a whole "family" of items largely resembling each other but differing only in specific detail of size or color, etc.)

Since jobs also differ in the exact manufacturing process to be followed, each requires its own *manufacturing plan,* to communicate to Production and Inspection the necessary details of input materials, operation sequence, inspection or laboratory release points, special or unique tooling, in-process properties required, mandatory processing restrictions, and the like.

There appears to be no accepted generic term to represent, for a specific job order, all the details of product and manufacturing process. "Job documentation" comes close, but it sometimes is used to include the recorded quality data, which are not part of our definition. Hence the author has coined the term "primary job numerics" to serve as such a generic term. Table 24.2 summarizes and gives typical examples of these primary job numerics. Obviously, mass production shops must also have these same numerics. However, in the mass production shops the numerics are few in number, tend to become stabilized, and are easily remembered by shop personnel. In the job shop they are many in number, are frequently changed, and require constant reference to the written documents.

Not all job shops have responsibility for preparing the numerics to define *both* product and manufacturing plan. Types III and IV (Table 24.1) ordinarily receive product specifications from their

TABLE 24.2 Primary Job Numerics

Aspect of definition	Typical examples
To define the product	
Materials	Material specification numbers for metals, chemicals, agricultural products, etc.
Formulation	Specific proportions of various materials to be used
Configuration	Drawing or sketch showing dimensions, component parts, assembly details, etc.
End-product acceptability	Dimensional, physical, chemical, optical, metallurgical, electrical, visual, etc., tolerances Functional test requirements
Reliability	Maximum failure rate, or degree of degradation in specified endurance test
To define the manufacturing plan	
Input materials	Sources, subcontractors
Operation sequence	Exact order of primary, secondary, finishing, packaging, etc., opera tions
	Specific machines, baths, ovens (when restricted)
Inspection points	Location of inspection stations or laboratory release points
Unique tooling	Design of specific form tools, molds, dies, assembly fixtures, artwork, etc.
In-process properties	Dimensions, thicknesses, densities, colors, electrical outputs, chemical values, strengths, etc., needed at specific operations
Mandatory processing restrictions	Temperatures and times for bakes, heat treatments, reactions, drying, curing, pasteurizing, etc. Hold times between operations

customers and hence prepare only the manufacturing plan. Types I and II prepare both sets of numerics for their own products, but only product specifications for those materials and components which they purchase.

The primary job numerics have long been recognized as essential and have found expression in various types of "legitimate" documentation in the shop. The product specification, manufacturing drawing, material specification, formulation or batching sheet, tool drawings, exploded assembly view, route card, operation sheet, inspection detail sheet, test procedure, and job order card are the more common names for the various means of communicating the needed numerics to shop personnel.

In the evolving techniques of computer-aided manufacturing (CAM), the problem of communicating and *updating* the primary job numerics to the production floor has been solved. The engineers or technical staff persons generally specify the primary numerics with inputs from manufacturing or process engineers. These are communicated via computer to the production personnel. The once-frustrating problem of time delay between the decision to make a change and the making of that decision officially known by advancement of the "change letter" is thus now avoidable.

The primary job numerics outlined in Table 24.2 are the minimum details necessary to define and make the product. However, they are seldom sufficient to assure the quality of the end product or to attain economic operation. There are additional numerics which provide the added information needed to minimize product deficiencies, rejections, repairs, yield losses, and customer complaints.

Some of these supplementary job numerics are shown in Table 24.3. For each aspect of product and process definition, there are special details, unique to the individual job, that are of value to the shop personnel. Communicating these details to the shop personnel provides the advance knowledge that can often spell the difference between success and failure to meet end-product requirements or between high and low quality costs.

It is probably no exaggeration to say that the key to preventing product deficiencies in the job shop lies in recognizing the importance of *specifying* the supplementary numerics. Once this is understood, the same computerized method used for the primary numerics is extended to the supplementary. This virtually eliminates the many "debates" and misunderstandings that formerly took place. Not all of these supplementary numerics are needed for all jobs. Indeed, one of the real dilemmas faced by job shop managers is the decision of how far to go in this direction (see below).

JOB PLANNING

To generate, communicate, and comply with all these job numerics requires that a major element of the job shop quality program must be concerned with individual job planning. This involves

TABLE 24.3 Supplementary Job Numerics to Prevent Product Deficiencies and Losses

Aspect of definition	Typical examples
Materials	Special supplier requirements for process control Special gages or test methods Packaging requirements Classification of characteristics Acceptable quality levels Certifications required
Operation sequence	Special work instructions Exact details of important hand operations Permissible deviations from sequence
Inspection points	Special gages or test methods Classification of characteristics Acceptable quality levels
Unique tooling	Identification numbers Tool inspection details Permissible tool deviations
In-process properties	Optimum settings of process variables Special gages or test methods Plans of control for operations with setup approval criteria, running approval criteria Statistical control plans to be used
Mandatory processing	Tolerances for times, temperatures, etc. Certifications required
End-product acceptability	Special gages or test methods Special customer "idiosyncrasies" Classification of characteristics Acceptable quality levels Customer data submittals or certifications Visible defect acceptability limits Customer sampling plan impositions
Reliability	Testing details

(1) organizing for job planning, (2) detecting and correcting job planning errors, (3) improving the job planning.

Organizing for Job Planning. A major question is how far to go in completeness of planning. It is usual to carry out planning of the *primary* job numerics in total or to leave only minor details to be worked out during the production run. However, the *supplementary* job numerics present a problem in striking the proper balance between overplanning and underplanning. Establishment of the numerics beforehand will work to avoid errors and misjudgments during the production run. However, the volume of detail and the lack of adequate information of some aspects (e.g., the expected rate of occurrence of specific defects, sequence deviations, or tool deviations; knowledge of the optimum settings of process variables) make it uneconomic or impossible to fill in all the details.

A major consideration in this decision is the "percent repeat jobs." A shop with a low percent repeat jobs must necessarily devote a major effort to planning the supplementary job numerics, since there is no "second chance." A shop with a high percent repeat jobs can place its major effort in control, at the sacrifice of planning, since the control activities will, over a period of time, influence the evolution of the correct numerics. Figure 24.3 shows this contrast diagrammatically.

A further consideration in extent of planning is the time schedule. Planning can be less than complete when the manufacturing cycle permits a trial lot to be piloted through ahead of the job order to pin down many of the supplementary job numerics or when the job running time is long enough to use data feedback and corrective action for the same purpose. (See Job Shop Control, below.)

Responsibility for job planning varies widely among job shops. In all but the smallest shops, the primary numerics are commonly developed and issued by a staff group, separate from line production. This group is variously designated as Research and Development, Engineering or Technical (especially when definition of product is part of the work), or as Manufacturing Engineering, Process Engineering, Production Engineering, Estimating, Planning or Industrial Engineering (when the planning is mostly limited to definition of manufacturing plan). However, there is no universal pattern of responsibility for generating the supplementary numerics. In some instances, staff quality engineers or process engineers have this responsibility. In other shops, line supervisors, inspection supervisors, and even workers and inspectors have the assignment. In still other cases, the supplementary inspection numerics are prepared by staff specialists, while the supervisor is left to his or her own devices to develop and convey information on tools, setups, settings of process variables, etc.

As is usual in matters of organizing, it is more important to be clear than to be logical or uniform. There is a need for providing the supplementary numerics, and the responsibility for doing

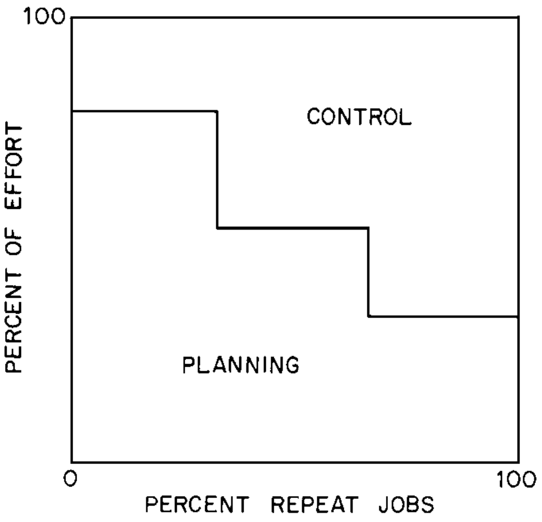


FIGURE 24.3 Effect of percent repeat jobs on allocation of planning effort.

so should be clear. The job shop which has left this question vague would do well to face it cleanly. As a general rule, if the generation and maintenance of any portion of the supplementary job numerics is to be delegated to Production, the responsibility and method must be made clear. Otherwise, in the author's experience, it tends to be neglected, poorly maintained, and ineffective.

Often the variety of work makes it necessary and possible to do the planning selectively on the basis of the size or complexity of the job. Jobs over a certain size, or involving new manufacturing techniques, or expected to become new standard products, are planned by the staff group, whereas small jobs, or those which involve only minor changes from "standard items" or previously run jobs, are planned by the line production people.

Detecting and Correcting Job Planning Errors. The sheer number of details involved in the primary and supplementary numerics makes it inevitable that errors will occur in job planning. Some will be the inadvertent errors of misplaced decimal points, transposed digits, incorrect arithmetic, and the like. Others will arise from lack of sufficient knowledge, by the planner, of processes, economics of manufacture, capabilities, and reliabilities.

To minimize planning errors, it is useful to review the planning in some appropriate way. For large jobs, this review tends to be elaborate and formal. The planning documents are circulated to the key departments, after which there is a formal review meeting. This meeting not only goes over errors and refinements; it also identifies possible problem areas. In addition, it may determine whether there is need to provide "sample" or "trial lot" evaluation before full production. The review meeting also may establish the guidelines for delegating development of the supplementary numerics to lower levels of organization.

For smaller, low repeat rate jobs, the planning documents are likewise circulated to the key departments. However, the review and sign-off usually take place without formal review meetings.

Enlisting the participation of workers in identification of errors has been a goal of many quality programs. Schafer (1978) describes a successful program for error identification in a machine shop. "Job check" cards (see Figure 24.4) were developed for machining, welding, assembly, electrical, paint, packaging, and crating to aid workers in performing a systematic review. When errors were found, workers filled out a problem report, which was circulated to the planners for corrective action.

MACHINING JOB CHEC

PRINT/PROCESS REVIEW	
•Blueprint Correct & Clear	•Information Adequate
•Process Correct	•Unknowns / Problems
•Process=Print	•Areas to Machine

MACHINE REVIEW	
•Correct Speed	•Correct Horizontal Setting
•Correct Feed	•Machine Functioning OK
•Correct Vertical Setting	•Machine Capable

TOOLS/FIXTURES/LOCATION REVIEW	
•Tools Correct & Sharp	•Inspection Tools
•Correct Fixture	•Locating Surfaces OK
•Fixture Capable, Complete	•Holding Method for Machining

MATERIAL/PARTS REVIEW	
•Correct Material	•Correct Prior Operations
•Correct Size & Shape	•Part Complete
•Material Condition OK	•Appearance OK

1st PIECE SAMPLE CHECK	
•Part to Print	•Part Damage
•Part Usable	•Machining Acceptable
•Off Specifications OK'd	•Appearance Acceptable

IN PROCESS SAMPLE CHECK	
•Part to Print	•Part Moving Location
•Machine Drifting	•Machine Settings OK
•Tool Dull	•Every 10th Piece OK

FIGURE 24.4 "Job check" card for operator detection of job planning errors.

For high percent repeat jobs, reliance is more heavily placed on the control system (see Job Shop Control, below).

Improving Job Planning. Improvement of this planning, as applied to manufacture, involves preparation and use of machine and process capability knowledge in establishing tolerances, choosing processes, classifying characteristics, etc. The approach, which is generally conventional, is discussed in Section 22.

A concept known as "group technology" involves planning of jobbing work by identifying "families" of parts based on commonality of operations. This commonality then is used as a basis for standardization of drawings, tooling, etc., with an obvious residual effect on quality planning. The group technology idea extends beyond planning to machine layout, product flow, and cellular and flexible manufacturing systems. See also Section 22 under Group Technology.

JOB SHOP CONTROL

The "jobbing" nature of the job shop is derived from the diversity of products. However, the manufacturing processes which turn out these diverse products exhibit a high degree of commonality in materials, machines, instruments, and people. As a result, the job shop systems for quality control of manufacture closely parallel the systems in use in the mass production shops, but scaled to the size and needs of the particular job shop. In addition, the large number of jobs per worker per week and the mass of detail contained in the job numerics make it important to have special approaches to data feedback and corrective action.

Overall Control System. Those minimal job shop systems that parallel the mass production systems are listed below, including references to the handbook sections that discuss conventional approaches:

Control system	*Section reference*
Supplier material	21
Identity and flow of "lots"	23
Process control decision making	45
Tool and equipment qualification and maintenance	23
Calibration and maintenance of measuring equipment	23
Disposition of rejected material	23
Analysis and followup of customer complaints	25

To formalize these systems, it is necessary to document them in a quality control manual which is then distributed to those concerned. Under ISO-9000 requirements, this is mandatory (see Section 11 under the Clauses of ISO 9001 and their Typical Structure for the ISO 9000 requirements of a quality manual).

In the job shop it is uncommonly important to provide a sound plan for making decisions on whether the process should run or stop, and to make clear delegation of responsibility for decision making on the factory floor. With limited workforce to spread over a multitude of jobs, it is also important that the job shop understand and make use of the concept of dominance (see Section 22 under Control Systems and the Concept of Dominance) in order to maximize the effectiveness of that laborpower. Setup dominance is the prevailing mode for most quality characteristics in the small-lot job shop, especially those of Types III and IV. The main reason is that the running time is usually so short that the "time-to-time" variation of the process is minimal. Hence "if the setup is right, the lot will be right." Accordingly, the job setup is a vital control station, and demands use of statistically valid plans for setup approval.

Earlier, simplified plans such as narrow-limit gaging and precontrol and control charts were used but were not widely understood. Computers have stepped into this breech. They have made statistical validity simple and automatic. There are numerous examples.

In the manufacture of expensive machined pieces, including multidimensional ones, special-purpose gages are used where needed to assure correctness of the *setup*. The data from these measurements are automatically fed into specially programmed computers to produce histograms, capabilities, control charts and other statistical evaluations to predict and thereby urge action, if needed, to assure lot conformance. (See Figure 24.5).

More generally, for any process, data from regular gages or visual inspection can be punched into hand-held computers by the person collecting the data. Instantly, the statistically valid "photograph" of the predicted lot quality from that setup flashes on the computer's miniscreen. The user doesn't have to understand the statistics; he or she sees the picture!

These developments have accelerated the trend toward establishment of a state of self-control by the operator, to whom the setup acceptance responsibility can now be delegated (See generally Section 22 under Self-Inspection).

Data Feedback and Corrective Action. Many job shop managers have fallen into the trap of believing that once they have established an inspection system (even if, in a small shop, it means the hiring of the first inspector), they now have "quality control" and can relax. Now "quality control" will protect them against bad purchased materials, stop defects from being manufactured, and guard the outgoing product. It may well do these things, but an essential added need is to use the *information* gained from performing the inspection to *improve* quality. It can do this in several ways if appropriate feedback mechanisms are established:

1. For preventing defects in the unmanufactured portion of a job
2. For preventing defects in repeat orders of a job
3. For preventing defects in future orders for other jobs in the same "family"
4. For correcting problems in the "ingredients" (i.e., policies, systems, procedures, practices) common to all jobs

The extent of these benefits available to a particular job shop depends on the "jobs per worker per week," the "percent repeat jobs," and other factors. Consideration of these factors leads to the "current job approach" and the "repeat job approach" as two basic ways of achieving feedback and corrective action.

The Current Job Approach. This is a means of preventing defects in the unmanufactured portion of a job through feedback of information from the manufactured portion of the same job. It can be used whenever the running time of the job is longer than the time necessary to give the feedback signal, diagnose the cause, and determine and implement the corrective action. See, schematically, the top part of Figure 24.6. The value of such prevention is so obvious as to provide an incentive to prompt feedback of data on quality troubles, and prompt corrective action on the feedback.

Figure 24.7 shows the mechanism used in one electronics assembly plant to secure such prompt feedback and corrective action. The results of subunit, unit, and systems test are recorded by serial number as to the item and the nature of the discrepancy. Copies of the test records are reviewed daily by a quality control engineer who determines the nature of each deficiency and initiates a "corrective-action request" (Figure 24.7) to the design engineer, manufacturing engineer, components engineer, test supervisor, test-set maintenance person, supplier liaison person, or other individual who can take the necessary action. The quality engineer follows up each of the requests and the associated replies until the matter is disposed of by action, or by decision that no action is necessary.

Corrective action that will benefit the unmanufactured product may either involve a change in the *job numerics* or correction of an error in *complying* with the job numerics.

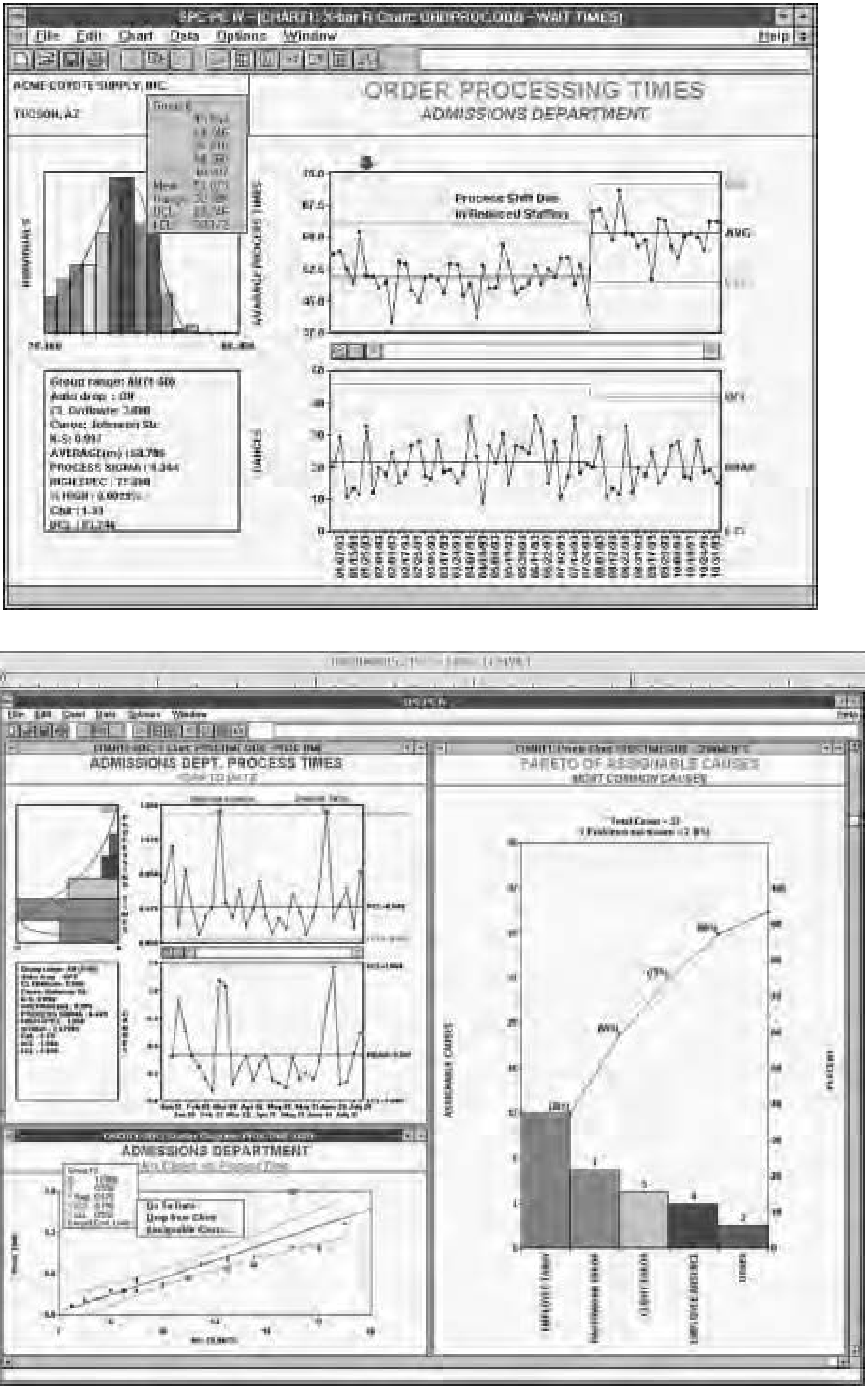


FIGURE 24.5 Computer software has enabled job shops to effectively utilize SQC tools. Shown are typical examples offered by Quality America, Inc.

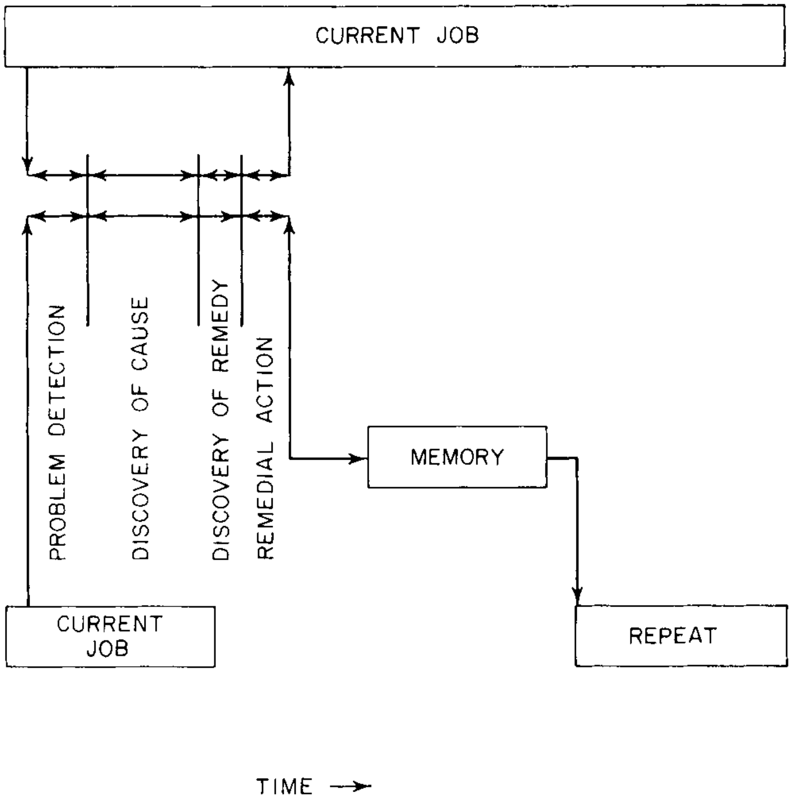


FIGURE 24.6 Current job versus repeat job corrections.

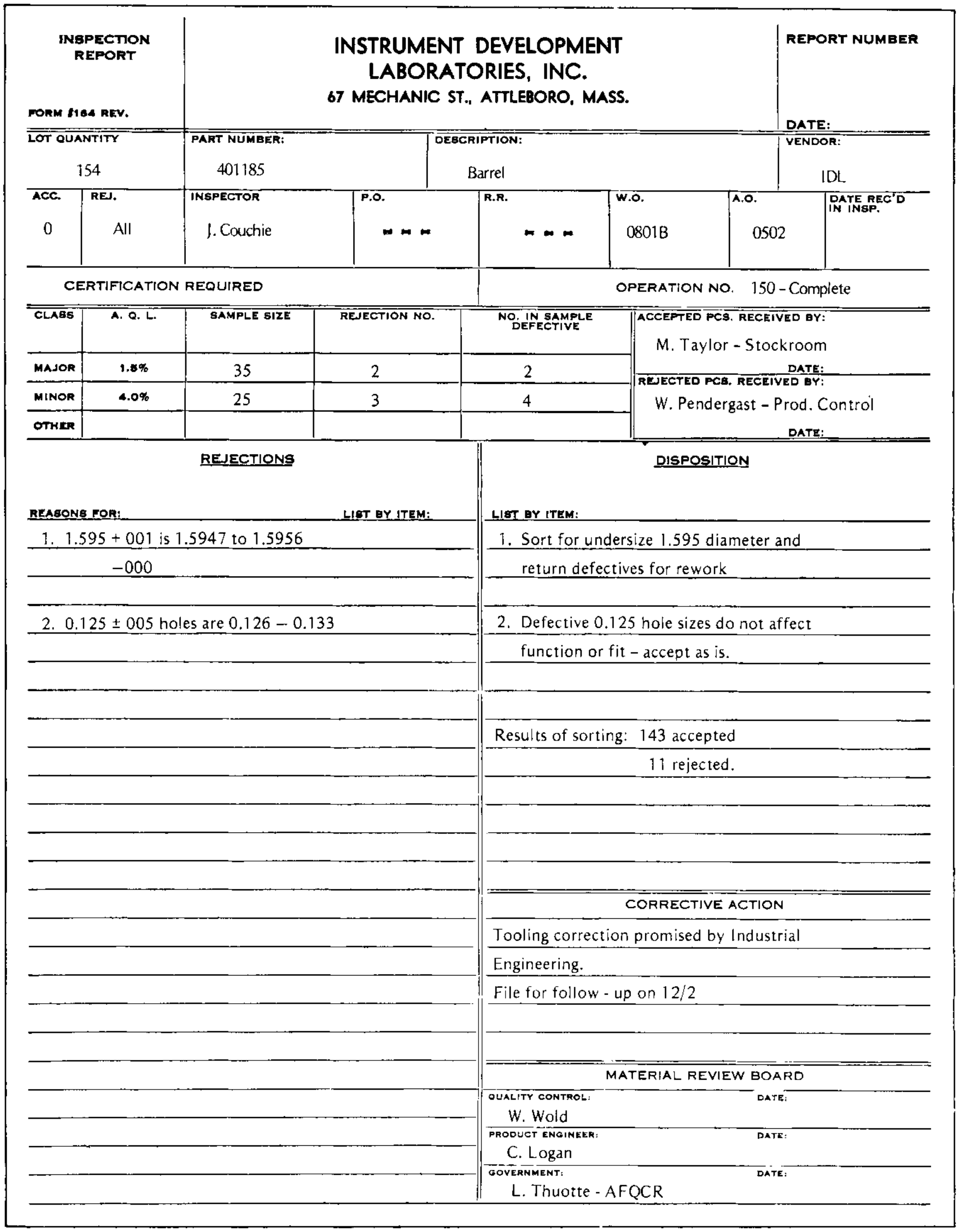
This current job approach is most applicable when the following combination of circumstances is present:

1. The economic gain through preventing defects in the unmanufactured units is obviously greater than the cost of the feedback and prevention machinery; i.e., large lots or expensive items are involved.
2. The causes of the defects are obvious enough to permit prompt diagnosis.
3. The organization for feedback and followup can be kept simple, e.g., one employee with a clear assignment.

In the job shop with a low percentage repeat job rate it is often desirable to create deliberately the opportunity to use the current job approach even when the normal running time would be too short to use it. Instead of processing the entire order as a lot, a small “pilot” lot or single item precedes the main lot, and time is allowed for the feedback and correction to take place.

The pilot lot idea has long been used in job shops. However, in its early form the pilot lot was processed like any other lot. Then the final results were scanned, and if no trouble was reported in production, everything was assumed to be satisfactory, i.e., the tentative job numerics could be made permanent. Often the pilot lot was considered to be solely the means of making samples for customer approval. Experience has shown that there is much value in expending extra effort in planning the trial lot, collecting special data, analyzing the data, and using the results to modify the job numerics.

For example, when a mechanical piece part moves through a series of operations, all of which can influence a critical dimension, the fact that 9 of the 10 pieces in the pilot lot conform to final specifications might seem to be adequate to firm up the numerics; yet the full job order could easily run 30 percent defective as a result of inadequate process capability or wrong process centering. By requiring measurements of the 10 pieces after each operation, and treating the means and ranges statistically, the alert analyst would easily discover the problem and, moreover, would be able to identify the operation responsible, thus preventing a large loss when the remainder of the order is run.



INSPECTION REPORT

FORM #164 REV.

INSTRUMENT DEVELOPMENT LABORATORIES, INC.

67 MECHANIC ST., ATTLEBORO, MASS.

REPORT NUMBER:

DATE:

LOT QUANTITY: 154	PART NUMBER: 401185	DESCRIPTION: Barrel	VENDOR: IDL

ACC.	REJ.	INSPECTOR	P.O.	R.R.	W.O.	A.O.	DATE REC'D IN INSP.
0	All	J. Couchie	* * *	* * *	0801B	0502	

CERTIFICATION REQUIRED

OPERATION NO. 150 - Complete

CLASS	A. Q. L.	SAMPLE SIZE	REJECTION NO.	NO. IN SAMPLE DEFECTIVE
MAJOR	1.5%	35	2	2
MINOR	4.0%	25	3	4
OTHER				

ACCEPTED PCS. RECEIVED BY: M. Taylor - Stockroom

DATE:

REJECTED PCS. RECEIVED BY: W. Pendergast - Prod. Control

DATE:

REJECTIONS

REASONS FOR: LIST BY ITEM:

1. 1.595 + 001 is 1.5947 to 1.5956
   −000
2. 0.125 ± 005 holes are 0.126 – 0.133

DISPOSITION

LIST BY ITEM:

1. Sort for undersize 1.595 diameter and return defectives for rework
2. Defective 0.125 hole sizes do not affect function or fit – accept as is.

Results of sorting: 143 accepted
11 rejected.

CORRECTIVE ACTION

Tooling correction promised by Industrial Engineering.

File for follow - up on 12/2

MATERIAL REVIEW BOARD

QUALITY CONTROL: W. Wold DATE:

PRODUCT ENGINEER: C. Logan DATE:

GOVERNMENT: L. Thuotte - AFQCR DATE:

FIGURE 24.7 Typical rejection, disposition, and corrective action scheme.

The Repeat Job Approach. For many jobs the running time is so short that the job is completed before the sequence of "analysis, feedback, and corrective action" can be completed. In such cases, the knowledge gained from the analysis cannot be put to use on the "current" job. However, this same knowledge can be put to use on a repeat order *provided there is a memory system* which can:

1. Store the knowledge
2. Provide ready recall when repeat orders are received

The lower half of Figure 24.6 shows diagrammatically the time relationship that permits this “repeat job approach” to give to future orders the benefit of the knowledge gained from previous orders. Since this approach involves the costs of maintaining a memory system, it is most applicable when the percent repeat jobs is relatively high, of the order of 75 percent or more. It probably cannot be justified economically if the percent is low, say 25 percent or lower. In between, the economics of the specific situation must be examined to determine whether it is less costly to provide protection for all potential repeat orders or suffer the losses of repeating the error for that smaller number of jobs that will be reordered. In addition, there are special situations that may warrant a memory system, as in the case of small first runs of development work on complex equipment, for it is generally important to “debug” the job numerics before production orders are received.

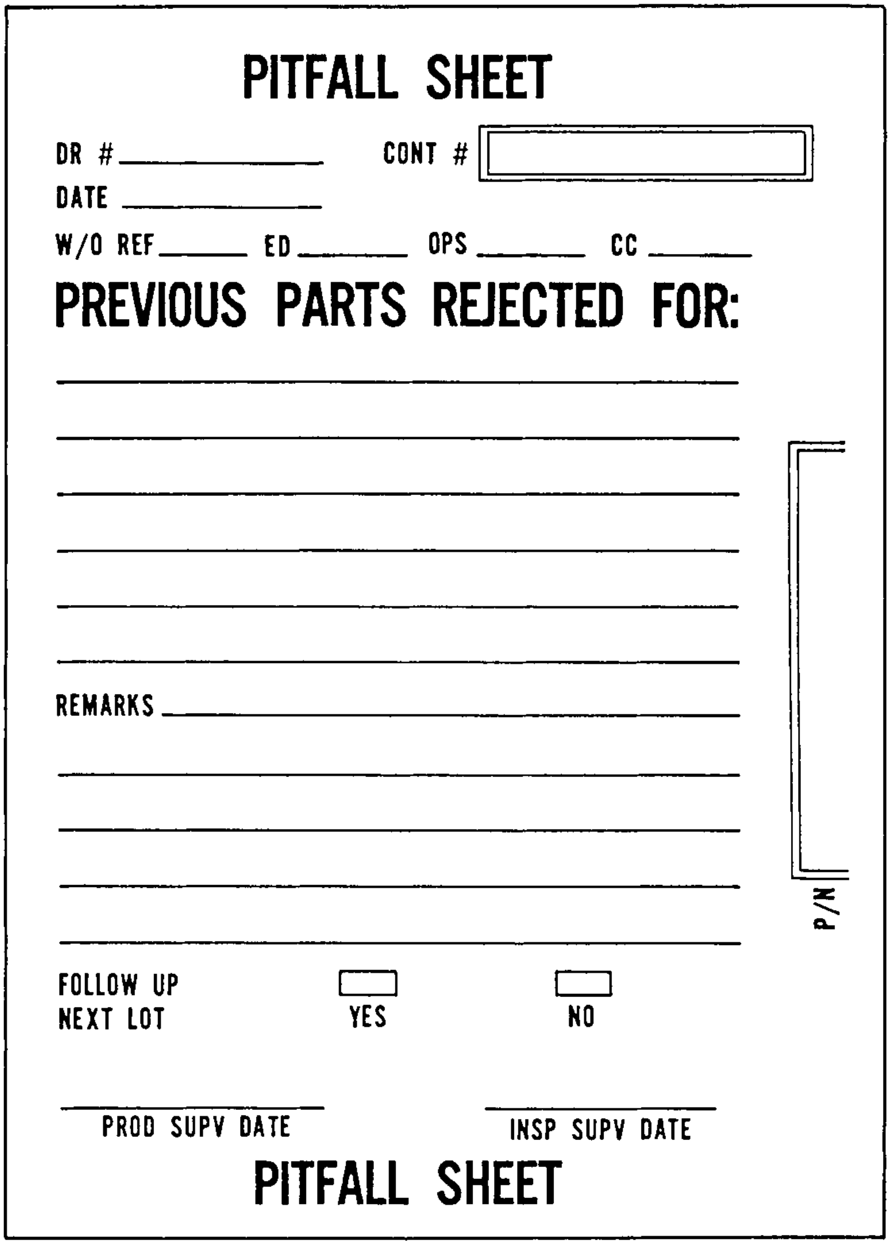
Memory System for Job Numerics. Before the computer came on the scene, an astonishing variety of memory systems had been invented to serve this need. In designing the computer system, the designer would do well to become familiar with some of these to understand what is needed, i.e., not just the *specifications*, but the *experience* gained on past job orders. For example, in a plant manufacturing custom aircraft parts (Type III), a “job history file” was maintained by the manufacturing staff group. Into this file went the customer drawing and/or the specification, the job numerics, in-process and final inspection data on each run, nonconformance record, problems encountered, corrective actions taken, results of troubleshooters’ investigations, recommendations, and formal change requests issued. When a repeat order was received, the planner would refer to this file and review the data and notes before issuing the new manufacturing order. Similar planning memories were in use in other shops covering items purchased from suppliers and/or items subcontracted to Type IV job shops. The purpose of all this information was that, on a repeat order, the designer could revise the specification, if needed, and the planner, in turn, could revise the other numerics.

Experience with such memory systems led to an important conclusion. They were most useful when the mix of data and notes were “digested” and the planned changes for future lots prepared during or immediately after the completion of the current job order. They were least successful when the data and notes were left undigested until the repeat order was received. By then, the undigested information would have deteriorated badly and the time pressure to produce the repeat order would often stymie the effort to take advantage of the system.

“Digestion” requires establishing the discipline of corrective action investigation and follow-up, *even though the current job may already be completed.* The organization for investigation may, as in the case of the current job approach, be limited to one analyst when simple technology is involved. However, where the causes of defects and the needed corrections are not obvious, more talents are needed. In any event, responsibility for the investigation and decision should be clearly allocated. It may be a material review board, corrective action board, factory service group, quality engineering, or other specially designated team. The agreed-on corrective actions are ordinarily recorded, and the responsible department designated, together with the expected date of accomplishment (see Figure 24.7). Diligent follow-up by a systematic routine is then needed to assure that these intentions are executed during the interval between orders. Someone must therefore be given the job of “keeping a book” on pending corrective actions until completion.

Memory Systems for Manufacture. These systems were created, usually by production departments, to alert personnel to the hazards of known prior errors of execution, and to evolve more optimum supplementary numerics. For worker-controllable defects, for example, special “warning” or “caution” slips are often attached to the blueprints or instructions in the job file maintained in the factory. The worker assigned to the repeat order is thereby “flagged” to exercise special care of a particular job. An example is seen in the “pitfall sheet” shown in Figure 24.8, which was used in a large job shop described by Fletcher and Novy (1972).

A further example is the job “setup card” file maintained for some processes. Each card is a record for a single job order. On the card are posted the conditions which prevailed in the process while that job was being run, as well as the results of inspection and test. For example, in calendering plastic film, the setup involves such numerics as roll speeds, roll temperatures, roll spacing, material feed rate, and many others. Often some of these are altered (and duly recorded) during the



PITFALL SHEET

DR # ____________ CONT # ☐

DATE ____________

W/O REF ______ ED ______ OPS ______ CC ______

PREVIOUS PARTS REJECTED FOR:

REMARKS ____________

FOLLOW UP NEXT LOT ☐ YES ☐ NO

PROD SUPV DATE

INSP SUPV DATE

P/N

PITFALL SHEET

FIGURE 24.8 Memory system "flag" for operators.

run to improve the quality of film being produced, based on the judgment of the supervisor. The subsequent inspection or lab test results are likewise posted to the card.

When this same plastic film is reordered, the setup person consults the card file to identify the lots which showed the best test results. He or she then tries to reproduce the process conditions which prevailed during the manufacture of this best product. As the card file builds up, a further step can be taken by analyzing the data through more sophisticated statistical methods, e.g., regression analysis (see Section 44). Computer programs offer an excellent opportunity to carry out such work "just in time" for the next order.

Memory Systems for Inspection. Such memory systems have usually consisted of job history cards to which inspection results were posted. The resulting knowledge of job quality levels and frequencies of specific defects can be used for a variety of improvement purposes. It can warn of inspection errors, lead to revision of defect classifications and acceptable quality levels (AQLs), promote changes in inspection or test methods or gages, provide additional supplier instructions or notifications, furnish Pareto summaries of the vital few defects of each job, identify jobs where inspection or testing can be reduced, etc.

In addition, the memory system concept offers the job shop a way to diagnose the causes of "mysterious" defects, to determine process capabilities, to discover dominance, and to perform other statistical analyses. For example, in mass production, a few days or even hours may produce enough defects to provide the data needed for conclusive analysis. Job shop managers ordinarily are envious at these opportunities to collect and analyze data in such short order, and they often give up trying to apply such techniques to jobbing work. However, repeated small lots, plus a memory system, plus patience, will likewise furnish the data, analyses, and solutions. When the data are organized by machine center rather than by defect type, the economics of analysis may be more favorable.

Computer Memory Systems. Computerization of such memory systems has provided much more effective and efficient accumulation of, and real-time access by production personnel to, the needed job numerics and useful information. At the same time, the stored data can be readily manipulated to prepare Pareto analyses and to perform the more sophisticated analyses referred to above. Rapid analyses made possible by the computer can go a long way in diagnosing job shop quality improvement problems, hitherto felt to be too complicated and time-consuming to pursue.

However, it is not obvious that computer programs will be dedicated to these memory systems unless the significance of the foregoing descriptions of the spontaneous and "unofficial" memory systems is recognized. They were the primitive responses to a real need; that need must now be satisfied by a well-planned computerized system.

SERVICE INDUSTRY JOB SHOPS

The thrust of this section is aimed at manufacturing industries where the term "job shop" originated and where the unique problems of such a shop tended to slow progress in applying quality control methods. However, many service industries, it turns out, are job shops. In hotels, hospitals, insurance agencies, and many others, everyday life is a variety of different events, patients, policies, or customers. The applicability of the methods of job planning and control discussed in this handbook section has been convincingly demonstrated by Patrick Mene, vice president of the Ritz-Carlton Hotel chain. He applied them to the planning and control of "events" (i.e., meetings and conferences). He defines the "primary event numerics" (his words) as "the minimum information to define event *products* and *work*." His numerics to define *products* include such items as

1. Types of guest rooms to be required
2. Configuration and seating capacities of function rooms
3. Particular audiovisual requirements
4. Food menus and specifications
5. Beverage brands and container sizes

The primary numerics for *work plans* include:

1. Required supplier input materials
2. Recipes and order of service for meals
3. Inspection points, rehearsals, food tasting
4. Exhibits, decorations, etc.

But, as in manufacturing, "the primary event numerics are seldom sufficient to assure the quality of the event…additional numerics are needed to minimize mistakes, rework, breakdowns, delays, inefficiencies, variation, customer complaints and rebates." The secondary event numerics to prevent defects and losses include:

1. Special supplier brand names, material requirements, test methods, AQLs
2. Sequence and exact details of important operations, special work instructions
3. Special test methods, control plans, AQLs, times, temperatures, staffing requirements, etc.
4. Special customer likes or dislikes

The Ritz-Carlton quality program includes the procedure for event *planning* to minimize errors. For large events, this includes formal review meetings and sign-off on the written plans. For smaller, simple, or repeat events, the written plan is developed without formal meetings. *Control* procedures involve ways of detection of errors in the event numerics or correction of errors in complying with the numerics. Efforts are concentrated on diagnosing the cause of an error "while the bits and pieces are fresh in mind" and, though the knowledge is too late to be used on the current event, it is put to use on a repeat order of the event or a future event in the same family. See also Sections 30 through 34 for quality in various service industries.

IMPACT OF ADVANCES IN METALWORKING TECHNOLOGY AND COMPUTERIZATION

Advances in metalworking production technology and computerization of process decision making have had a major impact on job shops engaged in the fabrication of metal parts. While most of these developments have been aimed at increasing productivity, they have dramatically altered the basic worker-machine relationships that previously characterized small batch production of metal parts.

New Developments. The thrust of the new developments, from the quality standpoint, has been to improve process capability in a number of ways and reduce the dependence on worker judgment for process control decisions. Among the developments have been:

- Improved tooling, fixturing, and work movement methods, such as pneumatic and hydrostatic holding devices.
- Numerically controlled machine tools, in which punched tapes or computers establish and set machine operating speeds, feeds, and other cutting conditions.
- Automatic selection of proper tools, from a carousel holding as many as 60, and their insertion into the machine chucks, which sharply reduces job setup time and makes small lot production even smaller.
- Computer control of the motions of the machine to execute the desired functions from simple hole drilling to very complex contouring.
- Production of a variety of goods from a single set of tools and equipment by means of programmable automation (see Blumenthal and Dray 1985).
- Use of sophisticated robots for assembly operations and inspection of dimensions of parts (see Blumenthal and Dray 1985).
- Design of high speed, multidimensional gages which not only speed up difficult measurements, but do so simultaneously at a new level of accuracy and precision.
- Direct input of the results of such measurements into computers.
- Mind-boggling ability of the computer programs to instantly turn out all manner of data summaries, including process centering and capability, control charts, positional diagrams, multivariate charts, gage repeatability and reproducibility, and other useful information.

Effect of Developments. The main effect of the metalworker developments has been to increase radically the amount of job planning and reduce, though by no means eliminate, the amount of job controlling in the traditional sense. In terms of the earlier discussion in this section, many of the supplementary numerics have had to be thought out and incorporated into the computer program. While such a move is to be applauded, it can bring on new needs for controlling:

> The programmer typically works in an office away from the factory floor. Only a few are experienced machinists.…Programs often have mistakes.…A misoriented tool can drill a hole in the wrong place or become chipped…and debugging takes anywhere from two hours to two weeks (Blumenthal and Dray 1985, p. 34).
>
> The machinist must still set up the workpiece to be cut, make adjustments to correct for tool wear and stop the machine if anything goes wrong (Shaiken 1985, p. 18).
>
> An operator may find that the rough casting to be machined is larger than the programmer expected and thus requires more cutting. An alloy may turn out to be harder than expected, in which case the part must be fed more slowly into the cutting tool (Shaiken 1985, p. 19).

Job Planning and Controlling. Most of these developments make the need for detecting and correcting job planning errors even more of a necessity than before. Software development and quality assurance, discussed in Section 20, becomes a new routine operation in shops that adopt the new technology.

A second necessity is validation of the correctness of all the planning details, including the software, by thorough setup acceptance of the very first pieces from the automated process. Process centering and capability are determined using any one of a number of available software packages. In addition to providing a validation of the setup, this establishes a benchmark against which to judge later repeat runs.

Regular setup acceptance at the time of each subsequent job order can thus be reduced to a simple determination that no change has taken place since the validation, i.e., tool sharpness has been maintained, work placement is correct, feeds and speeds are optimum for *this* lot of material, etc.

QUALITY IMPROVEMENT

To remain competitive the job shop must constantly engage in improvement or "breakthrough," quite aside from its day-to-day problems of enforcing quality compliance. The mass production shop must likewise engage in breakthrough, and the conceptual approach to breakthrough is identical for these two forms of industrial organization. Where they differ is mainly in the nature of the improvement "project." Because of sheer volume, the mass production shop quality improvement project usually involves a specific defect on a specific product, e.g., the 3KL cylinders are out of round on the 2.500-in (63.5-mm) dimension. In contrast, the job shop quality improvement project is usually concerned with remedy of some common cause which cuts across a variety of jobs.

The preoccupation with individual jobs is often a detriment to organizing for job shop improvement. A given common cause may adversely affect, say 25 percent of the jobs (see, for example, the case of "inductance out of specification" below). Preoccupation with looking for "blame" or for the "corrective action" in each of the jobs affected may blind the managers to the existence of a common cause, and thereby to the opportunity for leveraged improvement.

Identification of logical job shop improvement projects is largely a matter of ingenious use of the Pareto principle (see Section 5 under Pareto Principle). The need is to identify those common causes which are at the root of the greatest amount of job shop trouble, and thereby will result in the greatest value of improvement for the least cost of analysis. Once a project has been chosen, the usual limitation to solution is more a matter of management than technology; someone must be liberated from the daily, job-to-job problems and given a license to diagnose the improvement projects.

Three approaches for project identification in job shops are presented below:

The chronic offenders approach

The product family approach

The non-job approach

The Chronic Offenders Approach. In this approach, the use of the Pareto analysis is first one of identifying the few jobs that result in the bulk of the quality losses. The term "chronic offenders" refers to these few jobs.

For example, a manufacturer of a line of floor polishers found that punch-press scrap was an important quality cost. A Pareto analysis of this scrap by part number (Figure 24.9) established that six of the parts accounted for half of the value of the punch-press scrap. It became a logical project to reduce scrap on these chronic offenders, since the "percent repeat jobs" was high. (The detailed approach to analysis of causes and discovery of remedy is discussed in Section 5, The Quality Improvement Process.)

In the complex assembly job shop, interest centers on individual assembly defects rather than on jobs per se. Defects may be so numerous and varied on each job that corrective action must be concentrated on those recurring defects which account for the greatest dollar loss, or are the most serious to the customer, or both. A "chronic offender" chart is then made for each major job, indicating the predominant defects. When high losses and seriousness are both involved, the list can be a composite of "five top dollar-loss defects," plus all the serious ones.

Corrective action for chronic offenders follows the general methods discussed under the Repeat Job Approach, above. In addition, the list of chronic offenders is publicized for the attention and priority of all—managers, supervisors, analysts, production workers, inspectors, etc. (In one plant in which the defects were mainly worker-controllable, good results were achieved by posting the chronic offenders list in each production department.) Along with this, the plant manager received a weekly bulletin of progress in tackling these high dollar-loss items.

The chronic offenders list is never static. Some projects are removed from the list because they have been solved. New projects are added to the list as the result of new customer demands or com-

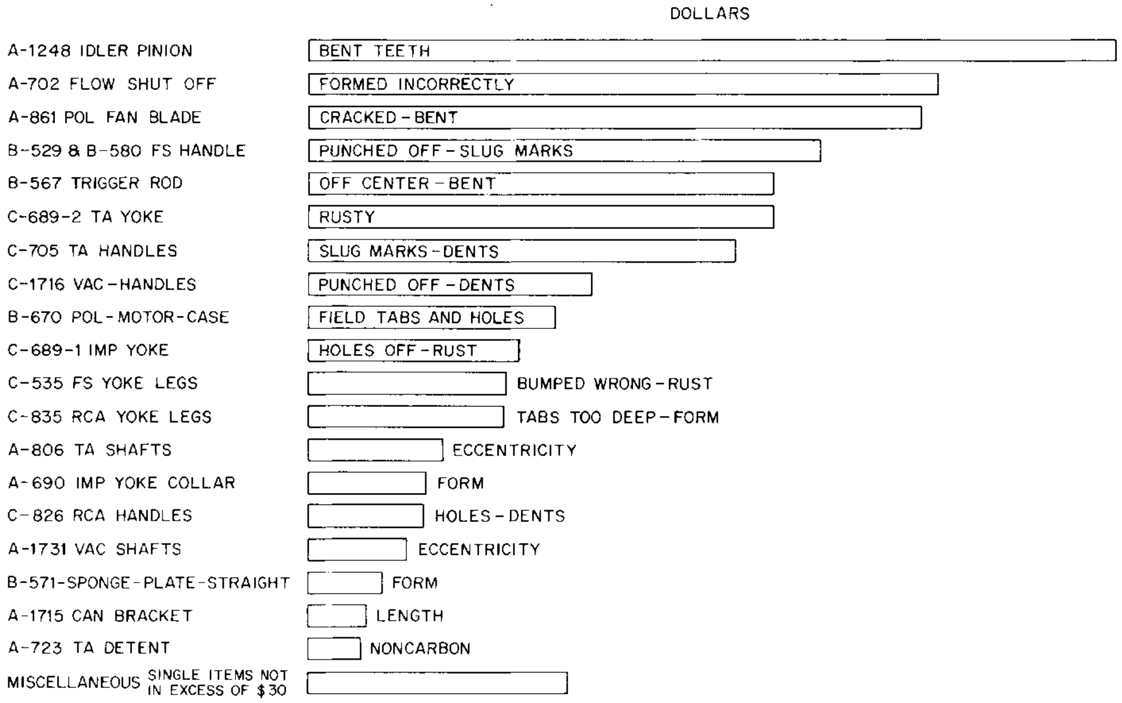


FIGURE 24.9 Pareto analysis by part number.

petitor practice. Accordingly, it is necessary to revise the list of the “worst” offenders periodically (in the same manner that law enforcement officers revise the list of the ten most wanted criminals).

The Product Family Approach. This approach utilizes the fact that all jobs in a product family have similar customer requirements, design specifications, sequence of operations, process variables, inspection instructions, or other job numerics. Under such conditions, any job is a repeat for any other job in the same product family. Through this relationship, the percent repeat jobs is greatly increased. In consequence, the effort of diagnosis and remedy is amortized over a greater number of jobs. This amortization tends to make this approach economic for moderate and even low percent repeat job rates.

The instances of “families” are legion. Tire manufacturers have hundreds of job specifications to cover all permutations of brand, size, fabric, construction, grade, wall color, tread design, etc. Yet, most of the numerics for, say, a four-ply nylon tire are alike (allowing for size scaling) for all members of that family. In the calendered vinyl plastics business, myriads of artistic printing and embossing patterns are applied to only a dozen or so basic families of laminated, unsupported, or coated films. Again, the job numerics for each of these families prior to printing and embossing are largely alike. In machine shops, the family concept has led to the group technology approach of identifying operations, sizes, materials, etc. that are common to a whole group of parts and restructuring the plan of manufacture.

The product family approach directs its efforts toward improving the job numerics for the entire family. This may come about in several ways:

1. By extending to all members of the family the knowledge gained when using the “current job” control plan. Once corrective action has become known for one job, such knowledge can be used to benefit other members of the family.
2. By utilizing the product family concept in setting up the memory system for the “repeat job” approach. Such usage supplies more data in a shorter time, and facilitates the identification of chronic offenders or defect concentrations. In turn, diagnosis of these “vital few” family problems leads to remedies which can be extended to the whole family.
3. By setting up a special project, in the absence of a memory system, to furnish the information in item 2 above and tackle the “vital few.”

The Non-Job Approach. “Non-job” is used here in the sense of an approach to chronic defect reduction through discovery and elimination of common causes that are not job-related, i.e., the causes that cut across many jobs. Because the causes common to many jobs are quite numerous, the first step in the non-job approach is to use the Pareto analysis to identify those common causes that might warrant further analysis. The Pareto study is conducted in various ways—by defect type, failure mode, process, department, discrepancy, “basic cause,” etc. Out of these studies emerges the most promising avenue for further study, usually that Pareto distribution in which the fewest number of defect types (or whatever) account for the greatest proportion of the trouble.

The usual starting point is to study the distribution of rejects or losses by *common symptoms*, on the normally valid premise that common symptoms will be found to have common causes when further analyzed. For example, an electronics assembly shop found (at subassembly) that a Pareto distribution by defect provided a good basis for further study, since one defect (solder) accounted for about 37 percent of all defects (Figure 24.10). Studies by failure mode, error type, discrepancy, etc., are similar in nature.

For many products, the study can usefully go one step further, even at the exploratory stage. Whenever the causes for the principal symptoms categories are “obvious” (i.e., all knowledgeable hands agree) from the nature of the symptoms, then an analysis can be made by *basic cause categories*. (Such obvious causes are so well recognized that they often find their way into the very name of the defect, such as “toolmarks,” “incompletely lapped,” “undercured,” or “double-knurled.”)

In an automobile tire plant, a Pareto distribution by defects was of no avail, since there was not sufficient concentration among the 85 identifiable defect types to justify study projects for each of

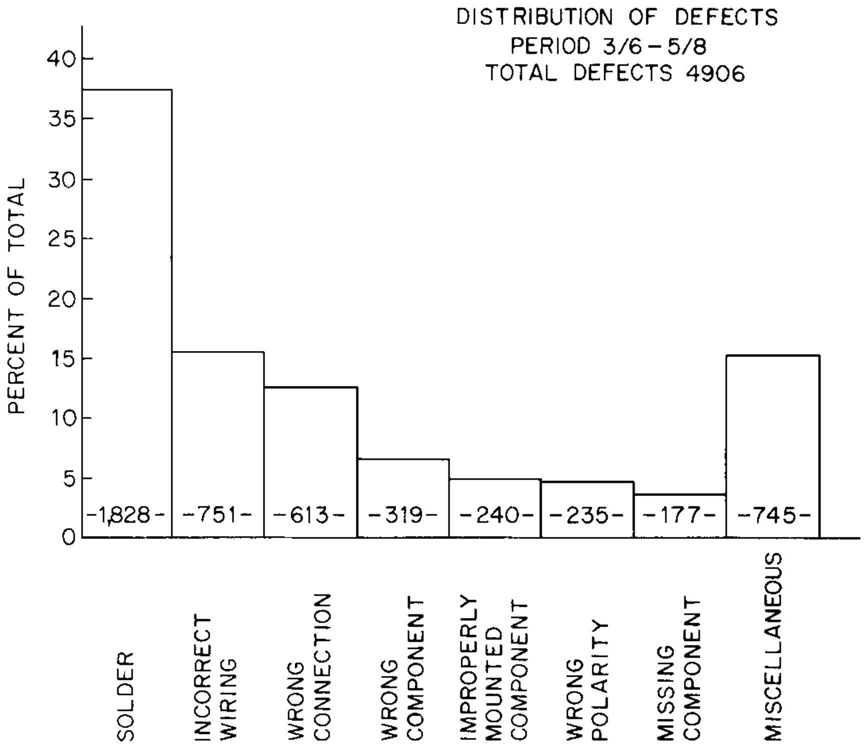


FIGURE 24.10 Pareto analysis by common symptoms.

about 20 principal defects. However, by regrouping the 85 defect types into 7 basic cause categories (Figure 24.11), it became evident that one operation (curing) required better control systems, while another operation (finishing) needed improved attention to setups. It also became evident that the relationship of ply angle to width required a more complete planning of the supplementary job numerics by Engineering.

In still other cases in which causes are not obvious and defects might be the result of any of several possible causes, it is nevertheless instructive to attempt to classify by basic cause categories in the job shop. This can be done by setting up a special study for a limited period (e.g., a week or a month), during which time each rejection or error is carefully traced to its origin by a task force representing Engineering, Production, and Inspection. Based on the facts unearthed, they try to agree on the cause classification.

For example, a sheet metal fabricating shop studied its rejections in this way and obtained the Pareto distributions shown in Figure 24.12. The most promising direction for study was the basic cause category “operator error,” since operator errors (acknowledged as such by the operator in each case) were by a wide margin the biggest single class.

One machine tool builder prepared a check sheet to assist supervisors in analysis of causes of defects. The check sheet required each foreman to:

Describe the defect in terms of the specification, and of the effect on assembly or customer

Identify the source of process dominance (see Section 22 under Planning Process Controls)

Identify the plan in use for detecting nonconformance

Identify where the defect occurred and where it was found

Determine the extent to which worker self-control was present (see Section 22 under Concept of Controllability)

Determine basic cause for the defect (Figure 24.13) (see Section 5 under Diagnostic Journey)

The resulting data offered many possible useful Pareto analyses.

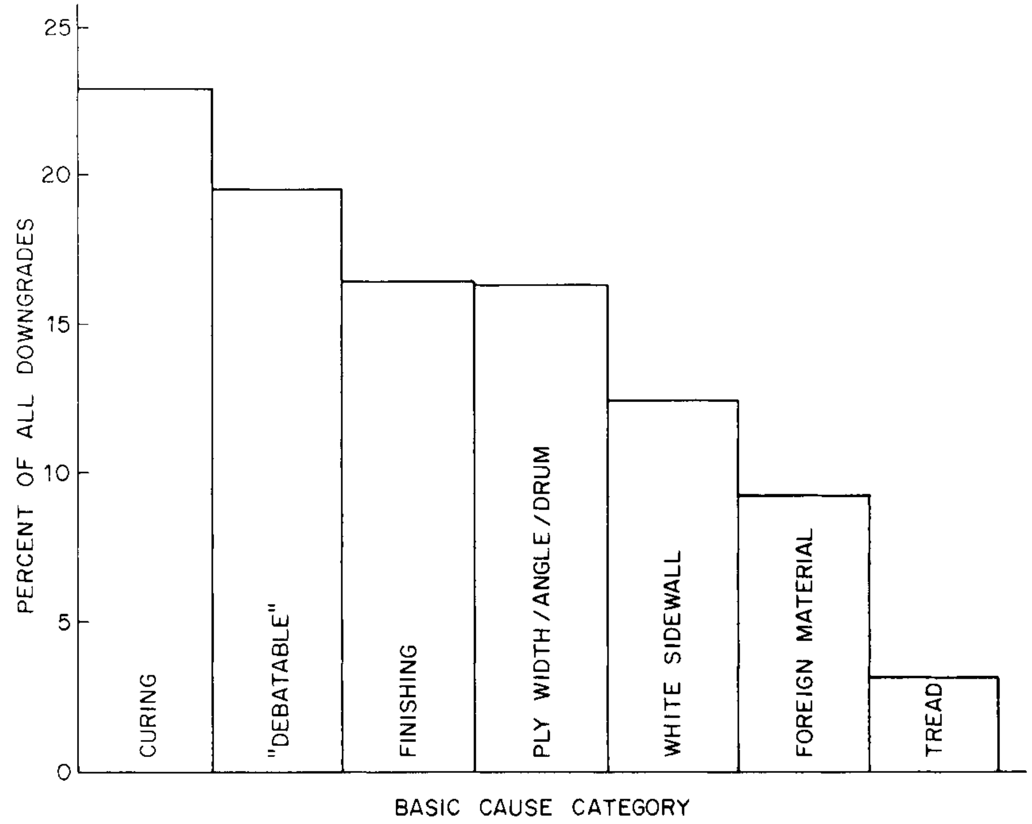


FIGURE 24.11 Pareto analysis of auto tire downgrades by basic causes.

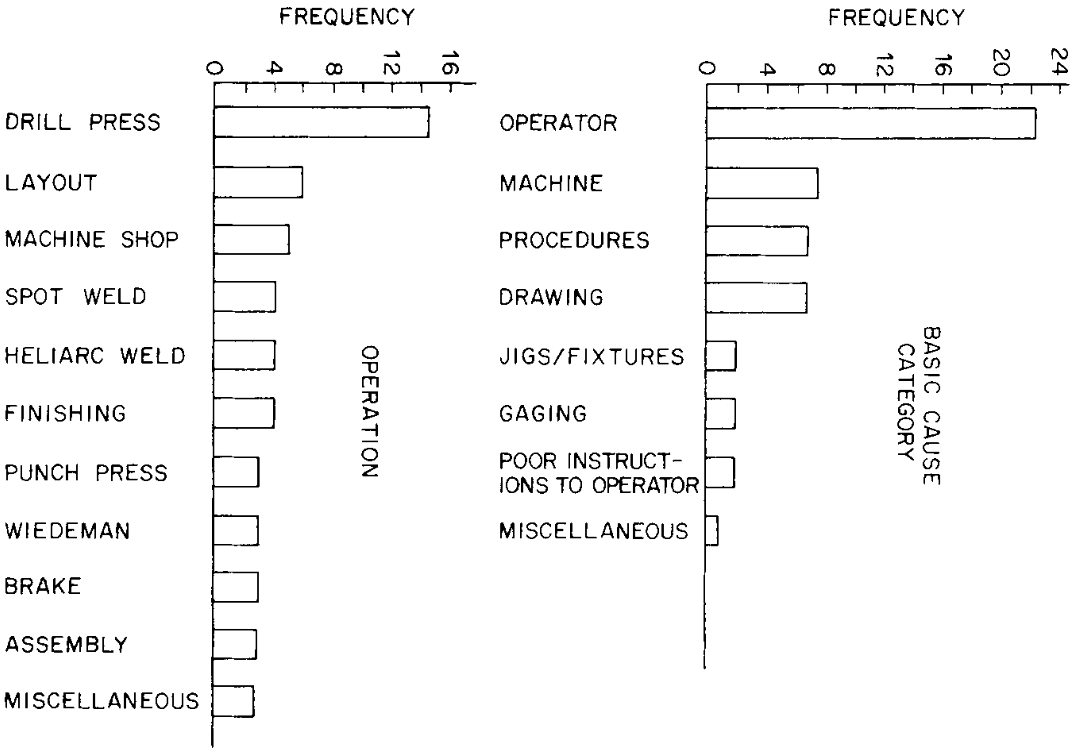


FIGURE 24.12 Two-way Pareto analysis by operation and basic cause category.

WHAT WAS THE BASIC CAUSE FOR THE DEFECT?

____Specification not clear
____Spec misinterpreted by operator
____Routing error
____Machining sketch error
____Tape error
____Tooling error
____Fixture wrong
____Operator setup error
____Layout error
____Prior operation wrong
____Other (describe below)
____Tool wear
____Operator loading wrong
____Operator repeatability
____Machine repeatability
____Measurement method
____Measurement error
____Deviation from routing sequence
____Supplier material defective
____Machine malfunction
____Wrong feeds and speeds
____Operator inattention

FIGURE 24.13 Check sheet for basic cause analysis in a machine shop.

In a company making electrical inductors, "inductance out of specification" was by far the most frequent defect. Frequency distributions of a dozen high-reject lots showed two different symptoms patterns:

1. Some lots had adequate within-lot variability, but had poor centering of the mean of the distribution, resulting in rejects all beyond one of the limits.
2. Other lots had excessive within-lot variability, resulting in defects outside of both limits.

The common cause in this case was in the Engineering department "sample shop," which established product tolerances (e.g., inductance, resistance) as well as manufacturing instructions for wire size and number of turns. The practice of the sample shop was to make a single trial coil to meet the customer's electrical requirements. Then, the wire size and number of turns that had been used to make this trial coil were incorporated in the manufacturing instructions. The system was defective because it failed to consider the effect of production variability from coil to coil. The results of one trial coil provided no information on natural coil-to-coil variability from which to establish the tolerance width, nor was the sample coil necessarily at the center of the tolerance range, as assumed by the Engineering department—hence the observed symptoms when the Production department followed the manufacturing instructions for wire size and number of turns. When the sample shop procedure was changed to making three coils, with calculated consideration for expected variability, there soon was a substantial reduction in the rejections.

It is evident from such cases, especially the last one, that job shop quality improvement is not confined to changing the job numerics or to providing a warning to Production the next time the job is run. The "common cause" often interacts randomly with jobs; it can affect any job at any time. Once tracking of such a common cause gets under way, the diagnostic trail frequently leads back to the fundamentals of the very system of preparing specifications, of assigning tolerances, of bidding or estimating, of controlling processes, etc.

Diagnostic Techniques. The techniques for diagnosis and remedy of the chronic problems in the job shop are similar to those in any shop; they are covered in detail in Section 5. However, the job shop diagnostician is seldom able to collect large quantities of data at will; lot sizes are too small. This calls for ingenuity by the diagnostician in collecting the needed data from repeat orders of a job or from several members of a family. Often a variant of the "memory system" (see under The Repeat Job Approach, above) provides the answer by accumulaing the data gradually over a period of time.

For example, machine capabilities in a job shop can be determined from an accumulation of measurements of 5 to 10 pieces per job over a series of jobs. As the data accumulate, a statistically adequate basis for estimating machine capability emerges from the "within-job" range. (See Section 22, under Process Capability.)

Similarly, dominance can be identified by recording 5 or 10 "first piece" and "last piece" measurements on a series of jobs in the memory system. If, for a given machine or process, the series of jobs shows no significant change between the two sets of measurements, setup dominance is indicated; otherwise, time dominance. In the latter event, the accumulated data give important quantified information on whether the time-to-time variation is steady or erratic from run to run. Recording of worker identity is the key to identifying worker dominance.

Even "within-piece" or positional concentration of defects can be discovered by accumulation of data from small lots. In a plant making large castings for pumps and air compressors, a condition of leaks in castings was remedied only after patient recording of the location of the leaks, month by month. In this case the castings were made a few at a time, repaired, and shipped out. The memory device was a drawing copy on which the diagnostician accumulated all leak locations.

REMEDIES FOR JOB SHOP PROBLEMS

When the identified problems are job-related, so are the remedies. In the chronic offenders and product family approaches, the remedies indicated by the diagnoses are usually changes in the job numerics. When the identified problems are not job- related, as in the non-job approach, the remedies must go deeper, e.g., modification of the overall system of specification, planning, or control.

Challenging the Basic Premises. The most difficult remedies are those for which it is necessary to question the basic premises or axioms underlying management thinking. These premises are often of such long standing that little effort is being devoted toward changing them or even questioning them. These premises are further entrenched because their effect is interdepartmental, i.e., several major company departments are involved. In consequence, a change requires acquiescence or formal approval from the upper management of the company.

Some widespread examples of the need for challenging basic premises are listed below. In studying these examples, it is well to keep in mind that these premises were very likely well founded in years gone by but have meanwhile become obsolete by the slow, undetected movement of events.

Unrealistic Specifications. The large number of jobs per worker per week (so usual in the job shop) exposes the production and inspection personnel to a very large number of quality characteristics. Under such conditions, systems of "unrealistic specifications loosely enforced" become unmanageable because the shop people must carry in their heads so much detail of how loosely to enforce the specifications.

For job shops engaged in custom work, the way to avoid recurring violation of specifications (by workers who conclude that the tolerance is unrealistic or unimportant) seems, on the face of it, to give binding force to the specifications. However, no amount of criticizing, threatening, or pleading will assure compliance if the process capability is inadequate. The trouble is that the system is founded on a defective premise. The remedy lies not in more intense use of the present system; the remedy lies in change of the basic system.

This is not as easy as it sounds, since the system is logical once the basic premise is accepted. It is common to discuss enforcement of tolerances without questioning the basic premise itself. Such discussions may settle the specific instance without settling the broad question. It is only when the question "tight tolerances loosely enforced versus realistic tolerances rigidly enforced" appears on some important agenda as a topic in its own right that the question has been brought out in the open.

Informal Communication. In very small model shops and specialty shops the communication from designer and planner to mechanic is highly informal and includes much oral communication. As the shop grows, this close relationship is gradually eroded by sheer size and complexity, and the need is for greater formality and greater reliance on written communication. However, in some job shops this communication retains many aspects of the informality of the model shop or speciality shop despite the fact that these have long since been outgrown. As discussed under The Job Numerics, above, the communication of the supplementary job numerics is a necessary response in the modern industrial world of multiplicity of requirements.

Quotation Review. The prevailing practice in quoting prices to customers is to base them on cost estimates prepared by an estimator who makes use of cost standards based on historical data.

In some types of product, the precision demanded has become such that the decisive factor in meeting cost and delivery standards is the ability to hold tolerances. Yet seldom is the estimator provided with adequate standard data (on the cost of precision) to come up with quotations which reflect the realities of holding the precision demanded.

Of course, adequate standard data should be prepared and made available to the estimators, who in turn should be trained in how to use them. Until this is done, the job shop is well advised to bring the Quality department into the quotation procedure so that available quality capability knowledge is utilized. Use of this knowledge can aid in identifying unrealistic tolerances, predicting costs, anticipating gaging problems, defining vague characteristics, and improving inspection planning.

The basic premise here is that the estimator should be able to prepare the quotation. The premise is sound only if the estimator is equipped with the data on which a sound quotation can be built up.

Quality Planning. The “basic premise” question here is primarily one of separation of planning from execution. However, the question extends to numerous facets—choice of methods, tool control, gage control, definition of responsibilities, feedback systems, etc. The really decisive question is whether to formalize or not. Once there is a decision to formalize, the people involved can usually find ways appropriate to their needs.

An example of combined quality planning and execution is the Engineering department model shop. These shops are staffed by skilled model makers working directly with the engineering designers. The atmosphere is highly informal, with little reliance on drawings, tolerances, methods sheets, or other written communication. The model maker is expected to make the model by utilizing general-use machinery, to create ingenious setups so as to avoid expenditure for tools, to consult freely with the designer on open questions, and even to contribute ideas to the design itself. In such an organization form, reliance for quality is on the model maker rather than on some formal system.

As the job shop grows, the need arises for a greater degree of separation of planning from execution. This need is met by the creation of separate planners and a Planning department. (The quality counterpart of this is separate quality engineers and a Quality Engineering department.) The planners soon find (as did the model makers before them) that the planning should not be uniformly applied to all jobs or functions. Some jobs are more defect-prone, more expensive, more unstable than others.Hence there arises the need for a rationale or logic to determine which part of the planning is to be done by the planners and which is to remain with the shop personnel.

Outdated Factory Organization. Many job shops organize their machinery on the colony plan, e.g., all lathes are in one room, all presses in another, etc. The intention is to reduce investment in machinery and to develop skills in the respective processes. This colony form of machine organization multiplies greatly the problem of preparing the job numerics and increases the opportunities for error. (It also increases process inventories, overall manufacturing intervals, and the complexities of process control.)

Here the basic premise is that as the job shop grows, the colony organization must be retained. This premise has been questioned on the grounds that growth should be through creation of “cellular” groupings, which use special machine designs to minimize the preparation of extensive job numerics, increase machine utilization, improve coordination, etc. Highly automated forms of such cellular groupings, known as “flexible manufacturing systems,” are in use, which can significantly lower production and quality costs. A good description has been given by Black (1983).

For example, a manufacturer of cigarette making machinery embarked on a program of:

1. Use of light alloys to increase speed of metal cutting
2. Design of special machines on the Numerical Control principle to perform multiple operations during a single setup
3. Design of special inspection machines to verify the setups
4. Organization of the shop into small, compact crews (see the discussion of "Group Technology" under Improving Job Planning, above)

Multiple Suppliers. For the small job shop, material usage is so modest that when an adequate source of supply has been established for any specific material, there is little point looking for a second source. As the shop grows, material usage grows with it, and there may be a need to shift from single to multiple suppliers for some materials. However, the basic premise of single suppliers may meanwhile have become so rooted that it blocks consideration of multiple suppliers.

Worker Motivation. The economics of job shop planning favor a higher degree of delegation to the work force than is readily feasible in the mass production shop. This delegation reduces the prevalence of worker monotony and boredom, but also increases the extent of worker controllability of defects. (See generally Section 15 and especially under Open Communications. See also Section 22 under Concept of Controllability.) As these defects are brought to light, the managers conclude that since worker inattention, blunder, etc., created these defects (which is often true), it follows that better worker attention, etc., will eliminate all defects. An extension of this logic is that the way to improve quality is to penalize workers for defects. However, the logic is based on a defective premise, since even if worker errors can be eliminated, there still remain the management-controllable defects (which usually are about 80 percent of all defects).

Actually, the wide delegation of duties to shop personnel, so prevalent in job shops, creates a favorable climate for new approaches to increasing job interest and improving worker motivation. The job shop is thereby a good laboratory for testing out some of the modern ways being evolved to improve motivation (see Section 15 under Design Principles of Work and Organization).

THE SMALL JOB SHOP

The approaches discussed in this section for planning, controlling, and improving quality require much technique and effort beyond that needed for the basic "line" activities of designing and producing the product. In the large job shop this additional work is mostly performed by staff specialists in a "Quality Engineering" department. However, the small job shop seldom can justify use of such full-time specialists. Neither can this small shop endure high quality losses. The answer to this dilemma is universal for all small enterprises: everyone wears several hats. The necessary quality "staff" activities do get carried out, but as part-time tasks for someone who is busy with many other part-time tasks.

For example, in one small job shop a wide array of quality tasks was assigned as shown in Table 24.4.

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TABLE 24.4 Assignment of Quality Tasks in a Small Job Shop

Tasks	Assigned to
Receiving inspection, in process inspection and test	Line inspectors and testers
Gage control and gage procurement	One full-time technician
Reliability test and evaluation, inspection planning, test equipment design, statistical methods	One quality engineer
Quality laboratory, special process controls	One laboratory technician
Supplier control, troubleshooting	Laboratory technician and quality manager
New design review	Quality manager
Command of the department	Quality manager

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