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## Research Report
## Rapport de recherche

DYNAMICS OF IMPLEMENTING
STATISTICAL PROCESS CONTROL:
A BEHAVIORAL SCIENCE PERSPECTIVE

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A research report submitted to:

The Technological Innovation Studies Program
Department of Regional Industrial Expansion
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The Japanese advantage rests, first and foremost, on an almost fanatical attention to detail provided by people....Substantial cost and quality advantages will be enjoyed by managers who believe that perfection is possible, that variance from what is expected constitute information to be understood and that quality standards are to be met (not approximated).

Jelinek and Goldhar
1984

Drastic changes are required. The responsibility for change rests on management. The first step is to learn how to change. Long-term commitment to new learning and new philosophy is required of any management that seeks to improve quality and productivity. The timid and the faint-hearted, and people that expect quick results, are doomed to disappointment.

W.E. Deming
n.d.

## TABLE OF CONTENTS

# DYNAMICS OF IMPLEMENTING STATISTICAL PROCESS CONTROL: A BEHAVIORAL SCIENCE PERSPECTIVE

by Gervase R. Bushe, Ph.D.

## A SUMMARY OF THE REPORT

This is a study of one automobile plant's attempt to implement statistical process control (SPC). It is written primarily for managers who are thinking of using SPC in their organizations to help them in considering the technical, political and cultural barriers to SPC found in typical North American factories. SPC is a method for understanding and controlling production processes to reduce deviations from specifications (1.2)*. The Japanese have credited much of their success in world markets to their use of SPC. When fully implemented, SPC requires having operators controlling variances and taking responsibility for the quality of outputs.

Section 2 of the report is a history of the change process at Plant X. Between 1980 and 1982 certain key events laid the groundwork for later events. These included a large scale, joint labour and management quality of work life project, a few scattered attempts to use SPC, the threat of having the plant permanently closed by the larger corporation, and the offer by the state to provide training and development funds for SPC (2.1).

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*Numbers in parenthesis refer to sections within the report.

The formal implementation of SPC began in 1982 (2.2). Six supervisors were made full time "statistical analysts" and given large amounts of training in SPC and in organization development. This section documents some events that contributed to and detracted from the implementation effort. In general, the implementation effort was very successful in 1983 but stagnated in 1984.

Section 3 of the report analyses some of the dilemmas to implementing SPC found in the Plant X case with special emphasis on those which may be typical of factories in general. Leadership became an issue due to the transfer of the production manager in the middle of the change effort (3.1) but is not considered here in depth. Problems built into the very structure of large manufacturing organizations are considered next. Most factories exist within larger divisions. Three problems with divisional structures are highlighted (3.2A). One is that initial SPC analyses and action plans tend to focus on outside suppliers but the contracts for suppliers are often set by the division. A second issue is that SPC tends to highlight engineering and design problems and often, these are controlled at a divisional level. The third issue is the use of deviation-from-budget control systems that analyze a plant's performance on a line by line basis. This can greatly reduce a plant's motivation to exploit opportunities and works against the kind of multi-variable thinking inherent in SPC.

Reporting and control systems within Plant X also created barriers to implementation (3.2B). There was a heavy, almost exclusive focus on labour efficiency at the operating level which discouraged first line supervisors trying out SPC. In addition, the system allowed scrap to be deducted from labour efficiency, thus providing a disincentive to reducing moderate scrap rates.

The functional structure of the factory, with sharp distinctions between manufacturing and service departments, also created problems (3.2C). This case found that the functional structure tended to detract from a focus on product quality and tended to lead to fragmentation in the organization. In addition, it separated those analyzing problems with SPC (workers and supervisors) from those responsible for fixing problems (service departments).

It was noted that the reward system in the factory was not directly related to the use of SPC (3.2D). The plant tried to "sell" supervisors on the use of SPC because it would lead to improvement in performance areas that supervisors are evaluated on. While this is probably true, it was not enough to motivate supervisors to use SPC, particularly where there would be a certain loss in short-term labour efficiency (to train workers, have meetings, etc) for uncertain future gain.

Barriers were encountered in dilemmas created by a centralized structure trying to decentralize decision-making (3.2E). Lower level managers were given responsibility for fixing problems without the necessary authority or resources. Significant resource allocation could only be authorized at the top. As more people got involved in trying to solve problems, resource allocation systems became bogged down and unresponsive. As supervisors were still held responsible for fixing their problems, the result was a disincentive to making problems visible with SPC.

Finally, the nature of the business, volume manufacturing, created barriers (3.2F). As the plant got better, it had more work and less time for SPC. There is a fundamental paradox here in that implementing SPC requires analysis and reflection whereas the nature of manufacturing emphasizes execution and doing. While these can be complementary, they can also be antagonistic.

The next section of the report explores barriers created by culture (ingrained habits) and politics (distribution of status and power) in the organization. Five broad themes are identified and explored in some detail. These are that implementing SPC requires major changes in power relations (3.3A); that implementing SPC requires creating uncertainty in order to reduce uncertainty (3.3B); that implementing SPC is hampered by manufacturing's short-term orientation (3.3C); that implementing SPC requires learning oriented norms in a performance oriented culture (3.3D); and that implementing SPC requires implicit self-condemnation by those who must drive the change (3.3E).

Section 3.4 of the report looks at the role of hourly employees and the union. While other organizations have met solid resistance to implementing SPC, Plant X received good cooperation from labour. This can be explained, at least in part, by the preceding quality of work life intervention and the threat of a plant shut-down. The first attempts to implement SPC on the floor occurred mainly where workers were already meeting in quality of work life groups. Operators were regularly using SPC and controlling their own variances only where they were task independent. Large amounts of task interdependence make it difficult to give individuals much discretion over decisions like stopping a run because it is producing defects. It appears that, in the long run, successful implementation of SPC will require restructuring work in ways that give small groups of operators clear task boundaries.

The Plant X case also showed that it was possible to solve specific problems by simply having operators collect data later analyzed by experts. In such instances, however, collection of data had to be policed and soon stopped after the problem was "fixed". Where operators participate in analyzing data and solving problems, the collection of SPC data tends to become institutionalized.

The final section of the report comments on the role of change agents (in this case, statistical analysts) in the implementation process (3.5). The statistical analysts were on the same hierarchical level as first line supervisors, even though they reported to senior management. This created advantages and disadvantages. The main problems were the need to break out of self-imposed limits, distorted authority relations, and the propensity to view themselves as victims of the system. The advantages were their ability to get trust and cooperation throughout the system and not be seen, hierarchically, as a threat.

# SECTION 1: BACKGROUND

## 1.1 INTRODUCTION

The research proposal which led to this report gave the following as the objectives of the study:

> "The main objective of (this) documentation study is to understand the process of change as it has occurred at (Plant X). This requires a political-cultural analysis....the focus is on understanding the dynamic processes involved in various groups of actors coming to agree on a technological change that has profound political and cultural consequences for them.
>
> Data collection will primarily consist of field interviews with a large number of organizational members supplemented by a large amount of archival data (e.g., minutes of meetings) and small questionnaires....it is anticipated that we will gain a better understanding of:
>
> 1. The various dilemmas that introducing SPC (statistical process control) creates and some notions of how they might be resolved.
>
> 2. The reasons various groups resist SPC technology and ways of neutralizing that resistance."

When this proposal was written in the fall of 1983, the case being studied (Plant X) had made great gains in implementing statistical process control in a short period of time. Statistical process control (SPC) is a technique for analyzing and controlling production processes. The Japanese credit SPC as being a key factor in their remarkable improvements in quality and efficiency over the last two decades. Today, a large percentage of North American firms are attempting to implement it without a lot of success. It was hoped that the Plant X case might offer some clues for how to ease the process of implementation.

360

In the subsequent year and a half, the SPC change effort at Plant X has slowed considerably. This, unfortunately, means that there is not as much to learn about promoting change as one might have hoped. There is, however, a great deal to learn about dilemmas and resistances to SPC found in North American factories. This report is, first and foremost, a study of the structural, cultural and political dynamics that impede the implementation of SPC in manufacturing.

The first section of the report provides some background to the study, the field site and the innovation, SPC. The second section of the report is an historical sketch of the change process at Plant X since 1980. The historical analysis is necessary for understanding the situation the plant faced in 1984. The final section of the report is an analysis of the dilemmas encountered by the change effort in 1984.

In writing the historical narrative and the analysis, the author has been aware that the report is likely to be read by people both inside and outside of the plant. Some attempt has been made to maintain the anonymity of the field site and it is referred to throughout the report as Plant X. Only information widely known within Plant X has been included in the historical sketch in those instances where such information might be sensitive or might pinpoint an individual. In the analysis section, an attempt has been made to not use examples or data which might harm someone.

Because this is an analysis of dilemmas and resistances, we will, of necessity, be focusing much attention on things that didn't work out, mistakes and missed opportunities. The reader should keep in mind that Plant X has managed to exploit opportunities and make a great many more things work out in implementing SPC than, for example, her sister plants in the same division. In order to keep this report to a manageable size, less attention has been paid to what worked. Management decisions and actions have only been analyzed for the ways in which they effected implementation of SPC. Obviously, some actions which were counter productive to the change effort made sense given the bigger picture but this has not been focused on and what follows, therefore, is not a balanced account. Let us recognize that simply the act of allowing this researcher into the plant during a difficult time of transition indicates an openness to learning rarely found in manufacturing organizations. But we are not studying how Plant X got to be the kind of organization it is. Rather, Plant X has been used as a jumping-off point for examining problems one would expect to find in any manufacturing unit of a large organization attempting to implement SPC.

This report is written for two main audiences. The first is managers considering implementing statistical process control. Hopefully, this report will give them a better understanding of what SPC is and enrich their thinking on how to go about implementing it. The second audience is students of organizational change and utilization of innovation. This study moves beyond most research on the diffusion of innovation by focusing on the dynamics of actual utilization over a period of years.

## 1.2 A BRIEF INTRODUCTION TO STATISTICAL PROCESS CONTROL

Statistical process control (SPC) or statistical quality control (SQC) are two names to describe a method of controlling manufacturing processes to ensure that outputs conform to specifications. Developed in the 1940's and 50's, this technique was largely ignored in North America. Japan, however, launched a national program to implement the use of SPC and attributes much of its success in world markets to its use. To fully appreciate SPC, it is useful to contrast it against standard North American quality control (QC) practice.

In North America, QC has traditionally been isolated as a separate function from manufacturing due to an assumed conflict of goals. Manufacturing's goal is to maximize output and minimize cost. QC's goal is to ensure that only those outputs which meet customer specifications are shipped. Typically, a quality inspector goes through manufactured goods just prior to shipment separating the good from the bad. Such ship or don't ship information is referred to in SPC as "attribute data". It generally provides little information that is useful in understanding the causes of defects and only spots these defects after productive resources have been spent manufacturing the product. The 'end of the line' type of QC inspection is one of the reasons that "hidden plant costs" or "rework costs" in North America have been estimated as high as 40% of productive capacity.

In SPC, however, an attempt is made to understand all the variables which effect output and how these vary together. In particular, statistical methods are used to detect special causes of variation and to understand what limits of variation will produce defects. First, the process capability of a manufacturing process must be known. This is the variation that will always be present and the best the process is capable of producing in its current state. Then, tolerances for each critical variable to ensure the final product meets specifications must be known. Finally, operators sample parts as they move through the manufacturing process to ensure they fall within these tolerances. As a result, one can be assured that the final output is within specification to whatever level the process is capable of. In SPC, QC is a line management and operator function and variable data is collected that aids in pinpointing the causes of defects.

It is useful to note here that while SPC techniques were invented in America, the Quality Control Circle (QCC) was a distinctly Japanese innovation. From a social systems viewpoint, QCCs were a method for ensuring operators understood and used SPC, thus resulting in the institutionalization of SPC as a way of doing business. QCCs are small groups of operators from the same area who meet regularly on company time to target and solve work problems. They are trained extensively in SPC and encouraged to analyze their work (all facets of it) with statistics. When they believe they have a suggestion for how to improve productivity, quality or delivery or reduce costs, they present it to management which has the final authority to accept or reject the suggestion.

When QCCs were first brought to the U.S., early innovators imitated the Japanese approach. American companies found, however, that they first had to deal with a distrustful, alienated and sometimes hostile workforce. American Quality Circles then changed from a method of institutionalizing SPC to a method for involving workers in problem-solving. Training materials changed to respond to this different emphasis, and much of the SPC focus was lost. In companies like the one studied here, Quality Circles and SPC became two separate innovations and many of those implementing them do not understand this common heritage. In America, SPC tends to be appreciated as an engineering and management tool. It's ability to more accurately portray manufacturing processes (and thus, more accurately control them) is easy to grasp quickly. It's relationship to the whole social system is less appreciated.

Generally, SPC is discussed in terms of deviations from specifications. Successful implementation of SPC has been shown to lead to higher quality (in the sense of conformation to specifications) and cost reduction (from building parts right the first time and eliminating waste). Note this relationship between quality and cost is the opposite of traditional thinking. The popular assumption is tnat increased quality requires more expensive materials, additional labour hours or other tangible resources. The Japanese have demonstrated that the costs of improving quality with SPC are lower than the resulting savings in waste, rework and warranty expenses, not to mention the increased economies of scale that result from increased volume due to consumer satisfaction. In their view, "quality costs" are any expenditure on manufacturing or service that results from not building the product right in the first place. Total quality costs typically come from four different areas:

1) Prevention: expenditures on planning, training, suppliers and others
2) Appraisal: expenditures on inspection and testing
3) In Process Failures: expenditures for rework and waste
4) External Failures: expenditures resulting from warranties and product liabilities

Over many years of applying SPC thinking to manufacturing, the Japanese have rooted out many hidden quality costs such as carrying excess inventory of raw materials and work-in-process components to ensure that defects don't shut down production lines or the costs of operating excess capacity to compensate for machine downtime. To offer a simple illustration, at Toyota the number of holes a machine drill bit will produce without deviations has been statistically examined and when that number is reached, the drill bit is replaced and the old one sent for sharpening with less than five seconds missed. In the typical American manufacturing plant, replacing a drill bit before it breaks is unusual and the decision to send one for sharpening typically involves a supervisor and/or engineer peering at it closely while scratching his head.

It is hard to accurately gauge the total cost differences in these two ways of doing business. In one study by Garvin, Japanese manufacturers had defect and field failure rates 15 to 70 times lower than their U.S. competitors.[1] Their average cost of quality was 1.3% of sales, while the Americans ranged from 2.8% to 5.8% of sales.

Garvin also found a positive relationship between quality and productivity in firms with similar technologies and capital intensity. In the industry he studied (room air conditioners) high quality American companies were five times as productive (units per man-hour) as low quality companies.

It is these kinds of results, coupled with the decline of American manufacturing competitiveness, that have led managers to explore SPC applications. In theory, SPC is really quite simple. The statistical tools most frequently used are very basic; various charting procedures, means and ranges, simple correlational statistics.[2] In Appendix A is a copy of a booklet prepared at Plant X describing some of these tools. As an innovation, it would appear to fit in nicely with the 'control mentality' of typical manufacturing management.

That it is not so simple is attested to through numerous examples of massive efforts to implement SPC in the U.S. that have yet to bear fruit. In conversations with individuals responsible for implementing SPC in such corporations as Honeywell, Boeing, Xerox, General Motors, Ford and others, the author has not found one case where the use of SPC has become an accepted way of doing business. Bill Conway, former President of Nashua and one of the most influential proponents of SPC was fired from Nashua before SPC could take firm hold there. Even the plant studied here, which was chosen because it was so far ahead of its sister plants in implementing SPC, is still far from institutionalizing its practice. It is the problems with implementing what appears to be so good, easy and congruent that are so fascinating to this researcher and that form the basis for this study.

## 1.3 BACKGROUND TO THE RESEARCH SITE

The research site, Plant X, is part of an automobile company. It was built between 1938 and 1942 and is located in the northeastern United States. It manufactures various and diverse pieces of hardware, producing approximately three quarters of a million pieces daily. The plant produces over 3,500 separately identified products that it ships to approximately 80 destinations. It had sales of approximately $300 million in 1984.

Plant X has a variety of manufacturing processes, making it a large, diversified "job shop". These processes include die casting and metal forming, injection molding, plastic extruding and various types of finishing and assembly. The range of products and processes makes Plant X somewhat unique and poses special problems and opportunities for managing change in general and implementing statistical process control (SPC) in particular.

The plant employs approximately 3,000 people, although this number can fluctuate a great deal depending on economic conditions. In the past few years head count has slowly declined though sales volume has increased. All hourly-rated employees are unionized. The ratio of salaried to hourly-rated employees is approximately 1 to 6 (salaried includes all clerical and non-supervisory staff as well as management).

Like most factories, Plant X has a functional structure with five manufacturing departments, a variety of service departments (e.g., engineering, maintenance) and financial and personnel functions. In general, the organizational design and attendant social system dynamics are like those of any large machine bureaucracy.[3] These include a large number of pre-programmed, repetitious jobs at the operator level, a fairly rigid chain-of-command authority structure, five to six levels of line management between the floor and the plant manager, fairly poor vertical information systems with an elaborate and extensive informal communications system (i.e., you hear it from the sweepers before you get the 'official' word), a fair degree of alienation among lower level employees, competing goals and behavioral antagonism between line and staff functions and an abundance of bureaucratic control mechanisms. Labour relations, particularly those between line management and the local union are, from this author's experience, uncharacteristically good. As well, the degree of rigidity in the operating core of Plant X has loosened up considerably in the past few years. Both of these appear to have resulted from a joint union-management attempt to improve the Quality of Work Life (QWL) that has been ongoing since 1981. In the next section we will briefly review some of the history of this effort as it has effects on later attempts to implement SPC.

## 1.4 BACKGROUND TO THE STUDY

This author has conducted field research at Plant X during three time periods; August to December 1981, November 1982 to April 1983, and June to December 1984. The research grant supporting this study covered the period in 1984. Interview notes and documents from the previous two time periods were used extensively in constructing the historical narrative in Section 2. By the time of the third set of field visits the author had developed a reputation in the plant for being trustworthy and most interviews were taped and transcribed verbatim. Most respondents showed no hesitation in discussing personal and sensitive material. This data forms the basis for most of the analysis in Section 3.

During the 1984 field site visits, the following were interviewed separately:

* all the statistical analysts
* the director of the Quality Management Program
* the QWL coordinators
* two members of the union bargaining committee
* eight service department representatives
* twelve manufacturing supervisors
* all but one manufacturing department head
* two service department heads
* three senior managers
* the salaried personnel director

As well, numerous informal conversations were held with the plant manager and various other managers and a continuous dialogue occurred between this researcher, the director of the Quality Management Program and the statistical analysts.

Interview data was supplemented by a large amount of archival data. This included:

* the QWL Coordinator's daily journal for 1982 and 1983
* records of meetings from various special task forces since 1981
* all minutes of the QWL Steering Committee and QWL Advisory Team

* copies of in-house publications
* all planning documents and reports generated by the statistical analysts
* the minutes of all meetings of the statistical analysts
* the minutes from key meetings held to discuss SPC in the plant
* the minutes of divisional SPC network meetings
* documents and memos related to divisional SPC efforts
* presentation materials prepared for plant tours since the fall of 1982

In addition, the author had access to survey data from studies he and others had done in the plant. These included:

* overall results of large attitude surveys of managers in the plant in 1982 and 1983
* a survey of manufacturing personnel's beliefs about problem-solving groups done in January 1982
* an open-ended survey of senior management's perception of consulting needs for the senior staff group, done in October 1982
* a survey of the perception business teams and QWL groups held of their relevant environments, done in March 1983
* a survey of worker groups and their perceptions of the change process, done in August of 1983

The methodology of this study was primarily anthropological within an Action Research context.[4] A small group of plant personnel aided the researcher in developing the research questions, getting access to documents, setting up interviews and interpreting data. Through a process of co-inquiry with plant members, the researcher sought to understand how things looked from the perspective of individuals. Then the researcher attempted to understand how the situation fit and didn't fit the perceptions of organizational members.

Concurrently, the researcher observed behavior and noted where described behavior and actual behavior did and didn't match. The analysis of this data is primarily concerned with uncovering paradoxes and dilemmas inherent in the situation that account for common perceptions of members and the behavior observed. No claim is made that all the dilemmas in the situation have been uncovered or explored.

A preliminary draft of this report was distributed to the statistical analysts and key managers in the plant. They reviewed the report for accuracy in the data given and critiqued the interpretations arrived at by this researcher.

Because this is a one-case study, it is exploratory in nature. Its purpose is to generate possible insights which can later be tested through more deductive research methods. An attempt has been made, however, to focus on those aspects of the situation known to be common to manufacturing organizations and, hence, less likeky to be idiosyncratic to the case studied here.

## Section 1 Footnotes

1 D.A. Garvin, "What Does 'Product Quality' Really Mean?", Sloan Management Review, 26:1, 1984, 25-43; and D.A. Garvin, "Quality on the Line," Harvard Business Review, Sept.-Oct. 1983, 64-75.

2 Commonly used texts on SPC include K. Ishikawa, Guide to Quality Control, Tokyo, Japan: Asian Productivity Organization, 1976; and J.M. Juran and F.M. Gryna, Jr., Quality Planning and Analysis, New York: McGraw-Hill, 1980.

3 The term machine bureaucracy was coined by Henry Mintzberg and he gives an excellent description of them in The Structuring of Organizations, Englewood Cliffs, N.J.: Prentice-Hall, 1979.

4 For more on Action Research, see K. Lewin, Resolving Social Conflicts, New York: Harper and Brothers, 1948; and G.I. Susman and A.D. Evered, "An Assessment of the Scientific Merit of Action Research," Administrative Science Quarterly, 23:4, 1978, 582-603.

Quotation Page:

M. Jelinek and J.D. Goldhar, "The Strategic Implications of the Factory of the Future," Sloan Management Review, 25:4, 1984, 29-37.

W.E. Deming, quoted in J.R. Black and B.J. Scott, "Quality, Productivity and the Management of Change in the Boeing Company," paper presented at The World of Productivity Conference, New Orleans, October 16, 1984.

# SECTION 2: AN HISTORICAL NARRATIVE

## 2.1 PLANT T 1980-1982: QWL, SPC, THE SHUT-DOWN ANNOUNCEMENT AND STATE FUNDS

In the last few months of 1979 a new plant manager arrived at Plant X. Within a year the plant would be experimenting with greater employee participation in decision-making.[1] At this time, the larger corporation was greatly expanding its efforts to improve the quality of work life through cooperative labour-management initiatives at the plant level. Such initiatives were given fairly high visibility by the corporation and were a constant theme in talks given by senior executives to audiences both inside and out of the company. This is to say that the plant had a relatively supportive corporate environment in which to pursue QWL.

In the spring of 1980 a young quality control supervisor who had shown interest and initiative was put on special assignment to find out about Japanese management practices and QWL. At the time, Quality Circles were very popular and it was through studying these that the notions of problem-solving groups and statistical process control were introduced to him (see section on SPC for more information here). Popular wisdom in the U.S. at that time was that worker quality circles and SPC should be kept separate. With the help of an outside consultant, the plant developed a steering committee and began setting the groundwork for creating supervisor-worker problem-solving groups. In the summer of 1980 the local union was asked to participate. They declined, saying that they would remain neutral. During the fall of 1980 and winter of 1981 the groundwork for setting up these groups went forward. A large number of line managers and hourly employees were given an introductory session and asked to indicate whether or not they were interested in becoming involved. About 50% of the workers who attended these sessions indicated interest. As these briefing sessions were winding down in the spring of 1981, the local union election campaign was heating up. Candidates in the election were caught off-guard by questions about these proposed problem-solving groups. The leaders of the different union factions jointly approached the plant management to call off the implementation of groups until after the election in the summer. The plant manager negotiated a deal whereby the union leaders promised that whoever won, the shop committee would go on a two-day retreat with management in the fall to discuss QWL in return for halting the creation of problem-solving groups.

Freed up from the implementation of problem-solving groups, the quality supervisor on special assignment turned his full attention to SPC. At this time a small number of other supervisors and managers became interested in SPC. Most of these people continued to be key actors throughout the period studied here. There were a number of projects initiated in 1981 but only one worked through to completion, an analysis of a paint system that led to a 37% increase in yield by late summer.[2]

The union election took place and in July of 1981, seventeen senior managers and nine local union officials, along with corporate and national union facilitators, spent two days away from the plant. At this "off-site" they developed a statement of purpose for QWL, agreed to set up a joint steering committee and to appoint two full-time QWL coordinators, one from management and one from the union. The quality supervisor on special assignment was selected as one of the QWL coordinators.

Through the fall of 1981, the Steering Committee educated itself about QWL and devised policies for how worker problem-solving groups should be implemented. A series of two-day off-sites were run to ensure that all elected union officials and most production managers were introduced to the QWL concepts. A decision was made to set the groundwork for worker groups by first having all managers and union reps in a department go through the same training and type of processes which the hourly groups would get (see Appendix B for more on this). This necessitated resolving old antagonisms in the manufacturing departments. This went forward rather extensively in two manufacturing departments, and to a lesser extent in a third, prior to March of 1982.

The point of documenting this joint union-management effort and the development of cooperation is that it helps to make sense of what happened next. 1980 and 1981 were poor economic times in North America in general and for the auto industry in particular. Mass layoffs of hourly and salaried employees occurred. In February, 1982 notice was given that Plant X would be shut down permanently by the corporation. Rather than fragment and fractionalize, as is often the case in unionized organizations facing crisis, the union agreed to radically alter the local contract in an attempt to make the plant more competitive. Production standards increased an average of 20%. Two hundred and thirty-three prior settlements that had adversely effected efficiency and productivity were eliminated. Nearly 70% of hourly manufacturing employees were assigned one job category. The latter two outcomes were particularly important as they increased the flexibility and adaptability the plant had for utilizing manpower in the implementation of SPC. A huge majority of the workforce voted in favour of the new agreement.

Key informants in the plant at the time, minutes from meetings and recent recollections of other informants all agree that the shut-down announcement had a two-sided effect. For some, it catalyzed them into action. For others, it reduced morale and led to a sense of hopelessness. One of the most demoralizing activities conducted at this time was a systematic 'make-buy' analysis of all Plant X's product lines. As part of a large, integrated corporation, Plant X had been somewhat buffered from competition. At this time an analysis was made of what products Plant X might be able to produce competitively and which it probably could not. Approximately 40% of the plant's product line was considered non-competitive.

With the "historic labour agreement" and the hope of a new life for the plant, the QWL process picked up a good head of steam. By early summer of 1982, hourly groups were operating in one manufacturing department, maintenance and the tool room. The other manufacturing departments were setting the groundwork except for one which had shown little interest.

Through a combination of increased efficiency and discontinuation of certain product lines, the plant improved its performance to approximately 7% non-competitive by July.

Shortly after the 1982 shut-down announcement, various politicians and officials of the state government called on the plant and offered assistance. The plant developed a plan to use state money to train and develop a group of "statistical analysts" who would aid in the implementation of SPC.

Since the summer of 1981, a number of attempts to implement SPC had gone forward. One of the supervisors associated with the previously mentioned successful utilization was put on to statistics full time. In the fall of 1981, a structure for implementing statistics was developed. A plant-wide task force was created with representatives from each functional area. This task force targeted specific projects in each department. Representatives on this committee, in turn, headed up task teams in their respective departments. In addition, a committee of the senior engineering and quality managers was created that met each morning with one department head to review progress on the project in his department and coordinate the use of resources. Documents from this time period reveal that some progress was made in only two departments. Significantly, in both cases task team leaders were freed from other responsibilities to pursue their SPC projects.

With the shut-down announcement in 1982, this structure fell apart in the resulting chaos. By March, attempts to utilize statistics were revived with each department head choosing an SPC team leader and the formation of specific project teams. During April, a number of issues related to SPC surfaced that were to guide later policy. One was that collection of statistical data could accurately pinpoint if someone was doing a poor job, either hourly or supervisory. Concern was expressed that data might be used to punish people. A second was the staffing issue. Were departments going to be given extra resources to be able to effectively utilize SPC techniques and data? Third was a question of the relationship between QWL and SPC. This question arose partly due to the QWL coordinators' heavy involvement in SPC, and partly due to the need for worker involvement in data collection and problem-solving. In general, the key actors understood by this point that implementation of SPC would require as much, if not more, attention to the social system dynamics of change as to the technical problems of data collection and statistical analysis. Apparently, this understanding that SPC would have an effect on the total organization (and was not simply another engineering tool) greatly impressed the state which quickly allocated the funds requested from Plant X's proposal.

Before moving on to describe the activities generated by this grant, it will be useful to briefly describe some other activities and data collected in the fall of 1982.

The corporate organization development (OD) staff was approached in the summer for advice on how to select the statistical analysts. During conversations it became clear that senior management at Plant X did not have a well-integrated vision of where the plant was going. The QWL coordinator invited a few of the consultants from the OD staff to spend time in the plant and see if something could be done. One of the coordinator's hidden agendas was to have a particular consultant with expertise in socio-technical systems theory[3] consult to the plant. The QWL coordinator believed that the goal of the QWL and SPC change process was a socio-technical systems (STS) redesign of the manufacturing process. This view was also held by different staff groups in the larger organization but was not widely known within Plant X.

What happened was that a staff OD consultant (but not the STS expert) visited the plant and had a series of conversations with senior managers. After this, managers were asked to anonymously write down whether or not they wanted help from the OD staff and if so, what kind of help. Responses to this were quite telling. Many referred to poor teamwork at the senior staff level, particularly between the service activities and manufacturing departments. Many cited a need to make their "business teams" more viable.

Business teams had been introduced sometime earlier as a method for achieving better integration among service functions and manufacturing. A business team consisted of the head of a manufacturing department, his direct reports and one representative from each of the service activities. Business teams met daily to coordinate work. Their effectiveness varied greatly. Other than having representatives meet daily, no other change in reporting structures, appraisal processes or reward systems were made to support the business team concept. Department heads from manufacturing and service departments met regularly with the plant manager and production manager in what was called "business team 6". Apparently, these meetings generally consisted of fighting, blaming and finger-pointing between manufacturing and service.[4]

Toward the end of 1982, only one department business team was rumored to be active; the others rarely met and if they did it was mainly an information session--not problem-solving. The atmosphere amongst senior management was not at all good. Firstly, the plant's performance had still not improved much and the spectre of the shut-down hung heavily over people's heads. Senior managers were concerned about where in the corporation their next job assignments would be if the plant were shut down. Secondly, almost all senior management openings in the past year had been filled with people from outside the plant; at least five and perhaps more. Thus they had had little time to develop into a cohesive working group. In fact, the senior staff was, at this time, not meeting as a group.

On the basis of this data the OD consultants offered to work with business team 6 to develop a comprehensive plan for how the business team structure should work and, in the process, facilitate the development of business team 6 into a cohesive, well-functioning group. Apparently, the plant manager did not think much of the consultant and the matter was dropped.

In November of 1982, the Division in which Plant X existed initiated a program of specifying where statistical process controls should be used. This was done by placing a symbol on product drawings. This program was aimed at outside suppliers as well as at plants in the division. At this point it was considered a preliminary program, in order to get feedback on its utility. It helped to serve notice that the corporate offices were serious about SPC and that they would be requiring suppliers to monitor their own outputs in this way as well. The program, however, had virtually no impact in the plant. Two reasons can be offered for this. One was the perception that the location of designated SPC controls on the drawings were arbitrary with little rhyme or reason. The second is that there was no system for ensuring compliance with this directive and no penalties for lack of compliance.

We will now return to the summer of 1982 and follow, in more detail, the events that occurred in Plant X's attempt to implement SPC.

## 2.2 IMPLEMENTATION OF STATISTICAL PROCESS CONTROL, 1982-1984

In the middle of the summer of 1982 the state provided the funds needed to free six supervisors and train them to be statistical analysts (SA). The key players behind securing this funding envisioned the six SAs as a team of change agents who would be competent with both the technical and social system dynamics of the change. From the outset it was decided that the position would be in the same pay category as a first line supervisor. In the selection process, a background in statistics, engineering and/or computers was given heavy weighting as were good interpersonal skills. The selection sequence took about two weeks. Department heads and senior managers spent a number of meetings deciding on how best to structure the SAs into the organization. Should they work as a group or should they be assigned individual areas? Should one be appointed a leader? If assignments were made, who should be assigned where? Apparently, the deciding factor was the desire to implement SPC in all the manufacturing departments as quickly as possible. They decided to assign the SA most familiar with a given department to that department.

Even though they were assigned departments, it was recognized from the beginning that the SAs should report to senior management in order to give SPC a high profile and give the SAs some clout. As well, it was recognized that if SAs reported to department heads, it would be very tempting for department heads to use them as production supervisors when manpower was thin. It was also decided that they would not be assigned to the Quality Control function as the plan was to make SPC a line responsibility. Just who they reported to was, at first, a source of ambiguity for them. Later it was decided that they would report to the production manager (the 'number two man').

For the first month they were trained in SPC. They became zealous advocates. They were out to save the plant. Unleashed upon their respective departments, they ran into the machine bureaucracy. They found it difficult to get the attention of busy managers with multiple tasks who barely understood what they were talking about. They faced an ambiguous task. State funding would last for two years, but then what? A decision was made at senior levels to <u>not</u> make SPC a job element of supervisors. Thus, it appeared that the formal organization was not backing them up.

At the suggestion of the QWL coordinator, they initiated a process for defining their roles. They began with the senior production and engineering managers. It was agreed that their role was <u>not</u> to simply do statistical analysis but to facilitate the adoption of SPC in the line organization. Then they went on to discuss roles with department heads. Here the main mode of facilitation envisioned was training. They were expected to train managers and operators in SPC. After the role negotiations were completed, the production manager asked them to develop a two-year plan for having 100% of the plant using SPC. To comply, they developed a document that time-lined a sequence of training activities.

By mid-October of 1982, morale amongst the SAs was very low. The fact that the office and computer terminals promised them had yet to appear exacerbated the situation. But more important was a deep sense of frustration. Intuitively they knew that the role negotiation process and the two-year plan were just smoke and mirrors. They knew that training alone would not change things, that there were culturally ingrained habits that also had to change. Their boss was holding them to their plans, which reinforced their perception that nobody understood, nobody cared, and that all of this was just more window dressing. They believed themselves to be victims of the very processes they were trying to change. They did not see their boss as holding them to their own plans. What they saw was an unthinking subservience to making "the numbers look right". Their disillusionment was reinforced by corporate requests to report how many SPC charts were being kept on the floor. Around them decisions were being made on gut-hunches and opinions, not data and analysis. Furthermore, they perceived themselves as lowly first line supervisors, in staff positions, with no authority to do anything. Even though they reported to the number two man, they did not perceive this as a power tool. Rather, they feared him and saw him as cold, impersonal, manipulating, uncaring, narrow and intractable. In point of fact, they projected all their negative fantasies about the organization onto this man.

This is an extremely critical point to learn from here. A group of supervisors suddenly found themselves with an ambiguous task reporting to a manager many levels above them. The situation was ripe for projection and distorted authority dynamics. Such dynamics are common and have been widely discussed in the literatures on group dynamics and on organizational change.[5]

This author had the opportunity to observe the marked behavioral change of the SAs when in the same room with their boss. They became silent, almost to the point of being non-responsive. They would apparently listen to what he said, then later they would try to "interpret" what he had meant, each projecting his own particular fears onto the interaction. We will return to this shortly.

Just about the only areas where the SAs felt they were making headway was where the QWL process had progressed to the point of having hourly groups established. These groups of workers were eager and interested in using statistics to better understand their production processes and solve their problems. The groups met regularly with their supervisors, so the time and place for analyzing data already existed. By late 1982 the SAs had begun to appreciate the extent to which implementing SPC would require social system interventions. It was at this point that they began a training program in human relations, group dynamics and organization development. The program consisted of three classroom days each month for six months. At first the SAs were very leery of this "behavioral science crap" and, if this training program had been given to them just as they were hired, they probably would have learned very little. Having found themselves running into walls for five months, they were much more prepared to learn. The fact that, a year later, all of them considered this course the most important and useful one they had taken reinforces the assumption in this study that behavioral dynamics are at the root of the implementation dilemma.

During the first three-day class, the group targeted their poor relationship with their boss as their most critical problem. During the class they devised a plan for co-opting the department heads and using them as a power base to influence the production manager and develop a "realistic" implementation plan. That they did not initiate this strategy for two more months attests to the degree of fear they were experiencing and the amount of courage it took to pull it off.

As 1982 came to an end, the SAs were attempting to have a job description written up with their key job elements. This was clearly motivated by despair that nothing would happen with SPC and that they would be blamed. At least with job elements, each could make sure to do those. The team was fragmenting and each analyst was following his own conscience in respect to how he intervened in his department. This ranged from those still trying to nudge others into using statistics, to those doing all the department's SPC work themselves. A deep sense of lack of support pervaded, and there were numerous events that could be pointed to to justify that feeling.

In January of 1983, the SAs convened a meeting of the heads of manufacturing departments. Here a plan was developed for implementing SPC. To their surprise, the department heads were not angry at lowly staff people convening a meeting. In fact, the meeting went very well and they had a second one to firm up the details. A week later, the SAs convened a meeting with the heads of service departments. During this meeting they developed a similar plan. A week later they brought both groups together to work out the slight differences in the two plans. This meeting went extremely well and was particularly striking as it was rare for service and manufacturing heads to meet without fighting. This group "demanded" a meeting with senior management. At that meeting, a revolt-like atmosphere developed and one of the department heads told the production manager "how it's going to be". The senior managers agreed to the plan. The statistical analysts were euphoric. They had developed a solid power base with the department heads. They now had a "realistic plan" and they now had some credibility for having pulled off this series of meetings. Indeed, soon after, the production manager was to comment that the most impressive thing at the meeting was the air of cooperation between service and manufacturing. After this, the problems between the SAs and their boss rapidly faded as the SAs took initiative in speaking up.[6] In fact, after that the SAs had very little trouble working easily at all levels of the organization. They became seen by senior managers and department heads as resources not only in SPC, but also in the areas of group process and problem-solving.

In February of 1983, sixty-eight people were interviewed by this author and one collaborator. During the interviews, respondents were asked their perceptions about SPC, QWL and about the organization in general.

Hourly employees interviewed were uniformly happy about the changes that had occurred in the plant and optimistic about the use of statistics. They believed that most workers were now more interested in the quality of their work and were taking the attitude that improvement was their job. At this time between 20 and 25 percent of the hourly workforce was directly involved in QWL groups. They felt that they had a great deal more access to management than in the recent past and were listened to more. They saw statistics as a valuable tool in the sense of now having facts to back up their assertions of where the problems were. They perceived first line supervisors as having very difficult jobs and, in most cases, were prepared to support them. They reported some concern on the floor that SPC data would be used against workers, but no actual case of this happening was known. There was some concern that SPC data already collected was not being attended to, but this was seen as a temporary problem.

The first line supervisors were more skeptical. They thought that statistical process control was a good thing and long overdue. However, those who had already done some data collection and isolated problem areas had had no response from their superiors. Most were concerned that SPC would go the way of most 'programs'--lots of fanfare and then fade away. At this point in time, most of the SPC projects in the plant consisted of keeping accurate scrap records and charting results. Thus there was a better understanding of what the major defects were and what problems needed to be addressed. Typically these were problems in engineering and tooling and so these service areas were expected to provide solutions.

Service department supervisors on business teams had more of a wait-and-see attitude toward SPC. Their experience of it to that point was of a shotgun approach with many small projects showing little return. They viewed the major issue as whether senior managers would be willing to choose priority areas and allocate resources and thought that this, in turn, would be effected by the level of support received from divisional and corporate offices. Many felt overwhelmed with their current job responsibilities so that relying on them to solve problems isolated by SPC on top of everything else would not work.

Supervisors in both groups felt a need for much more training in SPC. As well, virtually everyone indicated the following to be trends in the past 18 months:

* increase in ambiguity and chaos experienced
* increase in degree of latitude in how one does one's job
* decreased information from the top
* increased information from the bottom
* a sense of lack of leadership

* people not given credit for the good things they do
* the usual "crisis management" orientation had not changed
* large increase in amount of meetings and attempts at group problem-solving
* a great deal of peer support, but little sense of support from senior management

Interestingly, a number of respondents reminisced favorably about a production manager who had retired a year previously, "At least when X was here, things got done." This was ironic because when X was there, he was hated for being authoritarian and aggressive and used as an example of what had to change. The ambiguity and sense of non-leadership as well as improved relationships on the floor were interpreted by the SAs and QWL coordinator as evidence that a change process truly was under way. The other piece of data collected was that everyone interviewed was pleased with the SAs and most saw the SAs job as facilitators and teachers, not the doers.

A few days after this series of interviews (but not connected to them) the new SPC implementation plan was initiated. This plan was very similar to the ill-fated SPC structure initiated in the fall of 1981. A core group of senior managers was created. According to meeting minutes, their responsibilities were:

1) Select SPC projects based upon recommendations from departmental business teams.
2) Commitment to allocate resources for selected projects.
3) Active participation through involvement on the floor and through attendance at a weekly business team meeting.
4) Restrict "fire-fighting" techniques throughout the organization.

The business teams were to recommend major long-term projects that had to do with reducing scrap or cost or improving quality. Then, based on the approved projects, SPC teams would be created in each department with members chosen by the department heads. The plan called for the SPC team to report their progress on a weekly basis to a joint meeting of the business team and core group. The goal of the SPC team was "to have a process capability ratio at an acceptable level of .75 where applicable".

The major differences between this and the previous plan were that it had been created by the department heads (not imposed from above) and it included training for the SPC team. The plan called for the statistical analysts to provide an 8-hour block of training; first for the core group, then for the SPC teams, and eventually for all managers and engineers in the plant. This had been a somewhat contentious issue as there was some fear on the SAs part that they did not have credibility in the plant, nor the expertise to design and run a training program. There was talk of bringing in outside expertise. The production manager was adamant that the SAs do it alone. This turned out to be a very wise move as the training program was very well received and thus exposed the SAs to the total organization in a very favorable light.

Through the spring and summer of 1983, gains were made in implementing SPC but there were setbacks as well. Some projects showed major gains in yields, reduced scrap and improved quality. Others never quite got off the ground. Projects selected were those products that were hurting the balance sheet the most. Focused data collection aided, in the first instance, in showing managers just how little they really understood about their manufacturing processes. Often, major variances were found in raw materials or other products bought from outside the plant. Thus, pressure was brought to bear on outside suppliers and

SAs were involved in training suppliers in SPC. Some suppliers, however, had contracts with the division which did not specify the percentage of defective parts allowed and so there was little the plant could initially do. Additionally, the SAs tried to get those people responsible for incoming materials to inspect the inflow using statistical methods. For some reason, they had a great deal of difficulty getting cooperation here, and little was done.

By June it was clear that the SPC structure created in February was falling apart. Some projects were progressing well, but little new work was starting up. Additionally, departments were becoming increasingly dependent on the SAs and SPC was not integrating into line management. The SAs suggested that they begin working on projects in small teams (rather than one to a department) so that they could cover more of the change dynamics as well as the technical issues. The production manager agreed to this. This boosted the success rate on projects begun, but once the analysts left, things would slowly settle back to their previous state.

There were two types of follow-through problems, and these have persisted throughout the time period of this study. One was lack of decision-making and a low tolerance for taking risks. This author has been given numerous examples of data that was not analyzed, recommendations that were not acted on and promises that were never delivered. A number of respondents claim that at about this time SPC itself became one more tool for avoiding decisions. When an operating problem arose, action could be postponed by calling for an SPC analysis, and then forgotten.

The second persistent follow-through issue was, when a problem was solved, people would slowly stop gathering statistical data. Eventually, the same problem, or a new one, would occur. An analysis of these two issues will be offered in the next section.

During the spring of 1983, the QWL coordinator looked for consultants in the surrounding areas who could help with the change process. A college that was close by was contracted to provide a number of services. This was paid for by the state grant.

One service was to give the SAs advanced training in statistics and computers. This, apparently, progressed very satisfactorily. A second service was to provide a training program for supervisors on their new roles in the plant. Throughout the auto industry (and other industries) the number of supervisors was being reduced and the nature of their work was changing. Workers were taking on more problem-solving and decision-making tasks through meeting in small groups and using SPC. New plants were being built with semi-autonomous groups of workers responsible for many traditional supervisory jobs. At Plant X, the supervisors' span of control was getting larger through attrition. The plant manager and the QWL coordinator recognized a need to train supervisors in their new, more advisory and facilitative (as opposed to authoritarian) roles. Unfortunately, the training program was not designed around a master plan of what a supervisor's role in Plant X was becoming, as no such plan existed. Thus the training became a general human relations course with no lasting impact. For example, during interviews with supervisors the course was never once mentioned.

The third service sought by the QWL coordinator was help in devising a master plan. Both the QWL and SPC change processes were moving at a good speed, but there was no clear direction for the plant. The QWL coordinator wanted these consultants to facilitate a process which would hook up all the different change activities and result in a rationale plan for re-designing the organization.

What happened is that the consultants interviewed a diagonal slice of the organization and came to the conclusion that the senior management team needed to work together more effectively. From the summer of 1983 through the period studied here, these consultants worked with a small group of senior managers behind closed doors. What went on in that group was not communicated to the plant, except to say that they were working on a new structure for the plant. This had at least two interrelated, significant impacts on the change process. One, it increased the sense of directionlessness of those implementing the changes. Apparently, policy was being formulated, but nothing was communicated about it. Secondly, it excluded everyone directly involved in implementing QWL and SPC from the re-design discussion, including department heads. During the period studied here, no announcement or direction emerged from this group. A number of senior managers, however, commented favorably on its effects on their relationship with the plant manager.

During the summer of 1983, Plant X's success at solving its problems began to get divisional attention. New work came in the door and, partly through the use of SPC, the plant was able to successfully take it on. In addition, the division was requiring all managers to attend special training in total quality management (see section on Introduction to SPC). Apparently, the divisional personnel who offered the training program at Plant X were impressed with the sophistication of the change process there. Plant X volunteered to pilot the Quality Management Program (QMP) and was accepted. A manufacturing department head was put on special assignment as director of QMP (interestingly, this was the department head who had the first successful SPC project in 1981).

Other good things happened. For example, Plant X became the first supplier to be removed from a customer's "quality inspection list" due to consistently high quality. From all reports, management meetings were more productive and less stressful. There was more planning and rationale decision-making. Problems were being solved and staying solved. Department heads were developing good, cooperative work relations. By and large, meetings with the SPC core group were regularly held and this, at least, provided motivation to ensure SPC data was collected and resources were allocated to tackle major projects. Divisional meetings of SPC coordinators began at this time and it quickly beame evident that Plant X was far ahead of her sister plants in implementing SPC. QWL, as well, was at an all-time high. Hourly groups were meeting in every department and a number had come up with some very impressive innovations. During a divisional manager's tour in September, nearly all the presentations were made by hourly employees or first line supervisors and involved QWL and SPC projects. In October the plant reported approximately one million dollars in annual savings from eleven SPC projects.

In the Fall of 1983, a number of things occurred which hampered the change process. It is unfortunate that they happened around the same time, as it is impossible to untangle their various effects. Virtually everyone interviewed, particularly senior managers and department heads, targeted this as the time when "things started going backwards". And just about everyone put the blame on the transfer of the production manager and the management style of the new production manager. We must, however, be cautious of possible scape-goating going on here. Before elaborating on the production manager's actions as they relate to SPC, we will document other changes from this time that may have also contributed to the sense of "going backwards". By "going backwards", people mean more of a crisis, fire-fighting orientation toward managing, less planning, less group problem-solving, greater risk aversion, less candidness, more conflict, particularly between manufacturing and service departments, more authoritarian management style at all levels, and greater pressure to have one's numbers "look right", particularly labour efficiency.

One thing that happened was a sharp increase in the amount of work to be done. Economic prosperity in the U.S. brought back car sales and production demand went up. This, coupled with new products brought into the plant, meant there was more work to do and less time to do it in. As well, the 1984 model year was the first big change since 1982. This aggravated the problems of volume. Furthermore, all this was happening at a time when there was a compressed workforce, less engineering help from divisional offices and less engineering in the plant. The number of engineers had been steadily decreasing through attrition and in the fall two more retired (one very senior). Under such circumstances, it became more difficult to concentrate on only one problem for very long.

Added to this, some poorly-engineered products were foisted on Plant X by divisional offices, even though Plant X didn't want them. Standards were set that couldn't be made, reinforcing the feeling on the floor that management played an arbitrary numbers game. Attempts by the plant to influence the division's standards had little effect.

At this time, the corporation was beginning a massive restructuring and the fate of the division (and divisional managers' careers) was unclear. No doubt this created a number of politically motivated decisions taken at divisional offices that adversely effected Plant X. It is clear that most of her sister plants were also under-tooled, running over capacity, and expected to improve efficiency.

As well during this time period, all but one manufacturing department head was shuffled around. This created new kinds of uncertainty in the manufacturing departments. In addition, people who had been layed off in 1981 were re-hired as more shifts were added to handle the extra production. In the management ranks, these were the people who had been layed off because they were rated ineffective. No doubt many of these returned with a bad taste in their mouth. Amongst the hourly-rated employees, those re-hired were among those who had the poorest work records. In addition, they had never voted for the new union contract and did not necessarily feel committed to the 20% increase in standards. As well, both groups of re-hires had not gone through the "re-birth" experience in the plant after the shut-down announcement (as they had been layed off prior to it). There was no provision made for training these re-hires in either SPC or QWL.

Stacked up together, all of these events have the potential to derail a change process and cause a reversion to fire-fighting management. They pale in people's memories, however, compared to the effect of the new production manager. We will not review here the many anecdotes recounted to this author exemplifying the strained relations between the production manager and just about every other manager in the plant. We will, however, look at some major events which effected the implementation of SPC.

A few months after his arrival, the production manager changed core group meetings to once a month. Then, each month, he would cancel the meeting. He also changed the business teams to "quality meetings" and provided each superintendent with guidelines for what should go on in those meetings. At first he attended the quality meetings, but after a few months stopped attending. Then the quality meetings slowly fizzled out altogether. Once more the business teams died. In January 1984, the core group (which hadn't met in months) was officially disbanded.

As regards the Statistical Analysts, he had two meetings with them, and then started cancelling their meetings. In September he informed them that he planned to disband their group and have each report individually to a manufacturing department head. This move, however, was stopped and the SAs were made to report to the new Director of the Quality Management Program. Thus in a few months, the new production manager had virtually no direct contact with the implementation of SPC. It seems patently obvious that for a change process as significant as implementing SPC, the understanding and support of senior managers is necessary. Thus, there is little to gain from going into specific details about the production manager's behavior and how it differed from his predecessor's behavior. Suffice to say that all data indicates that during the period studied here, the production manager appeared short-term oriented in style and obsessed with having the numbers look right for divisional offices. Being the number two man, this had a major impact on the organization at all levels and on more than just implementing SPC. Again, we must be concerned about the possibilities of scape-goating this man, given all the other changes that took place at Plant X. It is worth noting, however, that Plant X began operating in the black (and significantly better on most indicators than its sister plants) just as he arrived. One year later, in the summer of 1984, Plant X was back in the red and things were looking worse. It appeared that they were getting farther from budget targets and panic was rising. Scrap rates were rising and lots of overtime work was being demanded of managers. Turnover in management ranks was higher than it had been for many years. At all levels of the hierarchy, a sense of impending doom pervaded.

As activities in the plant fragmented, so did the SA team. By the end of 1983 there was some feeling among senior managers that the SAs were not doing as well as they could. This reduced support only served to further undercut their power base in the system. This was mitigated somewhat in the early months of 1984 when the QMP director attended his first divisional SPC meeting and learned how much farther ahead, in terms of having work groups use statistics, Plant X was. This was brought home to others when, a month later, the divisional meeting was held at Plant X.

The climate for change, however, continued to deteriorate. Most respondents agreed that by the spring of 1984, meetings of department heads had regressed to how they had been a few years earlier--little problem-solving, lots of finger-pointing, little planning, little candidness, short-term fix oriented, little use of data to guide decision-making, and a general atmosphere of hostility and fear.

By the summer of 1984, the momentum of SPC implementation seemed lost. For example, in the spring the plant manager sent a letter to every employee stressing the importance of quality and stating that anyone had the right to stop any job that wasn't making the highest quality. During the next few days, the production manager told managers not to take the letter seriously. SAs continued to work individually in departments. There were a number of specific projects that resulted in large dollar savings but less and less line management time was spent using statistics. SAs attempted to intervene where they could but were having no success getting managers to use SPC as a normal way of doing business. A divisional report done in August showed that they had accomplished between 90 and 100 percent of the divisionally-imposed 1984 model year SPC goals; and indeed they had. But to the SAs, these goals were simply window dressing and another example of making the numbers look right.

Over the summer, two of the SAs had themselves reassigned to other jobs. One was replaced. By December, the other had not been. Though the state funding ran out, the SA team continued to exist. But they were very demoralized. In October, the SA's had a discussion with their boss in which they considered disbanding in protest at the lack of action and support. They were told things would happen and to hold tight. As of December, nothing had happened.

There are other events that occurred during the balance of 1984 that will, no doubt, impact Plant X's future implmentation efforts. However, they cast little light on the state of affairs as they existed in 1984. A number of employees at Plant X were interviewed in the summer and fall of 1984 in an attempt to understand how SPC looked from their vantage point. This historical narrative serves, hopefully, as a backdrop against which to understand their perceptions and the analysis arrived at in this study.

Section 2 Footnotes

[1] This is consistent with a large body of literature that notes major shifts in organizational direction often coincide with a change in leadership. See D. Miller and P. Friesen, Organizations: A Quantum View, Englewood Cliffs, N.J.: Prentice-Hall, 1984.

[2] Interestingly, two supervisors and the department head of this area were later transferred to full-time SPC-related positions.

[3] Socio-technical systems theory is a method for designing manufacturing organizations based on "joint optimization" of the social and technical system. For more information see W.A. Pasmore and J.J. Sherwood (Eds.) Sociotechnical Systems: A Sourcebook, La Jolla, CA: University Associates, 1978; and E.L. Trist, The Evolution of Socio-Technical Systems, Toronto: Ontario Quality of Working Life Centre, 1981.

[4] Conflict between service and manufacturing is built right into the structure of factories. See M. Dalton, Men Who Manage, New York: Wiley, 1959; and H. Mintzberg, Structures in Fives, Englewood Cliffs, N.J.: Prentice-Hall, 1983.

[5] For more on this see E. Jaques, The Changing Culture of a Factory, New York: Dryden, 1951; R. Lippitt, J. Watson and B. Westley, The Dynamics of Planned Change, New York: Harcourt, Brace and World, 1958; and P. Slater, Microcosm, New York: Wiley, 1966.

[6] It is fascinating how analogous this sequence of events is to developmental sequences in laboratory groups. "Killing the leader" is a widely-observed phenomenon that seems to lead to greater maturity in the group, a reduction of projective fantasy, and more realistic relations with the group leader. It may well be that when supervisors are put into change agent roles, the majority of them will have to enact a similar type of event if they are to find their own centre of power.

# SECTION 3: AN ANALYSIS OF DILEMMAS IN IMPLEMENTING STATISTICAL PROCESS CONTROL

This section of the report describes various dilemmas and resistances to implementing SPC experienced in Plant X during 1984. The question of leadership and the role of senior management in the change process is briefly touched on. Then dilemmas faced by managers are examined in two sections. The first, Technostructural Issues, explores the ways in which formal arrangements, like structure, reporting systems and rewards, get in the way of managers using SPC. The second section on Political and Cultural Issues looks at dilemmas caused by the web of power relations and factory culture. From here we go on to look at problems at the level of hourly workers and issues associated with the union. The analysis section ends with some reflections on the role of change agents (in this case, statistical analysts) and the problems and opportunities they face.

## 3.1 LEADERSHIP

The lack of leadership from the new number two man is obviously an issue in the Plant X case. It was not just a lack of interest on his part, but actions that were counterproductive to the change effort. Examples of this include disbelieving SPC data given to him; telling supervisors to stay physically present in their work areas (rather than, for example, find a quiet place to work on statistics); creating fear and secrecy in his subordinates; being primarily oriented toward labour efficiency; and so on. I am not sure what more can be usefully said about it.

The plant manager's leadership style was highly delegative. This was very often contrasted with the previous, authoritarian manager. At first, people found this very uncomfortable, but by late 1982 middle managers were beginning to feel secure enough to run their areas as they saw fit. His method of innovating appeared to be to find "champions" to promote the innovation and then support those people.

He had an excellent grasp of what was actually happening at any point in time. In my estimation he had a difficult time, however, dealing with the basic irrationality of organizations. For example, he found it very frustrating when perceptions would persist in the plant even though the facts showed a different story. I suspect that, at times, he allowed this frustration to blind him to what people much lower in the organization were thinking and feeling. I should point out, however, that I have met very few men who, in his position, had as clear a grasp of what was going on at the bottom of their organizations.

The plant manager supported SPC and really wanted it institutionalized. He had, however, many, many tasks to do and could not give it the leadership that might have helped Plant X be farther along. <u>The current literature on organizational culture says that cultural change requires an almost fanatical, daily attention to the message from someone at the top of the organization.</u>[1] <u>This, Plant X did not have</u>. Whether one needs this to implement SPC cannot be answered in this research and if there is something to learn from Plant X it is not in the area of leadership.

## 3.2 TECHNOSTRUCTURAL ISSUES

The case of Plant X highlights a number of things about the formal structure and organization of factories that creates blocks to implementing SPC.

Here we will focus on six broad areas: divisional structure, internal reporting and control systems, functional structure, reward systems, centralization and decision-making, and volume manufacturing.

A) Divisional Structure

Plant X, like most present-day factories, is only one of a number of plants in a division. The ways divisions operate vary between corporations, ranging from those that simply set operating goals to those that have a great deal of say over operations themselves. Plant X's division is probably more toward the latter end of the continuum.

The division avowedly supported the implementation of SPC and demonstrated this commitment through calling for controls on product drawings, networking SPC coordinators from different plants, and responding favorably to plant requests for changes in standards or products that were supported by SPC documentation. By 1984, senior managers at Plant X were convinced of the division's seriousness in this matter.

At the same time, there were operating decisions made at a divisional level that had negative impacts on the implementation effort. These include sending poorly-designed work to Plant X for production and increasingly tight manpower allowances. Indeed, this latter push to squeeze more cost out of products through improving labour efficiency, mandated by the division, appears to have been the number one source of strain on the implementation effort. Its effects will reappear throughout this analysis.

To be able to generalize from the Plant X case, however, we cannot focus on specific operating decisions. We have to look at the nature of plant-divisional relations. Three aspects of this relationship appeared to give Plant X problems and are worth noting as possible, general issues. These are purchasing, engineering and product design, and budgeting.

When Plant X began analyzing variances in production processes, one of the first areas where they consistently found problems was in the raw materials or purchased parts from outside vendors. Plant X found, for example, that specific steel hardness had dramatic effects on yields. While it is true that outside vendors were contributing to variances in production, it is also true that it is politically and socially easier, when first using SPC data, to point fingers at those outside the organization. This may be a general principle of implementing SPC: initial analyses and action plans will tend to focus on problems created by vendors/suppliers outside the organization. Therefore, implementation will require integrating the purchasing function into the SPC learning loop.

The problem in Plant X's case was that a lot of purchasing decisions were made at a divisional level, outside of Plant X's control. Integrating the purchasing function into the implementation effort was stymied by the distances, reporting relations and coordination problems. Many vendors were willing to try and satisfy Plant X's needs. Others were not, and in some cases they were protected by contracts developed at divisional offices. In such cases, not only was Plant X unable to influence the problem, but frustration over having done the SPC work and nothing coming of it hindered the implementation effort.

Most divisional structures centralize purchasing in order to take advantage of volume buying. This will be a problem for individual factories implementing SPC. Getting and keeping production processes under control require eliminating input variances. To do this, the purchasing function plays a critical role. But the divisional purchasing function is, in some ways, another input variance outside of the plant's control.

A second, general issues has to do with product engineering. Products and production processes at Plant X were designed at the divisional level. Major changes in products or tools required divisional support. By and large, this was not a problem. For example, a process capability study showed that a particular process was not able to consistently manufacture a part at a certain width, but could do so if the width tolerance was slightly enlarged. Apparently this change made little difference overall and was quickly approved by the division. For the plant it meant a sharp reduction in scrap and huge increase in yield.

Where problems may arise is where SPC data uncover a serious, costly mistake. For example, one study at Plant X uncovered that tools recently bought by the division were not capable of doing the job they were supposed to. Based on a total cost of quality analysis, a statistical team recommended constructing new tools and showed a payback period of 5 months and an annual savings of a quarter of a million dollars. What exactly happened with this recommendation is unclear, but it took nine months from the time the recommendation was given to senior management at Plant X to the time the new tools arrived. Obviously, it takes a few months to build and ship tools, but not nine. It has been speculated by those interviewed at Plant X that recommendations of this nature can be political bomb shells and that senior managers within Plant X spent a lot of time making sure their ducks were lined up before sending the recommendations up. It have no idea what happened at the divisional level.

To fully appreciate the magnitude of this issue, consider the possibility of a group of hourly employees using SPC and uncovering a costly design flaw made by a highly-educated, highly-paid, hierarchically-distant, engineering staff. Without going into the political and cultural implications of this, consider simply the structural issue: those who use SPC to analyze and solve problems (workers/supervisors) are different from those who are responsible for the problem (engineering). This is somewhat true within the plant, but things can be done to alleviate this. When those responsible for fixing the problem are at a divisional level, it is unclear what the plant can do.

Structurally, the issue here is a separation between learners and doers. If I design something, then use SPC to analyze its flaws and redesign it, I have improved on my work. However, if I design something and then you use SPC to uncover its flaws, I am in the position of either defending my original design or admitting failure. This separation between doers and learners builds the potential for conflict right into relations between the plant and the division.

Obviously, this need not be the case. SPC, through its objective, quantitative nature, can work toward reducing plant-division conflict and increase rational decision-making. Whether or not it is conflict-producing depends a lot on political and cultural aspects of the situation. For example, a culture that tends to punish mistakes will lead to very different dynamics than one where learning from mistakes is encouraged. We will focus on political-cultural issues in the next section. The point here is that the structural separation of a divisional engineering staff from a factory implementing SPC has the potential to create large obstacles to the change effort.

The final generalization about divisional structure has to do with the nature of budgets and reporting systems. The dominant North American method for controlling operating units from a central office is through developing a budget and reporting deviations from that budget. From a central office perspective, this makes a great deal of sense. It simplifies planning and decision-making over a range of units. It allows for comparisons between units doing different work. It provides a certain continuity and allows one to observe trends.

The problem is that this method encourages managers in the units to concentrate solely on meeting budget targets and sometimes in the process they lose sight of the bottom line. In Plant X's case, by 1984 they were having little difficulty staying within the budgeted amount for scrap. They were, however, feeling pinched on labour. Thus the production manager, whose primary concern was clearly making budget, focused all efforts on reducing manpower. In some cases this resulted in decisions which had the visible effect of increasing the amount of defects or scrap generated in a production run. This was even done in areas where the cost of materials was far higher than the cost of labour in the finished product. The consequences of such "mixed signals" for retarding the implementation of SPC were, in my opinion, far-reaching.

Without going into all the ramifications in this sub-section, let us simply note that this "deviation-from-budget" control system can severely reduce a plant's motivation to exploit opportunities for greatest profitability. It focuses senior management attention on separate variables that go into a profitable business, but not their interrelations. When plant management is evaluated by the division, it is through a line-by-line examination of deviations from budget. This fosters a concern with making the numbers 'look right' on each line and, in extreme cases, can lead to a disregard of innovations or opportunities that will not show up in the 'right' numbers.

This is a very tricky problem. Holding plant managers simply to the objective of being profitable or achieving a certain return on investment would appear to free them to exploit opportunities. The problem is that a manager might very well make large profits by sucking the plant dry and get promoted before the effects catch up. Such actions were rumoured to have occurred in the corporation. Using a large number of separate measures to evaluate performance helps to reduce the possibility of this happening, but it reduces the initiative of those closest to the work itself to finding innovative ways of being more efficient or improving profits. In the particular case of SPC, it can work directly against the kind of multi-variable thinking embodied in SPC and the Quality Management Program because it decreases management's motivation to reduce costs far below the budget in one column if it means being a little over budget in another column.

B) Internal Reporting and Control System

During interviews with managers in Plant X, it became very clear that their behavior was motivated, in large measure, by the information their boss requested at the end of the day. This could be seen operating at all levels of the organization. The barriers to implementing SPC built into conventional factory reporting systems include (1) the heavy emphasis placed on labour efficiency to the exclusion of such things as material efficiency, and (2) the utility of producing scrap to offset low labour efficiency.

The heavy emphasis on labour efficiency is a legacy of the "scientific management" of Taylor and Ford. Factories were and are built on the notion that cheap labour can be added to, or subtracted from, production processes as demand fluctuates. Thus the primary discretionary cost for manufacturing managers is labour.

This makes sense if you have production processes capable of making a part to specifications first time, every time. In North American factories this is generally far from the case. Yet internal reporting and control systems continue to collect information primarily on labour efficiency (to the exclusion of other data) from first line supervisors. As well, at Plant X, meetings between the department heads and the production manager tended to focus on labour efficiency and shipping schedules. One respondent told of a half-hour meeting concerning $40,000 lost in labour in an area that was scrapping over $50,000 in materials in the same time period. Yet the material utilization problem was not brought up.

Supervisors perceived that labour efficiency was the main priority in the plant. SPC, at least initially, would detract from this because labour would have to be 'wasted' training employees in SPC, meeting to analyze the data, and so on. Adding to this was the fact that the budget for scrap allows a department to subtract a certain amount of direct labour from production for defects produced. I was told stories of managers at various levels falsifying scrap reports so that the numbers would "look right". This is common practice in American manufacturing. Since SPC tends to aid, in the first instance, by increasing yields and reducing scrap, there was little incentive for supervisors to start up an SPC project knowing that, in the short run, labour efficiency would suffer. The same was probably true for department heads.

The Quality Management Program, piloted since 1983 at Plant X, was explicitly intended to move decision-making away from simply a direct labour viewpoint and to include all the costs of not doing it right the first time. However, this required special data collection efforts on a project by project basis as the necessary information was not routinely collected in a useable form. The director envisioned eventually developing a computerized information system that would provide all levels of management with real-time data on all production processes, analyze preventative costs, appraisal costs and failure costs, and allow one to evaluate various alternatives in a spreadsheet manner.

It is not clear to me why, by the end of 1984, Plant X was still using a rather antiquated information system. Key managers within the plant recognized the need for a new information system. It may have had something to do with divisional reporting systems and the problem of a plant influencing divisional practices. It may have had something to do with the production manager's apparent disinterest with QMP. It was very clear, however, that the information system was a major barrier to voluntary acceptance and use of SPC in manufacturing departments.

One senior manager pointed out that supervisors could provide the same information as they currently were, using two statistics and these would contain even more information. These would be (in the language of SPC) an $\bar{X}$ and R Chart for downtime and a P Chart for yield. Such a system certainly couldn't hurt the implementation effort. The problem with this, he pointed out, was that it would take translation time to figure out dollars earned. As he put it, "Crisis management requires knowing your pennies every day". While information systems are a technostructural issue, the Plant X case highlights the political and cultural issues associated with changing these and we will return to this in the next sub-section.

C) Functional Structure

Factories are generally structured through grouping people by function, and Plant X was no exception. The problems of functional grouping have been well studied and revolve primarily around the tendency for people to give priority to their function's goals, even when this is detrimental to the organization as a whole. Combined with a short-term orientation, this can lead to extreme inefficiencies. An example typical of many factories is where a tool department's manager will look good by building a tool at a lower than average cost, even though it then costs the maintenance department major amounts to keep repairing it. The arguments for functional structures are that they allow for economies of scale and they encourage functional specialization and expertise.

One of the negative features of functional grouping is that it encourages managers to assign blame for problems to other functions. Manufacturing has a problem meeting schedule. It blames maintenance for not maintaining tools. Maintenance blames the tool department for poor tools. The tool department blames engineering for poor tool design. And it goes on. The development of business teams in each manufacturing department at Plant X was intended to reduce this game of "blame-go-round" and create a sense of teamwork. Where effective leadership was provided, the amount of blame-go-round was reduced, but a more insidious game of "whose-problem-is-it?" would take its place. Meeting as a group, representatives of various functions would have to decide which function should be responsible for solving the problem. These discussions were generally held with little data and decisions were made on the basis of opinions and intuition. It was hoped that the implementation of SPC would eliminate this by providing accurate data on just what the problems were and, indeed, SPC does. But the implementation of SPC moves against the historic, structural separation of manufacturing and service departments and the culturally ingrained habits this has fostered. For example, SPC and the quality management process take a holistic approach to any particular product. QMP is an attempt to understand all the variables involved in making that product, integrating all the information and resources needed to make it first time, every time, and then monitoring those variables to keep them within control limits. Functional grouping, on the other hand, is fragmenting. It erects boundaries between different pieces of information and resources that go into the final product. It increases the variability that has to be contended with because of the varying goals of different functions.

Furthermore, functional grouping tends to detract from a focus on the quality of the product. All service functions are involved with all the products in a plant and so feel no particular identification with any one. Grouping by product, that is, having experts from different functions grouped together by the product produced and reporting to one person responsible for that product, is much more likely to foster a focus on product quality. This, however, is less efficient as it generally requires more personnel. Given that low cost is the main raison d'etre for mass production, factories generally are structured functionally. This, however, creates problems for implementing SPC and creating an integrated focus on quality.

Finally, the functional structure created within Plant X the same dynamic as was going on between the plant and the division; namely it separated learners and fixers into different groups. Initial SPC analysis generally uncovers problems with tools, materials and other service department responsibilities. Since the data is collected by manufacturing personnel, the temptation is there for service departments to get defensive. I was told numerous stories at Plant X of service supervisors and engineers refusing to believe SPC data. In addition, continuous statistical monitoring shows whether repairs actually did fix the problem. For example, one operator showed that the tool department was not repairing his machine correctly. Thus, use of continuous SPC will, in effect, allow manufacturing to measure the quality of service it receives. So conflicts built into functional structures and the separation of service from manufacturing are exacerbated by initial attempts to implement SPC. It is much easier to be a member of a group that solves its own problems as in the case of a multi-functional group responsible for a particular product. It is much more difficult to aid in the implementation of something that is going to help another group analyze and measure the competence of one's own group.

D) Reward Systems

A lot of effort was put out by key players at Plant X to ensure that people who used SPC successfully received recognition for it. Mainly this was through allowing them to make presentations to visiting corporate managers. All respondents gave the statistical analysts high marks for ensuring the credit was given where due.

Personal recognition, however, is a management-intensive, energy-consuming way of rewarding people. One of the most elementary rules of organization (constantly violated by large North American firms) is that you reward desired behavior. If we examine the kinds of behaviors needed to institutionalize SPC, we find few instances of them being rewarded. For example, we want supervisors to collect statistical data. However, at Plant X, the use of SPC was not an element of a supervisor's appraisal. The argument was that by using SPC, a supervisor would improve in those areas in which he was appraised. Few supervisors were impressed with this argument, however, especially in light of the certain reduction in short-term labour efficiency for uncertain future gain.

Implementation of SPC requires cooperation amongst functional managers of the very highest levels of the organization. But rewards are given to them for attaining separate, sometimes contradictory, functional goals. In fact, implementation of SPC requires cooperation between different groups (e.g., labour and management) that conventionally are at odds in manufacturing organizations. And the North American pyramidal organization, based around the promise of upward promotion, fosters competitive relations between managers who desire promotion.

The production of a low-cost, quality product is a group effort. Implementing and using SPC is a group effort. Reward systems that focus on individuals, not groups, are an impediment to implementing SPC. But, of course, reward systems of this kind are organization-wide and not within the control of Plant X. Indeed, rewarding individual effort is so entrenched in North American culture that it may be beyond the means of any one firm to change it.

E) Centralization and Decision-Making

Machine bureaucracies tend to be highly centralized structures. Plant X had been working on decentralizing since at least 1980. Strong cultural and political forces make decentralization a difficult process in such structures. Here we will simply focus on the technostructural issues.

In conventional North American factories, products and work processes are designed by staff groups of engineers with no input from operators and supervisors. Implementation of SPC changes that. It requires, in the first place, that previously ignored groups be encouraged to analyze their work processes, recommend changes and, where possible, solve their own problems. This, at least initially, places supervisors in an interesting, conceptual bind as any manufacturing supervisor can quickly show you half a dozen chronic production problems for which he has been begging for engineering help to no avail. A common reason supervisors initially resist involvement in worker problem-solving groups is that they fear embarrassment from not being able to deliver remedies to problems these groups will surely surface.

Where efforts to implement worker participation are serious (like at Plant X) the high visibility of initial groups leads to senior management intervention to ensure their problems are solved. Astute supervisors (and operators) quickly realize that these groups offer a way to get management's attention and the number of groups expands. As they expand, the number of requests for senior management to provide information, make decisions and/or take action also grows, increasing the amount of complexity senior management experiences. As complexity reduction is one of the primary motivations of senior management of any organization, a point comes when senior managers begin to distance themselves from the groups. Typically, this takes the form of insisting that middle managers solve their own problems and that the purpose of operator groups is to solve their own problems. This appears to have happened at Plant X by late 1982, early 1983. For example, during this period the original QWL steering committee faded out of existence. It wasn't until April of 1983 that a new steering committee, called the QWL Support Team, was formed and, not surprisingly, they considered their primary task to be facilitating worker groups getting responses to requests. Significantly, no line manager at the department head level or higher was on this team.

One can readily appreciate senior management's desire for subordinates to solve their own problems. Controlling variance at source, an ultimate aim of SPC, requires it. The problem was that no change in formal resource allocation procedures was made to facilitate this transition. Thus, supervisors were back to the same problem of trying to negotiate scarce resources, primarily aid from service departments, to solve their problems. The difference was that now the problems were being publicly aired in worker groups and, where SPC was used, the data was publicly available. Here then we have a classic case of lower level managers being given responsibility for tasks without being given the necessary resources or authority to effectively execute that responsibility. To compound this, senior management developed the perception that middle managers were weak, incompetent and afraid to make decisions and take action. I have observed this phenomenon in other plants implementing worker participation and so have others.[2/]

At Plant X, supervisors experienced a great deal of latitude in how they accomplished their tasks and felt there was little risk in trying to innovate. Where problems required major service department activity or capital expenditure, however, resource allocation systems forced them to push the problem upwards. Attrition in service department personnel made it even more difficult than it had previously been to get help. Yet at all levels of management, people were more often being held responsible for fixing their own problems. The net result of this was a disincentive for supervisors to use SPC, as it would make their problems visible. Then they could expect pressure to fix those problems without the necessary resources. Far better, said some, to keep one's problems to oneself and quietly work away at solving them.

The problem of allocating scarce resources to respond to SPC data was explicitly recognized when SPC was first being implemented at Plant X. This is why a core group of senior managers was formed. With the fading out of this core group, no formal device existed at Plant X for deciding which problems would get sustained attention. After September of 1983, major SPC-related innovations occurred only where service department aid or operator time off work were not needed.

Resource allocation prerogatives are at the heart of the centralization issue. The decentralization needed to institutionalize SPC requires that decision-making authority over use of resources be pushed down to lower levels. This includes authority at the divisional level being pushed down to the plant level, particularly in the areas of staffing and tooling.

In order to make cogent decisions about resource allocation, more information needs to be available to lower levels of management and information systems have to be more useable. Along with centralization of decision-making often goes secrecy. For example, at Plant X middle managers did not know exactly what the plant's budget was or how, as a whole, the plant was doing in meeting budget goals. Secrecy is a useful device for maintaining centralized control. Why this kind of secrecy still existed at Plant X was unclear to me.

In addition, reporting systems at Plant X gave middle managers little useful information for analyzing their problems. Other than amount of man hours in productive labour and number of shippable parts produced, information was either non-existent or inaccurate. For example, the amount of scrap was generally guesstimated by the supervisor poking around in a scrap bin and, unless SPC was being used, no record of what the defects were was kept. Information like energy usage, or the cost of idle inventory was non-existent. If the point of work innovations like SPC is to have every area run as if it was the supervisor's own little business, supervisors are going to need better information about their business as normal procedure (not as a special effort) and the authority to deploy resources to optimize effective manufacturing. To do this it may come to the point where supervisors are given their own budgets to "buy" manpower, materials and service, and "sell" their production to other areas in the plant that use it.

300

F) Volume Manufacturing

Most manufacturing requires volume to make a profit or keep costs competitive. When Plant X first began implementing SPC, car sales were low, a lot of capacity was idle and managers had time to experiment and give sustained thought to one problem. By 1984 the resurgence of car sales and Plant X's success in improving performance led to a situation where it could hardly keep up with demand. Almost everyone in the plant was consistently working overtime and a critical management concern was meeting delivery dates. Because of this, one manufacturing department had to cancel group meetings because it could not afford to lose the production. Operators and supervisors working ten-hour shifts were not keen to meet after work either.

There is a fundamental paradox here. Implementation of SPC calls for analysis and reflection; volume manufacturing calls for execution and doing. In the long run they may be complementary, but at first they are antagonistic. Supervisors could not find the time in the day to collect statistical data nor could they afford the time to meet with operators to analyze problems. Such an act would have to be approved by a department head willing to lose production. Not likely, unless the production manager was willing to risk not meeting schedule. He, in turn, would have to feel confident that divisional managers would understand and approve and that customers would not search for other suppliers.

The irony is that much of the frantic pace at Plant X was due to processes being out of control. An area, for example, would have to make 9,000 pieces in order to be able to ship 6,000 that met specifications. And the inefficiencies of 3,000 scrapped pieces in material utilization, machine wear, wasted manpower, energy, and so on, were simply costs of doing business. Everyone recognized the irony of the situation but no one had a good idea for how to get out of it.

One other aspect of volume manufacturing that creates problems and should be mentioned is shifts. Two and three shift operations typically experience problems with inter-shift cooperation. Plant X experienced some problems with coordinating data collection efforts across shifts. This was especially true when the project was initiated by a supervisor or worker group and was not a departmental project. The problems of inter-shift coordination are endemic to manufacturing, however, and did not appear, in Plant X's case, to have anything specific to do with SPC.

Summary

Built into the very structure of American manufacturing organization are barriers to implementing SPC. Plant X is not an exception; it simply exemplifies common manufacturing practice. If anything, Plant X has less built-in resistance than we would expect from factories because of its attempts to develop worker participation and business teams prior to implementing SPC.

A structural analysis shows that problems at every level of the organization are, in great measure, reflections of the larger organization. Many of the technostructural impediments at Plant X can only be fully solved by changes at the divisional level. One can only surmise that divisional changes, in turn, would require changes at the corporate level.

The paradox for managers is that required changes at higher organizational levels generally require a readiness at lower levels that must also be managed. For example, pushing decision-making authority downward requires that subordinates be willing and able to make the decisions. Without this, delegation often leads to a vacuum of decision-making. The process of structural change in large, complex organizations requires a sort of incremental, see-sawing kind of rhythm.[3] A little change at the top and the effects trickle down and accumulate until more change is needed at the top, and so on. The art is in knowing how big a step to take and when to take it. Senior managers at Plant X were like explorers in an uncharted and dangerous land. When to take a step forward and when to hold back and watch? Which direction to step in? How to manage the paradox that people won't act independently until they are set free, but can't be set free until they are ready to act independently? Implementation of SPC on the manufacturing floor was an uphill climb against decades of centralized control requiring fundamental changes within the plant and within the larger organization.

By the summer of 1984, the next technostructural intervention for Plant X, in this researcher's opinion, lay in the reporting and information systems at the supervisory level and above. A system needed to be worked out that more accurately reflected the true costs of doing business in any one area and that area's real contribution to producing a quality, money-making item. As it was, reporting systems emphasized labour efficiency and did not accurately reflect the interdependencies between different departments. Further, they provided little information that was useful for planning and decision-making at the operating level. As people expect to be rewarded for those things on which they are measured, reporting systems imply what desired behaviors are, and focus attention toward some things and away from other things.[4] The political-cultural implications of this will be taken up in the next section.

Another major impediment to SPC built into the structure of factories is the separation of manufacturing and service departments and the consequent separation between those using SPC to analyze processes and those responsible for creating (and consequently fixing) those processes. Even the business team structure at Plant X could not stop the understandable tendency of service personnel being defensive about data collected by manufacturing personnel. Political-cultural aspects of this will also be explored in the next section.

Finally, the paradox of action and reflection. SPC is, initially, a learning process. Learning and performance tend to be negatively related; one's performance is low while one is learning. As learning is completed, performance improves. Factories are structured to perform, to produce. They are generally poor at learning and this is built right into the fragmented structure, rigid chain of command and need for volume production.[5] When demand is high and the plant is running at capacity, it is very difficult to find the time for the sustained thought and reflection required for learning. Worker problem-solving groups, at least initially, provided the structure for learning as did the core group and SPC teams. But by 1984, production demand was taking its toll on these learning oriented structures. Building some balance between learning and producing into the structure of factories may be the most difficult task institutionalization of SPC faces.

### 3.3 POLITICAL-CULTURAL ISSUES

Though easy to distinguish conceptually, politics and culture often overlap in practice. In this section we will look at the problems created by ingrained habits (culture) and threats to the status quo (politics) which impede the implementation of SPC, particularly those that pertain to supervisors and managers.

A lot of the cultural and political norms commonly found in factories can be traced to the underlying logic of machine bureaucracy organization.[6] Factory organization is based on the idea that production is most efficient if tasks are broken down into small steps and each operator performs one of the steps. This allows for the use of low skilled labour with little needed training. Operators can be slotted in and out of work processes as needed. Thus a major design norm is to make jobs as "idiot proof" as possible, ensuring that jobs are designed for idiots.

The work process is designed by staff engineers and it is the work process that, more or less, directs and controls worker behavior. In mass production manufacturing, supervisors tend to do little more than directly supervise workers, ensuring their compliance and the execution of boring, monotonous jobs. With the advent of unions, supervisors were left with very little they could use to motivate workers, except threat of punishment.

The logic of organization is based around the manufacturing process and is modelled on the rationality of machines, thus the term "machine bureaucracy". The factory is like one big machine, transforming raw materials into finished products. The large amounts of interdependence between discrete operations means that if one little area ceases production, many other areas are adversely effected. When something does break down, it is imperative to fix it as quickly as possible. This leads to the commonly referred to "crisis management" or "fire-fighting" orientation found in factories. Much of management's time is spent trying to quickly respond to breakdowns in work processes of one sort of another. Those who do well in such organizations are those who are able to quickly grasp a situation, firmly take charge, and fix it fast. Therefore, seat-of-the-pants thinking and a "hard charging" management style tends to be institutionalized through rewards and promotions. In addition, the need for quick decisions and quick action make it impossible to decide things democratically. Crises require autocratic leadership and this, in turn, fosters a high value placed on subordinate obedience and strong, centralized control.

The prime value is to always maintain a smooth, uninterrupted flow of production so organizations traditionally attempt to buffer their operating cores from uncertainty.[7] Manufacturing organizations, because they are like machines, have low flexibility and because they are buffered from uncertainty, develop a low tolerance for ambiguity. Certainty, stability, continuity are core values one expects to find in factories. This control "culture" is further reinforced by the amount of conflict structurally built into factories. Workers treated like idiots doing boring, monotonous work are watched over by supervisors held responsible for processes they didn't design in an environment of daily crisis and authoritarian management. Threat and punishment are the primary means of ensuring compliance that the system provides.

Obviously, individual factories will vary. It is against this backdrop of a generalized factory political and cultural system, however, that dilemmas of implementing SPC must be understood. Through anecdotes, interviews, documents and reflections, many different barriers were encountered. For the sake of simplicity and coherence, I have organized them into the following five themes.

A) Implementing SPC requires major changes in power relations.

At Plant X, as in most organizations, decisions are made by those with positional authority. A typical "problem-solving" meeting involves subordinates tossing out ideas and their superior making a choice. Problem-solving meetings, however, are not that common. Their occurrence at Plant X waxed and waned. Most common are meetings where performance is reviewed and demands for better performance are made. While what happens in a meeting has a lot to do with who is running it, it is not uncommon to observe a room full of adults with very few people other than the boss speaking. The principle that "what the boss says goes" is a strong norm in Plant X and in factories in general.

One aspect of power relations and problem-solving is in who defines the problem. The way a problem is defined has major implications for subsequent actions. In the past where there was ambiguity, those with authority defined the problem. SPC changes that because, when used, those with the data now define the problem. Typically, those with the data about manufacturing operations are those at the bottom of the hierarchy. So use of SPC turns power relations upside down when it comes to problem definition.

The other way in which problems are defined is through functional expertise. In this case, experts often define the solution as well. Again, SPC will change that because the data now defines what the problem is and whether or not it has been solved. So, for example, at Plant X an operator was able to show that an engineering solution to a problem had not solved the problem and had to be redone. This is a major reversal of roles and power relations.

A number of people interviewed complained specifically about the attitude of engineers toward SPC. There was some feeling that engineers were more concerned with questioning the data and the data collection method than with dealing with what the data showed. This seemed particularly true when a process capability study would show that a process was incapable of making the standards set for it. A related issue was that the credibility of the data was often tied to the credibility of the person providing the data. There were instances of people being told to collect data on the same problem two or three times because they were not believed the first time. A related dilemma for department heads was in who to believe; a supervisor with data saying one thing or an engineer saying another?

It may be important to note that engineering was not very involved with planning the implementation of SPC at Plant X. Given that SPC is likely to uncover problems with the engineering and design of work processes, as well as threaten the power of their expertise, it may be important to include engineering much more from the outset. One of the problems at Plant X, however, was that the engineering function was understaffed and it would have been difficult to involve them in more change-agent type roles.

The payoff from SPC comes not solely from analyzing problems, but from controlling processes. This requires that variances be controlled as close to the source of variance as possible. This requires giving discretion to those controlling variances. This, in turn, means decentralizing decision-making and delegating responsibility and providing authority to deploy resources as necessary. Plant X's experience with this was discussed in the previous sub-section. Problems encountered here included giving people lower down in the organization added responsibilities without the necessary authority or changes in resource allocation procedures to allow for effective execution of those responsibilities. In such a situation, it becomes politically unwise to publicize one's problems through using SPC. A related issue is the degree of secrecy found in factories and the lack of useful information available to supervisors and workers. All of these impede the necessary transfer of power over daily operating decisions.

One political issue about this change not discussed in the previous section is the implications for managerial careers. As decision-making gets pushed downward, some layers of management become obsolete. Obviously, this is threatening to some managers. Attrition in management ranks had taken care of most of this concern at Plant X, but a secondary issue arose of less opportunities for promotion. Organizations in North America are in a process of removing levels of hierarchy. How to deal with the aspirations of young, lower level managers in a promotion, climb-the-ladder oriented culture is going to be a difficult problem. It was becoming one at Plant X.

Another way in which implementation of SPC changes power relations is by making coordinating mechanisms obsolete. Worker behavior and the coordination of tasks is controlled through standardization of work processes and direct supervision. Implementation of SPC encourages operators to mess around with work processes and effective supervision requires being more facilitative and consultative. Rather than work processes controlling operators, SPC makes operators control work processes. New control and coordination mechanisms will be needed that foster operator commitment and responsible action. This will be taken up in more detail in Section 3.4.

B) Implementing SPC requires creating uncertainty in order to reduce uncertainty

Theoretically, SPC should fit nicely into the culture of control found in factories and add to the stability and predictability of work flows. Once in place, this may very well be the case, but the process of implementation is a different story. As with any major change, SPC creates a great deal of uncertainty. For example, implementing SPC on any one process in a way that will institutionalize operators controlling variance opens up the system to involvement from workers. This was less of a cultural shock in Plant X (due to the QWL intervention) than one might expect in conventional factories.

The involvement of new players in decision processes is only one type of uncertainty. Another comes from the data itself. What will it show? It may reveal past bad decisions, such as in choices about materials or tool design. It may show that supervisors or workers are not doing their jobs. Apparently, there was one case of this at Plant X and it created a quandary for the SAs. If a supervisor were disciplined because SPC data showed that he wasn't doing his job, it would probably increase the resistance of other supervisors to using it. What should they do in such a situation?

SPC is also likely to show that some past decisions and actions were faulty. This is almost sure to happen as these decisions and actions were taken without the high quality data that SPC provides. Therefore, it takes a great deal of courage for plant management to risk finding out what the data will show.

Not surprisingly, a particular concern for managers lower down in the hierarchy was what if the data one collects shows one's superior in a bad light? Organizations with strong chain of command, authority cultures (like machine bureaucracies) tend to have strong norms about loyalty to superiors and strong penalties for "treason". At Plant X there were a couple of well-known stories about subordinates who apparently did not cover for their superiors and were later subtly punished. It matters not if the stories are true, it only matters if people believe them. At Plant X some people believed them. Key players at Plant X were very concerned that people not be punished for what initial SPC data showed. Their concern appeared to be paying off as very few interviewees evidenced any fear of the data itself.

Still the whole implementation effort was fraught with uncertainty. How do you do SPC? What's it going to show? Will operators collect accurate data? What is going to be supervision's job if operators are controlling variance? These are just a sampling of the questions. Yet the major way SPC was being "sold" was by telling supervisors it would make their work more predictable and controllable and hence, easier. The paradox, then, is that implementing SPC requires creating uncertainty to reduce uncertainty.

C) Implementing SPC is hampered by manufacturing's short-term orientation.

North American business in general has been severely criticized in recent years for its short-term orientation. This is built into the system of quarterly reports to stockholders and the short amount of time 'fast trackers' normally stay in one job. This is compounded in manufacturing by the daily crisis management that evolves in response to the need to maintain uninterrupted production.

At Plant X, there was a strong "short-term fix" orientation to problems that hampered the SPC effort. Interestingly, this was identified by several respondents as a problem, indicating at least awareness about a cultural barrier to SPC. One hopes that this indicates that it was in the process of changing. Nevertheless, many aspects of this orientation created dilemmas. For example, one strong norm was that things didn't get 'fixed' unless they were broken. Partially this was due to a lack of slack resources and partially it was due to a cultural norm. This, of course, works against SPC because the point of controlling processes is to prevent breakdowns in production. At Plant X, however, one could not get service department resources unless one was severely threatening production.

Another spin-off of the short term, day-to-day orientation at Plant X was a lack of follow-through in problem-solving and decision-making. Apparently it was expected by most people that the majority of commitments made at a meeting would not be followed up on. In late 1983 the SAs distributed an article on ways groups avoid making decisions called "Eight Running Games". To this they added a ninth, as follows:

> "I'll take that", is very similar to the children's game "hot potato". Eager staff and executive types are quick to play this game, as it shows the player's special interest in solving problems. Played in any size group, whoever answered "I'll take that" with the most reassuring tone of voice was considered a superb game player--but to keep the game "running" the player must drop the problem like a hot potato so another can loudly say "I'll take that".

Lack of follow-through was considered the most critical barrier to SPC implementation by the SAs, and the most frustrating. Numerous stories were recounted to this author of data collected but never used, of solutions to problems working in one area but not diffused to other similar areas, of materials or resources promised but not delivered. Lack of response and follow-through by superiors had led to frustration and eventual abandonment of some SPC projects by some worker groups and some supervisors. Attempts to overcome this were regularly tried. For example, at one point groups started using meeting forms that listed each decision or promise made, who was responsible for follow-up and by when. This, however, slowly faded out of use, another victim of no follow-through.

Another aspect of the short-term orientation that creates problems for SPC is that initial implementation requires short-term losses in labour efficiency and production. These are two outputs of manufacturing that are monitored on a daily basis. Somewhere in the management hierarchy someone has to take responsibility for authorizing these losses. During the 1984 interviews at

Plant X, it appeared that no one was stepping up to this responsibility.

D) Implementation of SPC requires learning-oriented norms in a performance-oriented culture.

Implementation of SPC is primarily a process of learning about one's technical systems. As things are analyzed, a lot of past standard practices are going to become unacceptable and new ways of doing things will become required. It is very important that people feel that SPC data will be used to learn from and not to evaluate past practice. The problem is that in manufacturing, quantitative data tends to be used primarily for evaluation, comparison and control, not for learning. In the first instance, data tends to be collected in ways that don't make it useful for line managers to pinpoint problems and learn about their systems. Secondly, reporting meetings tend to involve comparisons of different units (production lines, departments, plants--depending on who is in the meeting) on various measures, with dire consequences for managers whose units consistently fall at the bottom. Built into the culture, then, is an orientation toward data as an evaluation, not learning, tool. As well, there is a tendency for people to expect to be berated for problems, not supported in overcoming them. Obviously, this creates a barrier to SPC.

A related norm is the practice of attacking those who present problematic data--also known as killing the messenger. In a crisis-oriented, fast-paced and stressful work environment, it is not uncommon for subordinates to have to suffer their superior's wrath simply because they have reported something unpleasant. Such practices reduce the enthusiasm of subordinates to report data accurately or in a timely fashion.

A further barrier to SPC and to creating an environment for learning is the lack of any budget for learning. This is another way of stating the problem that SPC requires short-term losses for training, meeting time, reflection and experimentation.

Plant X had managed to create a climate by 1984 where supervisors felt there was no risk in trying innovative approaches to their job (as long as efficiency and production were not too adversely effected). In more rigid machine bureaucracies we might expect a lower tolerance for risk-taking and, thus, one more barrier to implementing SPC.

E) Implementing SPC requires implicit self-condemnation from those who must drive the change.

Implementation of an innovation like SPC and the Quality Management Program involves a major change in the way business is done. For senior managers to embrace this new way is for them to implicitly say, "We weren't that good before and now we have to change. The system that has rewarded and promoted us is not that good and it has to change." No respondent identified this as a barrier to SPC but it is hard to believe that it doesn't exist at least unconsciously. SPC is a way of managing manufacturing in a rational, methodical, and one might even say, dull way. Those running organizations like Plant X have been successful in fast-paced, chaotic, stressful environments. The cultural contradictions are enormous.

A similar problem exists for the engineering staff who are intimately involved in the use of SPC. For them to begin using a technique that has been around for over 30 years (and which many of them studied in school) is to implicitly condemn themselves for past incompetence. The impact of this cannot be measured but it must be considered.

Perhaps the scariest part of SPC is the need to accurately report data up the hierarchy at all levels. For a number of reasons, units in large complex organizations tend to distort information going upwards.[8] This is particularly true of plant-divisional relations where hidden budget items and juggled accounts are virtually standard practice. Any line manager who has had a successful career has learned how to make the numbers "look right", how to hide some things and highlight others, how to save some production for a rainy day. This ingrained norm is reinforced by the practice of comparing and evaluating units on various measures against some standard or budget. While the "bottom line" probably won't change, a switch to accurate reporting will probably result in major changes in other figures like material utilization and routing efficiency. We should expect, especially the higher up in the organization one goes, to find that this is a potentially very embarrassing situation. It will have to be taken into account and dealt with or it will surely cause a barrier to SPC.

Summary

We have looked at a number of areas where the culture and political status quo of machine bureaucracies create dilemmas for implementing SPC. Primarily, they create dilemmas because SPC is a profound cultural and political change in traditional manufacturing management. This may seem obvious to the reader, but it has not been obvious to many organizations when they begin experimenting with it. Indeed, reports from the divisional SPC network about problems with implementation focused almost solely on technical issues such as the need for more statisticians, more accurate gauging, more hardware and software.

On the surface, SPC looks fairly easy and seems to fit the rational, control culture of manufacturing. It may well be that, once in place, SPC does fit very well, but we must remember that in organizational change there are "transition dynamics".[9] Often the structures and processes needed to get somewhere are different from the structures and processes one is hoping to institutionalize. This seems to be the case with statistical process control. For example, the purpose of SPC is to make manufacturing more certain, stable and predictable. It requires, however, a tolerance for uncertainty, instability and unpredictability in order to implement it.

A tolerance for uncertainty generally requires some level of trust between people. So does the implementation of an innovation that radically alters power relations and requires accurate reporting of information which may, in the past, have been distorted. Built into most machine bureaucracies, however, is a climate of distrust between different groups (e.g., manufacturing and maintenance) and between different levels (e.g., supervisors and senior managers). At Plant X, many efforts were made to increase the sense of trust and cooperation people felt. It was clear that implementation proceeded most quickly where trust existed between superiors and subordinates. In particular, superiors needed to trust their subordinates' competence and commitment to doing a good job. Subordinates needed to trust their superiors to tell them the truth, to maintain consistent policies, and to look after both their interests.

It may be that SPC will aid in the development of trust (when operating policies are known and held to) by allowing decisions to be based on objective facts and basing access to decision-making on possession of data. Again, however, transition dynamics are different from end-state dynamics. Initial attempts to use SPC fly in the face of political and cultural systems in factories. Any successful implementation effort will require leadership focused on political and cultural change.

### 3.4 HOURLY WORKERS AND THE UNION

Plant X has had remarkably few problems with getting the cooperation of hourly employees in the implementation of SPC. At least two of its sister plants have had a great deal of problems with their unions. Technically, collecting SPC data is not an operator's job, it is a quality control technician's job. In addition, working to control a manufacturing process requires interactions across operator work boundaries. Again, this is something that operators are contractually not required to do. Certainly, the new labour contract negotiated at Plant X in response to the shut-down announcement helped unfreeze rigid job classifications, but without real support by employees and the union, numerous subtle ways of sabotaging an SPC effort could be found. In this author's opinion, the key factor here was not the contract, but (1) the fear of losing the plant, and (2) the QWL intervention that preceded SPC. Managers and union officials at various levels of Plant X had been meeting regularly since 1981 to discuss the quality of working life and to find ways to reasonably resolve differences. The plant manager and union leadership met on a monthly basis to review the organization's business plans. Workers were provided opportunities to address and resolve problems in their work areas. While the situation was by no means one big, happy family, there was an atmosphere of some trust and communication between labour and management at Plant X.

There are a number of reasons why unions could fear SPC. These include the usual concerns that it is a gimmick to get more work for less pay, it is a sophisticated time and motion study, it will result in fewer jobs once processes are under control, it is an attempt to co-op workers and weaken the union, and so on. Those who attempt changes in unionized environments know that any negative fantasy can be, and often is, projected onto innovations that change the nature of the work. Therefore, it is clear that to implement SPC in a manner that has workers collecting and using data, cooperation between union and management must exist.

In the early implementation efforts at Plant X, it was found easiest to start up SPC in those areas that had worker problem-solving groups active. Some of this can be attributed to the life cycle of such groups. Often they start off with environmental concerns (e.g., getting more drinking fountains), possibly as a test of management commitment. Soon, however, they look for more ambitious projects to tackle, particularly around work problems. SPC provides them with a tool for usefully analyzing their work.

More importantly, and perhaps more explosively, SPC has the potential to greatly empower workers as it gives them accurate data with which to "confront" managers. I say "potential" because managers can still choose to disbelieve or ignore that data and there were examples of this at Plant X. There were also examples, however, of workers having a big impact on decisions because they had the data.

The logic of SPC is such that total implementation requires moving power lower down the organization. Using statistics to understand a process and correct a problem is only the first step. Once the process is understood and in control, variances that arise in the normal course of production must be controlled by those closest to the source of variance. This is where the big payoff of SPC comes as it ensures more efficient production with less downtime. Those most often closest to the source of variance are operators, so, in effect, control must be transferred to them. In Plant X there were a few areas where this was in fact happening. These were areas where the technology was such that operators worked on independent tasks. Therefore, they could take discretion over their own work without adversely effecting the work of others. These areas had shown extremely high payoff in developing uninterrupted, high quality production. One worker in particular had become legendary for his use of SPC data to get needed changes made.

This is potentially explosive as it crosses a culturally-ingrained boundary between management and labour. Management generally maintains it has a "right to manage" and unions generally want to keep it that way so they can blame "management incompetence" if business is bad. This separation between those who do the work and those who decide what they will do creates many distortions and inefficiencies.

Organizations structured in this manner cannot hope to compete for long against organizations where skilled operators accept responsibility for producing quality outputs and are given the authority and resources necessary to carry out that responsibility. This, perhaps more than anything else, is what is motivating work innovations in North America. Survival dictates that factories must work toward that end unless they envision exploiting cheap labour or they envision rapid automation.

There are a number of interrelated issues having to do with power in machine bureaucracies that are pertinent, not only at the hourly operator level, but at all levels in the organization. These were discussed in an earlier sub-section. At the hourly level, the core political (and technical) issue is how work is standardized. The traditional method of standardizing work processes designed by engineers and then slotting workers in and out of pre-programmed jobs, works against operators controlling variances through SPC. A major problem here is that the logic of work standardization leads to long assembly lines and results in a large number of task interdependent workers. If fifty people's work is interdependent, it is very difficult to give anyone discretion over their own work. This is, no doubt, why operator discretion exists at Plant X only where workers are not dependent on each other. To overcome this, work will have to be re-designed so that a whole task is controlled by a relatively small group of operators, in the manner of socio-technically designed factories. Task discretion can then be given to the small group. Their tasks will obviously have to be engineered but the group should be able to innovate and change the task design as it learns. Instead of coordinating and controlling work through the imposition of work processes, upper management would control by specifying the quality and volume of outputs expected. In other words, to control variance at source, small groups of workers need to be given control over whole tasks and what they produce specified, but not how they produce it. This is a fundamentally different way of organizing work than in traditional factories and requires changes in work roles at all levels of the organization. For more elaboration on this, the reader should look at the literature on socio-technical systems theory referenced in footnote 3 of Section 2 of this report.

To return to Plant X, there were two ways hourly operators were involved in SPC and these appear to have had different long-term effects. One was where operators were involved in collecting and interpreting the data and solving problems with it. In these cases, the use of SPC generally became ingrained and operators continued to control their processes through SPC. The second way was where operators simply collected the data but had little to do with analyzing it. In these cases, supervisors had to constantly remind operators to keep collecting data or they would slowly stop doing it.

If what one wants to do is solve a specific problem, the latter route can be less time consuming and does not work against traditional factory roles. It does not, however, lead to the use of SPC as standard procedure. Whether or not workers could be made contractually obliged to collect data and, more importantly, whether this would be effective, is debatable. Implementing SPC in a manner that ensures continuous process control requires that those who collect the data get to use the data or else they will surely have little commitment to accurate data collection.

The final issue raised in the Plant X case is that of transferring operators. Traditional union contracts with seniority clauses mean that as business fluctuates, workers get moved around to different operations. There were instances in Plant X where such shifts meant that effort spent getting workers to use SPC fell apart. (Where the SPC process had been showing success, however, the transfer of workers also aided in diffusion of the SPC concept in the plant.) If factories are eventually designed around small operating work groups, new kinds of contracts will have to be developed that maintain the integrity of these groups.

To summarize, in the case of Plant X, the union was cooperative and did not impede efforts to implement SPC. Most workers were willing to collect data. In the case of those in problem-solving groups created by the QWL process, workers were eager and active in using SPC. In some areas where workers are not task

330

dependent with others, they use SPC to continually monitor and control their work processes. In other areas where work is designed in ways that give operators little discretion, data collection fades if the data is not visibly used. The political and cultural ramifications of operators using SPC to control their own operations is enormous and probably cannot occur without fundamental changes in the way work is traditionally designed and in the nature of traditional collective agreements.

### 3.5 CHANGE AGENT ROLES

The six statistical analysts were an important resource at Plant X and I suspect that a good deal of the success Plant X has had with implementing SPC is directly related to the skills and motivation of this group. Unfortunately, in 1984 they were being severely underutilized as the plant was increasingly obsessed with labour efficiency, shipping schedules and a growing space problem. By October, the SAs considered disbanding.

Increasingly, manufacturing organizations undertaking work innovations are assigning line supervisors and managers to new, change agent roles. They are given titles like coordinator, facilitator, trainer or analyst. Their job is to implement some set of techniques that have ramifications far beyond the techniques themselves. Often they find themselves reporting to someone many levels above them in the hierarchy. As we saw in the Plant X case, moving line supervisors into ambiguous staff roles reporting to senior managers is very likely to create severe distortions, projections and authority dynamics. Those with personalities least likely to be awed and frightened by their new boss are also unlikely to be chosen for sensitive, change agent roles. The exception to this at Plant X was the QWL coordinator, whose background in the plant, personality, and subsequent impact on the change process could warrant a study in itself. The statistical analysts, however, were more what one would expect and a risky intervention was necessary to help the group find its centre of power. Once they did, their effectiveness as change agents increased dramatically. Note, however, the many advantages they had over the more typical case where only one or two supervisors are put into such roles:

1) They had a group of six to provide some safety in numbers as well as more ideas, talents and perspectives.
2) They had a role model and ally in the QWL coordinator who was already well connected in the plant and was an extremely sophisticated change agent.
3) They had a very large training budget and were provided training not only in the technique (SPC), but in being change agents.

One suspects that where only one person is given an SA role, the obstacles to being an effective change agent are immense. The change agent trying to implement SPC in a machine bureaucracy is a lot like David taking on Goliath. If he is going to be at all successful, he cannot pay much heed to the status quo, chain of command oriented culture. Since the change agent can't be afraid to bend a few rules, he must feel supported and trusted by the senior manager(s) he reports to. The temptation to simply make the numbers look right and play to the boss's own perspective (probably limited as the boss has had a lot less training) is enormous.

Movement into a change agent role is an opportunity, as it brings high visibility. But is it also an enormous risk as the chances of failure are high. It takes a unique individual to accept the risks and act in ways that are best for the organization, even though they may ruffle feathers. Ruffling feathers is one of the certainties of change. It says a lot about the quality of management at Plant X that it managed to select six statistical analysts who, by and large, had the motivation and dedication to take on a Goliath and, at times, place their individual careers in jeopardy for what they believed to be in the organization's best interests. And it highlights the immense pressures on this group that when senior level support was reduced in 1983, the group fragmented.

The fact that all the SAs were on the same level as first line supervisors created certain advantages and disadvantages worthy of note. The disadvantages had mainly to do with the limitations people at the bottoms of hierarchies place on themselves. In addition to the distorted authority dynamics already discussed, there is a tendency to view oneself as powerless and to assume 'victim' qualities.[10] The advantages are that the position is non-threatening to just about everyone else in the organization. If an SA were, hierarchically, on the same level as department heads or senior management, he would be a victim of the same distortions of information that anyone at the top of a system has to deal with. He would have much less access to the true feelings and opinions of workers and supervisors.[11] On the other hand, the same distortions tend not to occur in a downward flow. Senior managers are quite prepared to discuss things with someone who is, hierarchically, much further down. It's as though when people in hierarchies look up, they see the position; when they look down, they see the person. Having change agents placed near the bottom provides them with enormous access to the whole organization if they can find a way to overcome the natural tendency to feel trapped at the bottom and unknowingly place self-imposed limits on their activities.[12]

260

Within Plant X, virtually everyone agreed that the SA's role was to facilitate the use of SPC, not to do the statistical work of the plant. This, in theory, makes a lot of sense if the point is to make SPC a normal way of doing business. In practice, though, there is a dilemma. About half the supervisors interviewed in 1984 did not really understand SPC or what it could do for them. Each one thought he knew what it was. This was mainly because a lot of areas had, at some point, gone through a process of analyzing scrap; that is, counting up the different defects and charting them and discovering what their various percentages were. This is a first step in using SPC, but for a significant number of supervisors, this was all SPC was. Having taken the eight-hour training course didn't make much difference. Not surprisingly, these supervisors showed little interest in using SPC unless there was a particular quality problem to be solved. They did not appear resistant to SPC, they simply didn't understand what process control really meant.

The dilemma for SAs is that their direct involvement in a supervisor's area, doing the statistical work, deciding what data to collect, setting up the data collection system and doing the analyses, appeared to be the only way such supervisors developed an appreciation of what SPC could do. On the one hand, if SAs do the statistical work, we can expect that many supervisors and managers will be quite happy to leave it all up to them, hindering the institutionalization of the change. On the other hand, if the SAs don't do the statistical work, people don't get an opportunity to learn SPC in a hands-on manner. Finding the fine line between these two positions is a difficult and delicate matter. It was not obvious that the SAs in Plant X had been able to find that line.

To summarize, moving lower level supervisors into change agent roles has advantages and disadvantages. It appears that the disadvantages can be overcome if the change agent(s) can break out of hierarchically embedded roles. One of the most often described ways of doing this, and the one which occurred at Plant X, is to go through an act of rebelliousness "successfully". In working to institutionalize a technique like SPC, change agents must remain sensitive to when people don't really understand the technique, but say they do. A dilemma change agents face is in maintaining a clear separation between their roles as teachers and the managers' roles as doers when teaching requires some doing.

## Section 3 Footnotes

[1] For some current perspectives on cultural change in organizations, see H. Schwartz and S.M. Davis, "Matching Corporate Culture and Business Strategy," Organizational Dynamics, Summer 1981, 30-48; R.M. Kanter, The Change Masters, New York: Basic Books, 1983; and Special Issue on Organizational Culture, Administrative Science Quarterly, 28:3, 1983, 331-497.

[2] See, for example, B. Oshry, "Middle Manager Dilemmas in P/QWL Efforts", Readings for the Ecology of Work Conference, Bethel, ME: National Training Laboratories, 1982; and G.R. Bushe, "Developmental Trends of Parallel Structure Interventions in Unionized Manufacturing Organizations," paper presented at the 44th Annual Meetings of the Academy of Management, Boston, August 12-15, 1984.

[3] This same notion of incremental change, though in a very different context, has recently been put forward by J.B. Quin, Strategies For Change: Logical Incrementalism, Homewood, IL: Irwin-Dorsey, 1980.

[4] See D.A. Nadler, Feedback and Organization Development, Reading, MA: Addison-Wesley, 1977.

[5] This point about the effects of structure on learning has been usefully expanded on by D.E. Zand, Information, Organization and Power, New York: McGraw-Hill, 1981.

[6] Many studies of factories or 'mechanistic structures' have found consistent qualities. For an excellent synthesis, see the chapter on "Machine Bureaucracy" in H. Mintzberg, The Structuring of Organizations, Englewood Cliffs, N.J.: Prentice-Hall, 1979.

[7] See J. Thompson, Organizations in Action, New York: McGraw-Hill, 1967.

[8] See, for example, L.D. Brown, Managing Conflicts at Organizational Interfaces, Reading, MA: Addison-Wesley, 1983.

[9] See, for example, R. Beckhand and R.T. Harris, Organizational Transitions, Reading, MA: Addison-Wesley, 1977; and J.R. Kimberley and R.E. Quinn (Eds.), Managing Organizational Transitions, Homewood, IL: Irwin, 1984.

[10,11] For an excellent discussion on the effects of hierarchy on power relations and information flow, see B. Oshry, Power and Position, Boston: Power and Systems, 1977; and K.K. Smith, Groups in Conflict: Prisons in Disguise, Dubuque, Iowa: Kendall/Hunt, 1982.

[12] In response to the first draft of the report, some of the SAs were of the opinion that being in the same category as a first line supervisor acted so as to demotivate the group. They pointed out that individuals with comparable jobs in other plants were almost always one or two pay levels above them. In addition, there appeared to be no opportunity for promotion within the SA role, so that career advancement required moving to other jobs. By the end of 1984, two of the original six had left and others wer 'looking'.

Obviously, managing a group of change agents to maximize motivation and productivity requires special attention. Current wisdom in O.D. is that such groups should comprise about half professionals, dedicated to that role more or less permanently, and about half young promotables, rotated through the function for one to two years. The professionals would probably enjoy a higher salary classification.

It seems to me that the motivation issue here has less to do with the actual positioning in the pay scale and more to do with perceptions of equity and mobility. Therefore I have included this critique in a footnote rather than in the text.

## APPENDIX A

## SPC Tools

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# TABLE OF CONTENTS



## HISTOGRAMS

DEFINITIONS

1. FREQUENCY DISTRIBUTION - Pattern or shape formed by a group of measurements.
2. HISTOGRAM - A formal way of plotting a frequency distribution.

I. WHAT WE MUST UNDERSTAND TO USE HISTOGRAMS

A. Everything varies
B. Individual things are unpredictable
C. Groups of things from a constant system or process tend to be predictable

II. AS AN EXAMPLE OF THE ABOVE

A. People live to be different ages
B. No one knows exactly how long he/she will live
C. Insurance companies can tell with great accuracy what percentage of people will live to be 60, 65, 70, etc.



III. IN THE SAMPLE HISTOGRAM SHOWN ON PAGE 3, A FREQUENCY DISTRIBUTION (OR PATTERN) OF HOW LONG PEOPLE LIVE IS PRESENTED.

A. If you look at the Histogram and can tell that most people die at age 65, a few less die at age 60 or 70, and very few people die at age 20 or 120, then you understand what Histograms tell us.

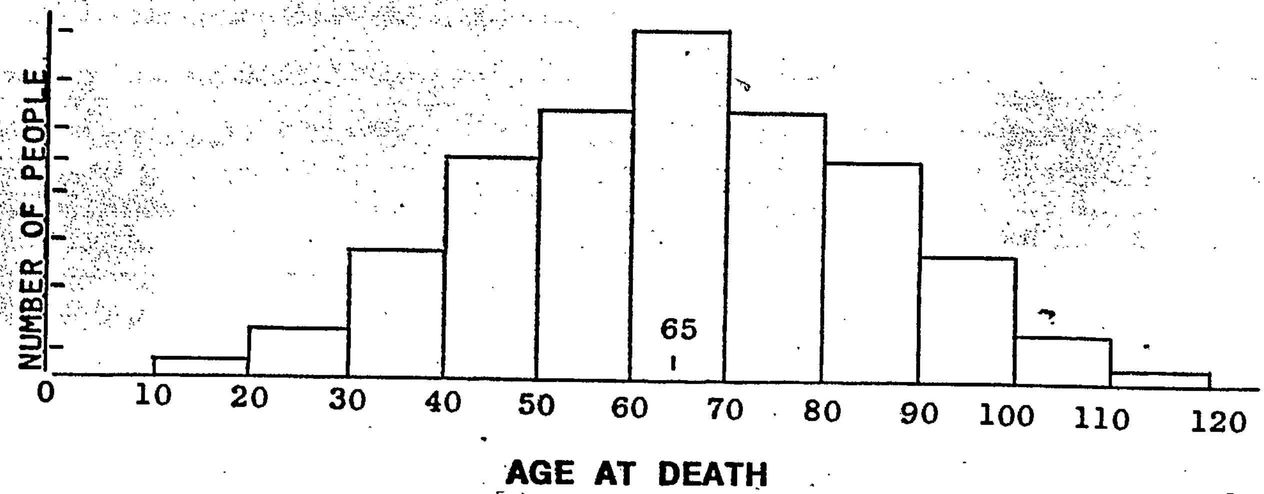
B. Histograms provide us with a picture of the data. From this picture we can get the following information:

1. Centering (where most data points fall)
2. Spread (difference between lowest and highest data point)
3. Shape (whether data is a normal distribution or not)

C. If you are still unclear what Histograms tell us, proceed back to step I.



280




3

## PARETO CHART

One of the easiest and most effective analysis tools is the Pareto Chart. It is a picture used to display data in the order of its severity.

EXAMPLE:

Figure 1 is the traditional method of collecting and displaying data in this plant. Review the data. Can you easily determine the major cause of scrap in this process? In what order would you work on these problems?

**Paint Area Defect Sheet**

| DEFECT \ DATE | 12-1 | 12-2 | 12-3 | 12-4 | 12-5 | 12-6 | 12-7 | 12-8 | 12-9 |
|---|---|---|---|---|---|---|---|---|---|
| DRY SPRAY | 16 | 19 | 14 | 15 | 17 | 19 | 17 | 17 | 19 |
| SCRATCHES | 21 | 14 | 13 | 12 | 21 | 13 | 12 | 14 | 13 |
| DINGS | 15 | 21 | 17 | 18 | 15 | 18 | 17 | 17 | 18 |
| SHORT | 23 | 15 | 17 | 22 | 22 | 22 | 15 | 22 | 22 |
| LONG | 29 | 14 | 16 | 13 | 15 | 13 | 29 | 15 | 13 |
| BLISTERS | 14 | 36 | 30 | 31 | 25 | 31 | 14 | 31 | 30 |
| MISFORMED | 13 | 8 | 11 | 13 | 14 | 11 | 8 | 11 | 8 |
| BENT | 30 | 27 | 28 | 26 | 25 | 27 | 28 | 28 | 30 |

**Figure 1**

4

This same data taken from Figure 1 is shown in the Pareto Chart in Figure 2. Now ask yourself the same questions: What is the major cause of scrap in this process? In what order would you work on these problems?

## PARETO CHART

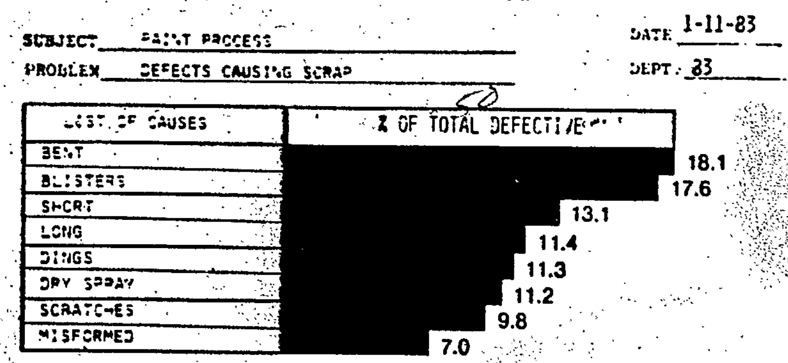



**Figure 2**



170

By defining the major problems in this manner (Figure 2), projects can be developed to attack and reduce each problem.

As you can see, the Pareto Chart is an effective decision-making tool BUT how do you put it together? It's not only an easy tool to use, but very easy to construct:

**STEP 1:**
- Total each defect type

**STEP 2:**
- Total all defects.

**STEP 3:**
- Divide the total of each defect type by the total of all defects

**STEP 4:**
- Record each defect on the Pareto Chart form in rank order and your chart is complete



**REMEMBER . . .**

IT MAKES GOOD SENSE TO
ATTACK THE LARGEST PROBLEM FIRST
TO RECEIVE THE GREATEST PROFIT!

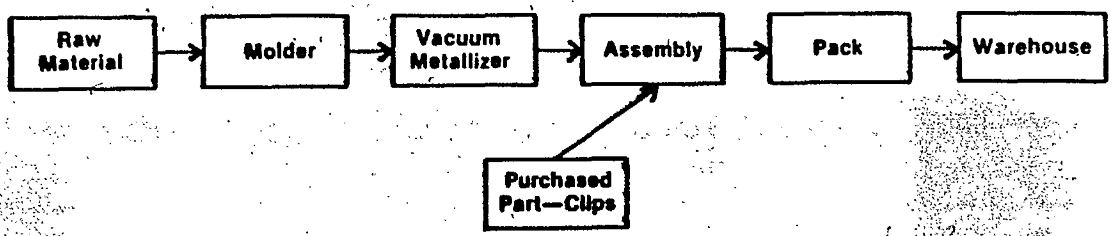


## FLOW CHARTS

A Flow Chart is a graphic illustration of the flow of a product through a process.

A Flow Chart is used to show the various steps used to manufacture a product. This chart identifies all steps of a process and shows the relationship between them.

The following is an example of a Flow Chart for a typical process — the manufacture of a reflector with clips.




This process starts with the raw material which goes to an injection molder to be molded. After molding, the reflector is sent to a vacuum metallizer for finish. The reflector is then sent to an assembly operation where the purchased part (clip) is attached to the reflector. After assembly, the parts are packed for shipment.

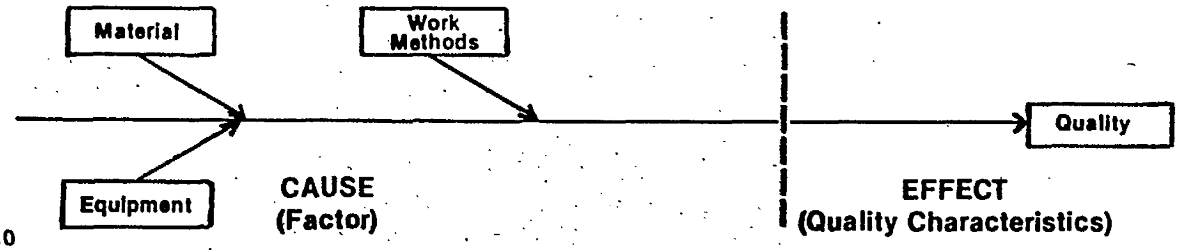


## FISHBONE DIAGRAM or CAUSE/EFFECT DIAGRAM

Why do we use Cause/Effect Diagrams? Cause/Effect or Fishbone Diagrams are drawn to clearly illustrate the various causes affecting product quality by sorting out and relating those causes. It is a tool used to help groups brainstorm a problem.

Variation occurs in all operations. Why does this occur? In almost half of the cases, it is because of:

- The raw materials
- The machines or equipment
- The work method



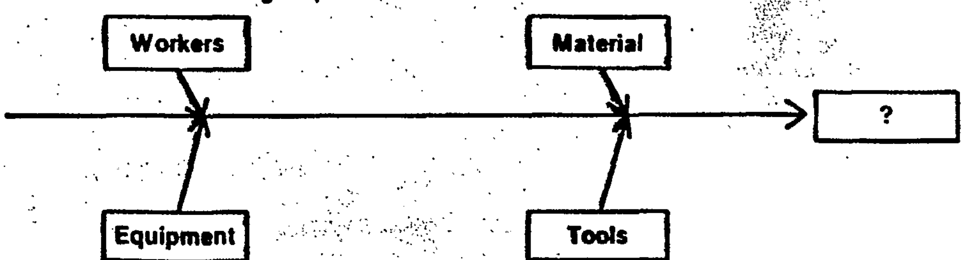



**STEP 1:**
Decide on the quality characteristic you want to improve or control. To do this, you must find the causes.

**STEP 2:**
Write the quality characteristic on the right side.


**STEP 3:**
Group causes of variation into sub-groups:

- Workers
- Material
- Equipment
- Tools






200

**STEP 4:**

Build on each branch by writing in detailed factors which may be regarded as causes. Subsequently, build on these detailed factors with a further breakdown of causes. Ask yourself the following:

- Why do production process defects occur?
- Why does machine variation occur?
- Why does material variation occur?
- Why does tool variation occur?

**STEP 5:**

Someone must check to make certain that all the items that may be causing variation are included in the diagram. If they are, and the relationships of causes to effects are properly illustrated, then the diagram is complete.



## HOW TO USE A FISHBONE or CAUSE/EFFECT DIAGRAM

- Making the diagram is educational in itself.
- It serves as a guide for discussion and keeps the speaker from straying from the original topic.

### A Guide For Carrying Out Discussions

A. Causes are actively sought and results are written in on the diagram. Update your diagram when the facts are discovered.

B. Data is collected with a Fishbone Diagram. Use circles and dates to show when causes occur.



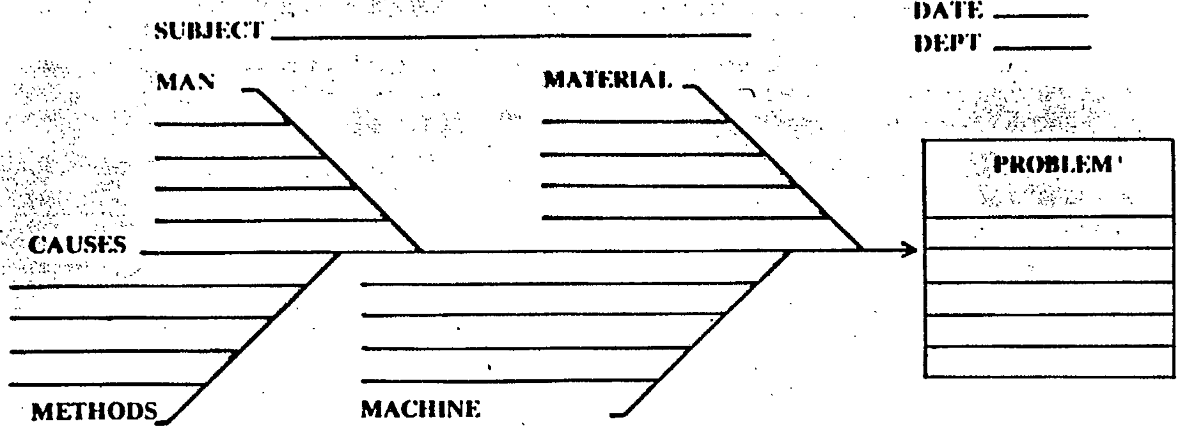
C. Shows the level of technology. When the relationship between the quality characteristics and a cause can be shown quantitatively in exact figures, put a box around it. When the relationship is difficult to show in figures, underline it. For a cause which has no proof, leave it alone.

D. Can be used for any problem for which we need to know the relationship between cause and effect in order to take action to solve that problem.

E. **Bad Cause/Effect Diagram:**

- Shallow
- Lists only five or six causes

# FISHBONE CHART




CONCLUSIONS ______________________ RESPONSIBILITIES ______________________



## CONTROL CHARTS

Control charting is an effective tool to quickly and inexpensively determine how a particular process or product performs during normal operating periods. A Control Chart may be used for variable data as well as attribute data. Examples of variable data are:

- Diameter of a hole
- Length of a molding
- Rockwell hardness of tool steel

Variable data has a particular numerical value assigned to it. In contrast, attribute data refers to characteristics of a product or process. Most commonly, attribute data generally refers to an item as either being "good" or "defective." A light bulb either lights or it doesn't; a molding has an acceptable surface finish or it has an unacceptable surface finish. Neither can have a numerical value assigned to it and both are examples of attribute data.

### Why Use Control Charts?

Rarely do we have the time or money to inspect 100% of a given lot of material or gage 100% of all critical dimensions on a particular part or tool. The use of Control Charts enables us to take small sample sizes and, by using mathematical formulas, make a prediction concerning the entire lot of parts, production process, or tool. Control charting and the use of "control limits" can predict where 99% of an entire lot of material will fall.



### Steps to Construct a Control Chart for Variable Data $\bar{x}$ & R Chart

**Step #1** Take a random sample of 5 pieces and measure the dimension you are concerned with for each piece. Record each measurement.

**Step #2** Add up the five readings and divide by 5. This is the sample average and is designated by the symbol $\bar{x}$.

**Step #3** Subtract the smallest value from the largest value in your sample of 5. This is the range within your 5 piece sample and is designated by the symbol R.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| INDIVIDUAL READINGS | 1 | +3 | -3 | +4 | +5 | +2 | -1 | | |
| | 2 | +2 | +6 | +8 | +1 | +3 | -6 | | |
| | 3 | 0 | +5 | -1 | +7 | -4 | -7 | | |
| | 4 | +3 | +1 | +4 | +6 | -8 | -2 | | |
| | 5 | -2 | +6 | -2 | +2 | -8 | 0 | | |
| | 6 | | | | | | | | |
| | 7 | | | | | | | | |
| | 8 | | | | | | | | |
| | 9 | | | | | | | | |
| | 10 | | | | | | | | |
| TOTAL | | +6 | +15 | +13 | +21 | -15 | -16 | | |
| AVERAGE | | +1 | +3 | +3 | +4 | -3 | -3 | | |
| RANGE | | 5 | 9 | 10 | 6 | 11 | 7 | | |
| TIME OR DATE OF READINGS | | | | | | | | | |

Step #1: Take Readings

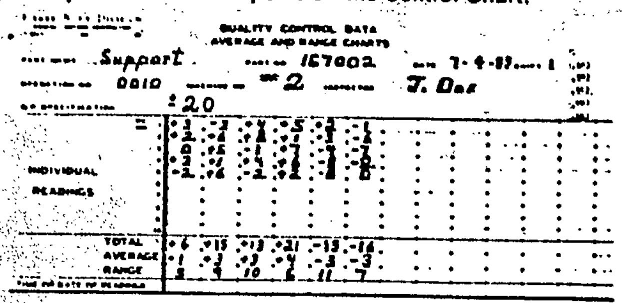
Step #2: Total Readings & Average

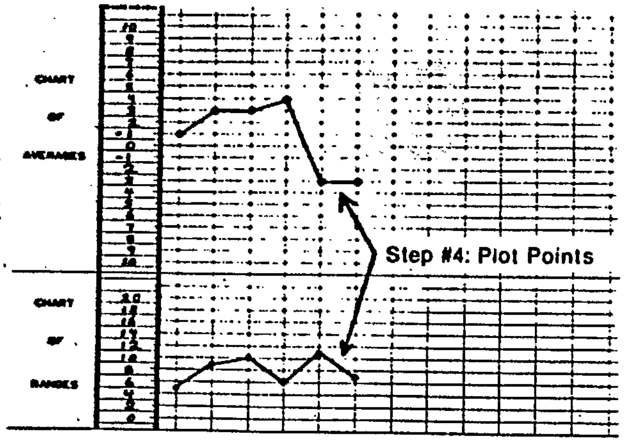
Step #3: Compute Range



350

**Step #4** Plot each point on the Control Chart.

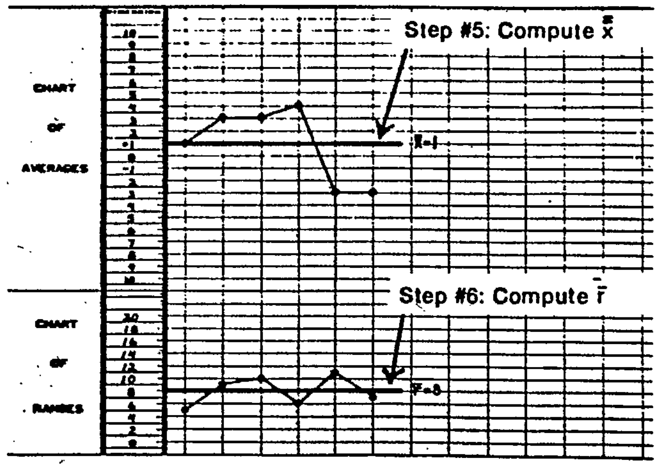





**Step #5** Add up your sample averages and divide by the number of samples. This gives you the average of the sample averages. Draw this line on the Control Chart and label it $\bar{\bar{x}}$.

**Step #6** Add up your sample ranges and divide by the number of ranges. This gives the average of the ranges. Draw this line on the Range Chart and label it $\bar{r}$.





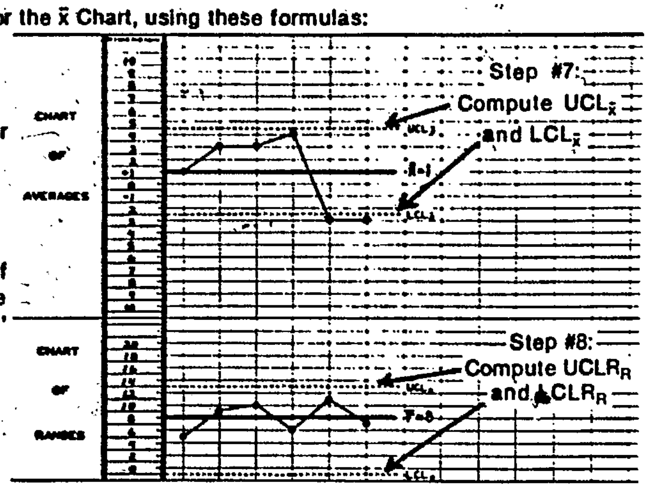

**Step #7** Compute upper and lower control limits for the $\bar{x}$ Chart, using these formulas:

$$UCL_{\bar{x}} = \bar{\bar{x}} + A_2\bar{r}$$
$$LCL_{\bar{x}} = \bar{\bar{x}} - A_2\bar{r}$$

**Step #8** Compute upper and lower control limits for the Range Chart, using these formulas:

$$UCL_R = D_4\,\bar{r}$$
$$LCL_R = D_3\,\bar{r}$$

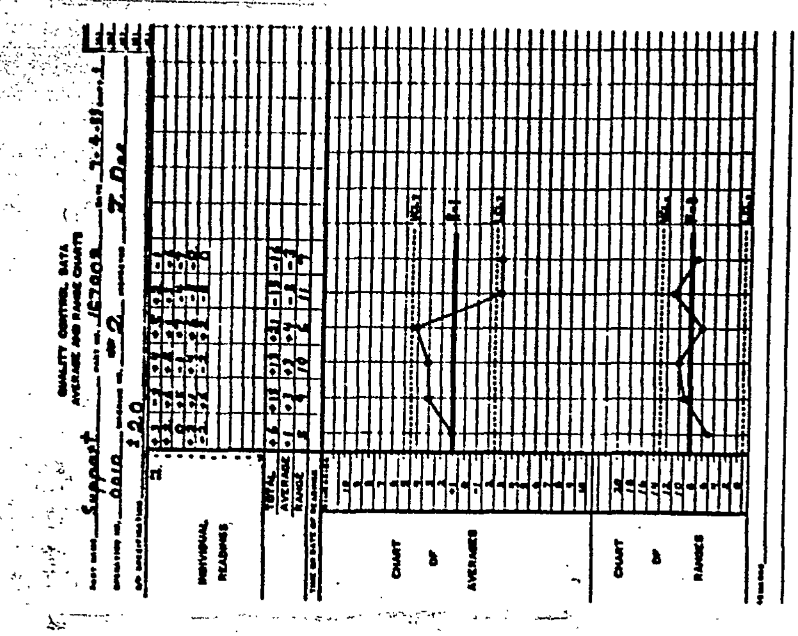
**NOTE:** The $A_2$ factors used in the construction of control limits vary depending upon the sample size selected. Consult the "Factors for Control Limits" chart (page 30) for the proper factor number.






210

The chart below is an example of a completed (all data included) Control Chart for Variable Data.





### Control Charts for Attribute Data

The Control Chart most commonly used with attribute data is the P Chart or Percent Defective Chart. This type of chart utilizes small samples from large lots of material or parts with mathematical formulas to predict the total amount (within control limits) that will be defective in the entire lot.

### Constructing P Chart

A. Select a workable sample size and always keep the sample size constant for each specific part or material. This maintains the consistency of the mathematics involved in determining control limits. It is generally recommended that sample sizes be a minimum of 25.

B. Determine $\bar{p}$ (percent defective): $\bar{p} = \frac{\text{Total of Percent Defective}}{\text{Number of Samples}}$



**EXAMPLE:** 10 shipments of light bulbs arrive at the plant. Margie selected random samples of 25 bulbs from each crate and tested them with the following results:

| SAMPLE # | # IN SAMPLE | # DEFECTIVE | FRACTION DEFECTIVE |
|---|---|---|---|
| 1 | 25 | 1 | 0.04 |
| 2 | 25 | 0 | 0.00 |
| 3 | 25 | 0 | 0.00 |
| 4 | 25 | 0 | 0.00 |
| 5 | 25 | 3 | 0.12 |
| 6 | 25 | 1 | 0.04 |
| 7 | 25 | 1 | 0.04 |
| 8 | 25 | 1 | 0.04 |
| 9 | 25 | 0 | 0.00 |
| 10 | 25 | 2 | 0.08 |
| | | TOTAL | 0.36 |

In this example, $\bar{p}$ is equal to $\frac{0.36}{10}$ or .036.



230

C. Calculate control limits by using the following formulas:

$\bar{p} \pm 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$ where n = # of items in sample or sample size

Continuing with the light bulb:

$.036 \pm 3\sqrt{\frac{(.036)(.964)}{25}} = .036 \pm 3 \quad (.037) \quad = .036 \pm .112$

UCL = .036 X .112 – .148 or 14.8% defective

LCL = .036 – .112 = 0 (since there cannot be less than 0 defective)



D. Plot these values on the P Chart in the same manner as you did with the $\bar{x}$ Chart.

**NOTE:** There isn't any Range Chart with a $\bar{p}$ Chart.

Control Charts paint a picture of what we should expect assuming we do **NOT** change a process or product. If a reading falls outside of the control limits established, it signals something has changed and that source of change should be investigated.



## SUMMARY OF MOST COMMON CONTROL CHART METHODS

| Type of Data | Control Chart | Characteristic to Investigate | Method of Measure | Sample Size |
|---|---|---|---|---|
| Attribute | "P" Chart | Defective parts per unit | Go/No Go Visual | At least 20 |
| Variable | $\bar{X}$R Chart | One Characteristic | Measurement Device | 5-10 |
| Variable | Moving Range | One Characteristic | Measurement Ratio/Index | 10-20 Data Points |

**NOTE:** See text of class for additional types of charts.



180

## CONTROL CHART FORMULAS

### Percent Defective Chart

n = number of units in sample

P = fraction defective in sample

$\bar{p}$ = average fraction defective

$p_t = \dfrac{\text{number of defectives}}{\text{sample size (n)}}$

$\bar{p} = \dfrac{\text{total defective}}{\text{total inspected}}$

**Control Limit Calculations**

Centerline = $\bar{p}$ = 100 $\bar{p}$

$UCL = \left[\bar{p} + 3\sqrt{\dfrac{\bar{p}(1-\bar{p})}{n}}\right] \times 100$

$LCL = \left[\bar{p} - 3\sqrt{\dfrac{\bar{p}(1-\bar{p})}{n}}\right] \times 100$

---

### $\bar{x}$R Chart

x = individual readings

R = range

R = largest — smallest reading

$\bar{r}$ = average range = $\dfrac{\Sigma R}{n \text{ (\# of ranges)}}$

$\bar{x}$ = average reading = $\dfrac{\Sigma X}{n \text{ (\# of values)}}$

$\bar{\bar{x}}$ = average of average readings

$\bar{\bar{x}} = \dfrac{\Sigma \bar{x}}{n \text{ (\# of } \bar{x} \text{ values)}}$

**Control Limit Calculations**

$\bar{x}$ Chart

$UCL_{\bar{x}} = \bar{\bar{x}} + A_2\bar{r}$

$LCL_{\bar{x}} = \bar{\bar{x}} - A_2\bar{r}$

Range Chart

$UCL_R = D_4\bar{r}$

$LCL_R = D_3\bar{r}$

$A_2$ and $D_4$ and $D_3$ = factors which will be found on FACTORS FOR CONTROL LIMITS Chart (see page 30)



**Control Chart Formulas (continued)**

Moving Range Chart

MR (moving range) = the difference between 1st and 2nd readings, 2nd and 3rd readings, etc. until all points have been calculated.

(NOTE: ignore ± sign)

$\bar{x}$ = average of original data points = $\dfrac{\Sigma x}{n}$

$M\bar{r}$ = average moving range

$M\bar{r} = \dfrac{\text{total of MR}}{\text{number of MR}} = \dfrac{\Sigma MR}{n-1}$

**Control Limit Calculations**

$\bar{x}$ = centerline

$UCL = \bar{x} + 2.66\ M\bar{r}$

$LCL = \bar{x} - 2.66\ M\bar{r}$

2.66 = a constant factor

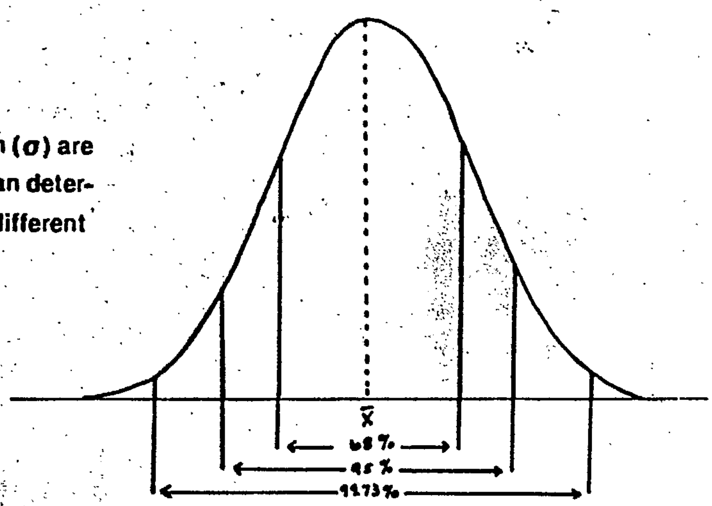
---

## GLOSSARY OF TERMS

| Symbol | Name | Description | Definition |
|---|---|---|---|
| $\bar{x}$ | Average (mean) | Measure of central tendency | The numerical average ($\bar{x}$) The sum of X numbers divided by n |
| R | Range | Measure of spread or dispersion | The difference between the largest and smallest reading in a sample |
| $\sigma$ | Standard Deviation | Measure of spread or dispersion | A measure of the scatter of data about the mean |



**If the mean ($\bar{x}$) and standard deviation ($\sigma$) are known, and the distribution is normal, we can determine the amount of data that will fall into different ranges.**






260

## FACTORS FOR CONTROL LIMITS

| Number of Observations In Sample n | $A_2$ | $d_2$ | $D_3$ | $D_4$ |
|---|---|---|---|---|
| 2 | 1.880 | 1.128 | 0 | 3.267 |
| 3 | 1.023 | 1.693 | 0 | 2.575 |
| 4 | 0.729 | 2.059 | 0 | 2.282 |
| 5 | 0.577 | 2.326 | 0 | 2.115 |
| 6 | 0.483 | 2.534 | 0 | 2.004 |
| 7 | 0.419 | 2.704 | 0.076 | 1.924 |
| 8 | 0.373 | 2.847 | 0.136 | 1.864 |
| 9 | 0.337 | 2.970 | 0.184 | 1.816 |
| 10 | 0.308 | 3.078 | 0.223 | 1.777 |
| 11 | 0.285 | 3.173 | 0.256 | 1.744 |
| 12 | 0.266 | 3.258 | 0.284 | 1.716 |
| 13 | 0.249 | 3.336 | 0.308 | 1.692 |
| 14 | 0.235 | 3.407 | 0.329 | 1.671 |
| 15 | 0.223 | 3.472 | 0.348 | 1.652 |
| 16 | 0.212 | 3.532 | 0.364 | 1.636 |
| 17 | 0.203 | 3.588 | 0.379 | 1.621 |
| 18 | 0.194 | 3.640 | 0.392 | 1.608 |
| 19 | 0.187 | 3.689 | 0.404 | 1.596 |
| 20 | 0.180 | 3.735 | 0.414 | 1.586 |
| 21 | 0.173 | 3.778 | 0.425 | 1.575 |
| 22 | 0.167 | 3.819 | 0.434 | 1.566 |
| 23 | 0.162 | 3.858 | 0.443 | 1.557 |
| 24 | 0.157 | 3.895 | 0.452 | 1.548 |
| 25 | 0.153 | 3.931 | 0.459 | 1.541 |



10

# APPENDIX B

## Parallel Structure Document

Date: June, 1981

Subject: Employe Participation Groups and the Parallel Organization in Unionized Settings

Currently, the notion of 'parallel organization' is gaining the attention of behavioral scientists and managers. Many different kinds of job redesign and QWL interventions over the past twenty years have implicitly used pieces of parallel organization. Only recently has this variety of experiences begun to be synthesized into a theory of parallel organization.

Employe Participation Groups (EPG) is an intervention which, when used with hourly rated production workers, sets up pieces of a parallel organization in the operating core of a manufacturing facility. The purpose of this note is to explain the way parallel organization works, particularly in unionized settings and then critically look at present models of EPG implementation.

The idea of parallel organization begins with the assumption that organizations are designed to solve problems and that different methods of organizing are more effective for solving different problems. We can distinguish between two broad categories of problems. One category contains production/ performance type problems. We can refer to these as 'closed' problems. These problems usually have a 'right' and a 'wrong' answer and feedback about the correctness of solutions is easy to obtain. The problem itself usually shows up in the difference between expected results and actual results.

The second category of problems deals with knowledge/developmental types of problems. We can refer to these problems as 'open'. Open problems usually do not have clear cut right and wrong answers and feedback about the correctness of solutions may take years or never be available. The problem itself is often one of deciding what the expected results should be. Improving tolerances in machining parts is a closed problem. Setting goals is an open problem.

Just as these are different types of problems, the most effective ways for solving these problems are different as well. Closed problems require 'hard' data and need precision both in the data collected in assessing the problem and the solutions suggested for solving the problem. A key criteria for solutions to closed problems is efficiency and solutions are often needed quickly. There is generally not a lot of time to solve these problems so that along with efficient solutions, implementation must be rapid. This requires that those who must implement the solutions do so obediently and quickly.

Open problems, on the other hand, need 'soft' as well as hard data. People's ideas, opinions and feelings are often important inputs to solving open problems. Fuzzy, half formed ideas are necessary catalysts for solution generating and the process of problem-solving must be allowed a lot of time. Open problems often deal with values and so implementation of solutions to open problems usually require changes in people's attitudes, values or work routines. Therefore, implementation is aided by getting those who will be effected by the solution involved in deciding on the solution. Table I on the following page summarizes the points made so far.

Most manufacturing facilities are designed to handle closed problems. Operating norms require that problems and solutions be precisely defined and acted on quickly. A strong hierarchy and chain of command require quick, obedient action on the part of subordinates. Subordinates are usually discouraged from innovating and questioning orders from superiors.

Table I CHARACTERISTICS OF CLOSED AND OPEN PROBLEMS

| Closed Problems | Open Problems |
| --- | --- |
| • Production/Performance problems<br>-right and wrong answers<br>-feedback on correctness<br>-deviation of actual from expected | • Knowledge/Developmental problems<br>-no right or wrong<br>-little feedback potential<br>-defining the expected |
| • Requires<br>-hard data<br>-precise solutions<br>-efficiency<br>-quick solutions and quick implementation<br>-subordinate obedience | • Requires<br>-soft and hard/data<br>-fuzzy ideas<br>-completeness<br>-long time frame<br>-subordinate input |

To the extent that these operating norms aid in the solution of closed problems, they hinder solving open problems. They stifle subordinate input and make fuzzy ideas and soft data illegitimate.

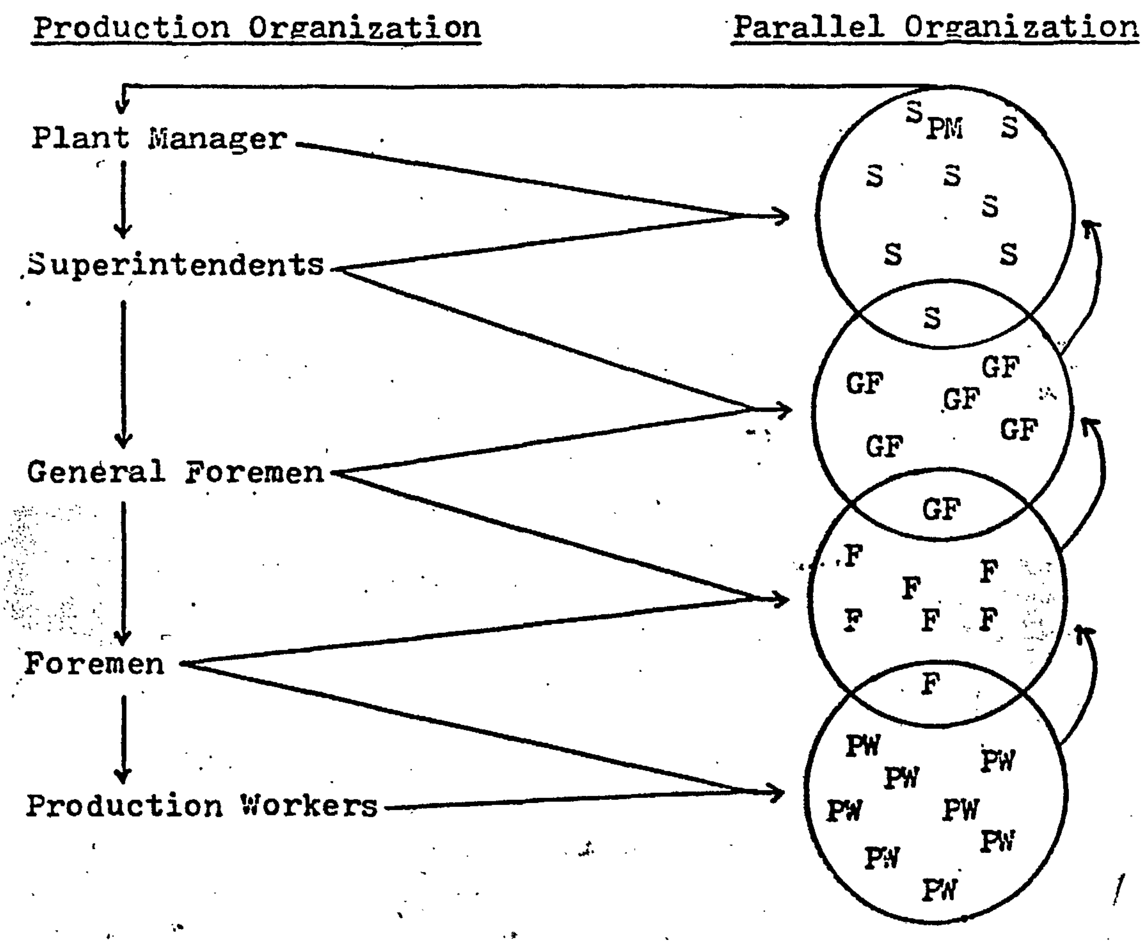
Parallel organization is a way of organizing to solve open problems. In essence, a total parallel organization consists of problem-solving groups up and down the organization hierarchy with membership overlapping in each group. For example, one group could consist of a superintendent and his general supervisors. Then each of these general supervisors would participate in groups with their foremen. Each / foremen would also be in a group with production employes.

A key requirement for effective parallel organization is that the groups must develop operating norms which are different from daily production activity and more appropriate to solving open problems. Major requirements for parallel group operating are:

- flattening the status hierarchy
- use of consensus decision-making
- shared leadership
- open and honest communication

Below, Model I gives a visual picture of the production organization and the parallel organization. In one sense, the arrows in the model show how information flows.

Model I THE BASIC PARALLEL ORGANIZATION



In the parallel organization, much information flows from the bottom up through the overlapping membership. Groups work on solving problems they define or on solving plant wide problems (eg: production goals, who gets to park where) defined for them. In the latter case, various group inputs are synthesized at the top and translated into policy decisions which are fed back into the production organization.

In the typical manufacturing location the introduction of parallel organization can contribute to overall effectiveness in more ways than just solving problems. Other potential benefits include:

- increasing information flow, particularly bottom up;
- increasing the use of human resources;
- increasing the amount of long range planning;
- addressing the deep rooted causes of problems rather than simply 'fire fighting';
- improving the quality of working life by increasing employe participation.

In order for the parallel organization to work effectively, the following appear to be important:

- members must have skills in group problem-solving and participative leadership (or have opportunities for receiving training in these skills);
- the groups must have access to all relevant information they need to effectively work on problems;
- group meetings should occur regularly (eg: once a week) and not be allowed to drop off.

Unionized Locations

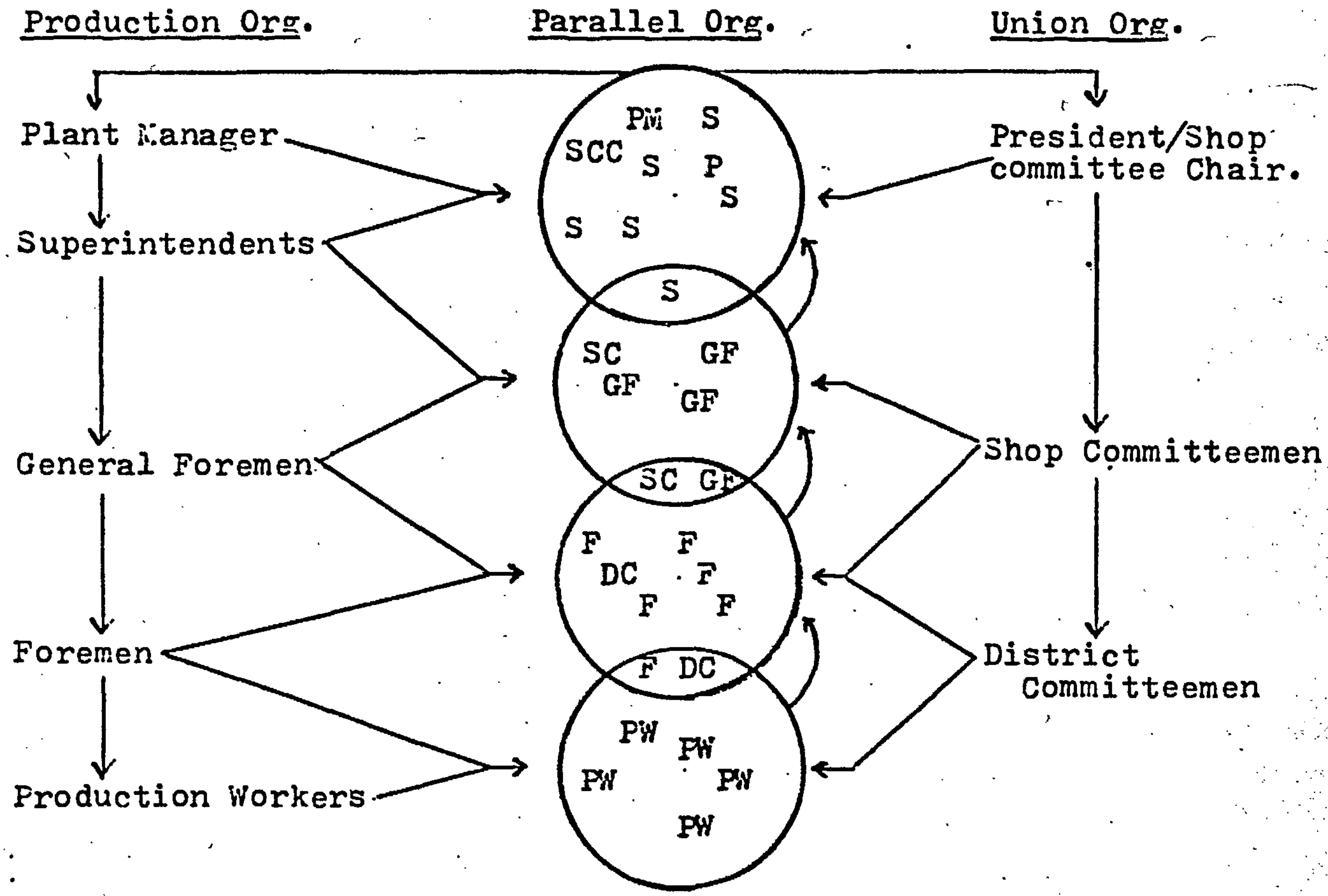
While a parallel organization can be instituted in the supervisory structure alone, its greatest benefits in manufacturing plants are to be found when production workers are involved. There are a number of reasons for this. First, hourly employes tend to be the largest, untapped pool of mental, human resources in the organization. Second, they tend to have the greatest expertise about day to day problems in the production work of the organization. Third, their involvement is usually necessary in the implementation of solutions to large, open problems.

Involving production workers typically means also involving a union. Thinking of the production organization and the union organization as two separate line organizations, the parallel organization provides a forum where they can join together in the pursuit of common objectives. Some examples of concerns that local management and unions have in common are health and safety, maintaining or increasing employment through enhanced competetiveness, reducing absenteeism and improving the quality of work life.

Model II on the next page shows the parallel organization in unionized settings visually. In these settings, it is necessary to ensure that common adversarial issues and relations are kept out of the parallel organization. The pursuit of common objectives takes a different form than the traditional union-management concerns of collective bargaining and redress of grievances. A firm commitment must be made by both sides to keep these issues out of the parallel organization.

A second issue is the union's access to information. As members of these groups, union representatives will have access to all the information that groups receive to effectively work on problems. In some cases, this includes data that was previously kept secret. In this case,

## Model II PARALLEL ORGANIZATION WITH UNION INVOLVEMENT




management must understand that 'opening the books' is the only way to develop the cooperative spirit necessary to pursue common objectives.

Experiences from a Location

The parallel organization being built at the plant we'll examine here is similar to Model II with some important differences.

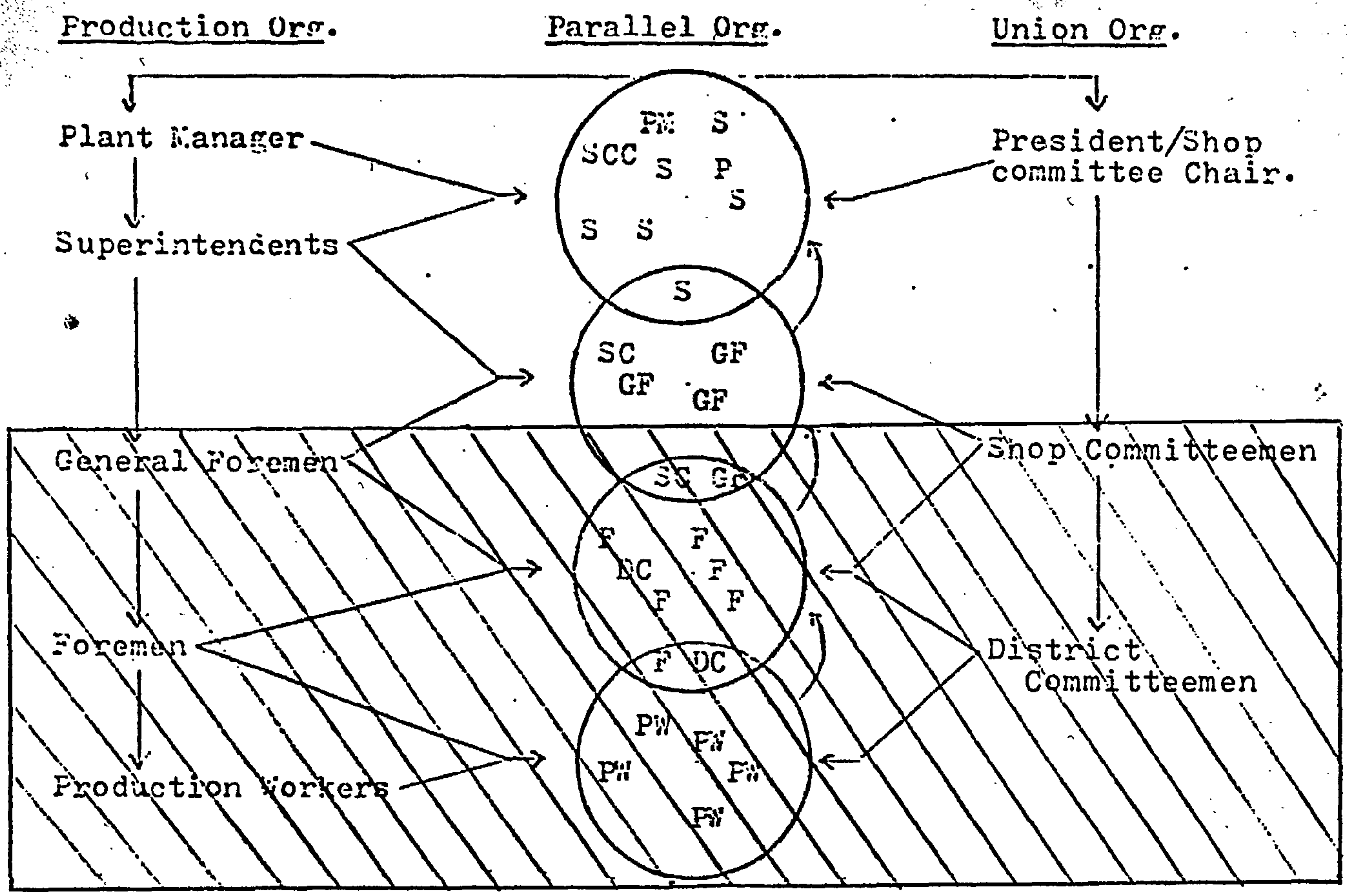
The parallel organization at this plant serves as an integrative mechanism for management and the union and is implemented through the various levels of the hierarchy depicted in Model II. However, while the implementation process begins at the superintendent level, no groups have been kept in operation at this level ( with one exception). Regular meetings between foremen and general foremen are more common but do not exist in all cases. The major focus of effort is on meetings between foremen, union reps and production workers. There exists a committee with top management and union leadership but this has only met twice in the past year.

Reviewing Model II, we can isolate those parts of the model which appear to be the typical case at this location. This is pictured on the next page. The box demarcates those parts of the parallel organization in place and functioning here. As it is, this structure appears to have had high payoff in reducing grievances drastically and improving product quality just as dramatically.

Viewed from the perspective of the parallel organization, the 'incompleteness' of this location's structure (see Model III) most likely accounts for two facts of life at this plant:

1. The greatest amount of resistance to this innovation is at the superintendent level.
2. The parallel organization has never been used (and is not considered for use)for working on problems of a plant wide nature, or problems concerning the refinement or improvement of the parallel structure itself. Groups continue to be concerned exclusively with their own little domains.

Model III PARALLEL ORGANIZATION IN A LOCATION



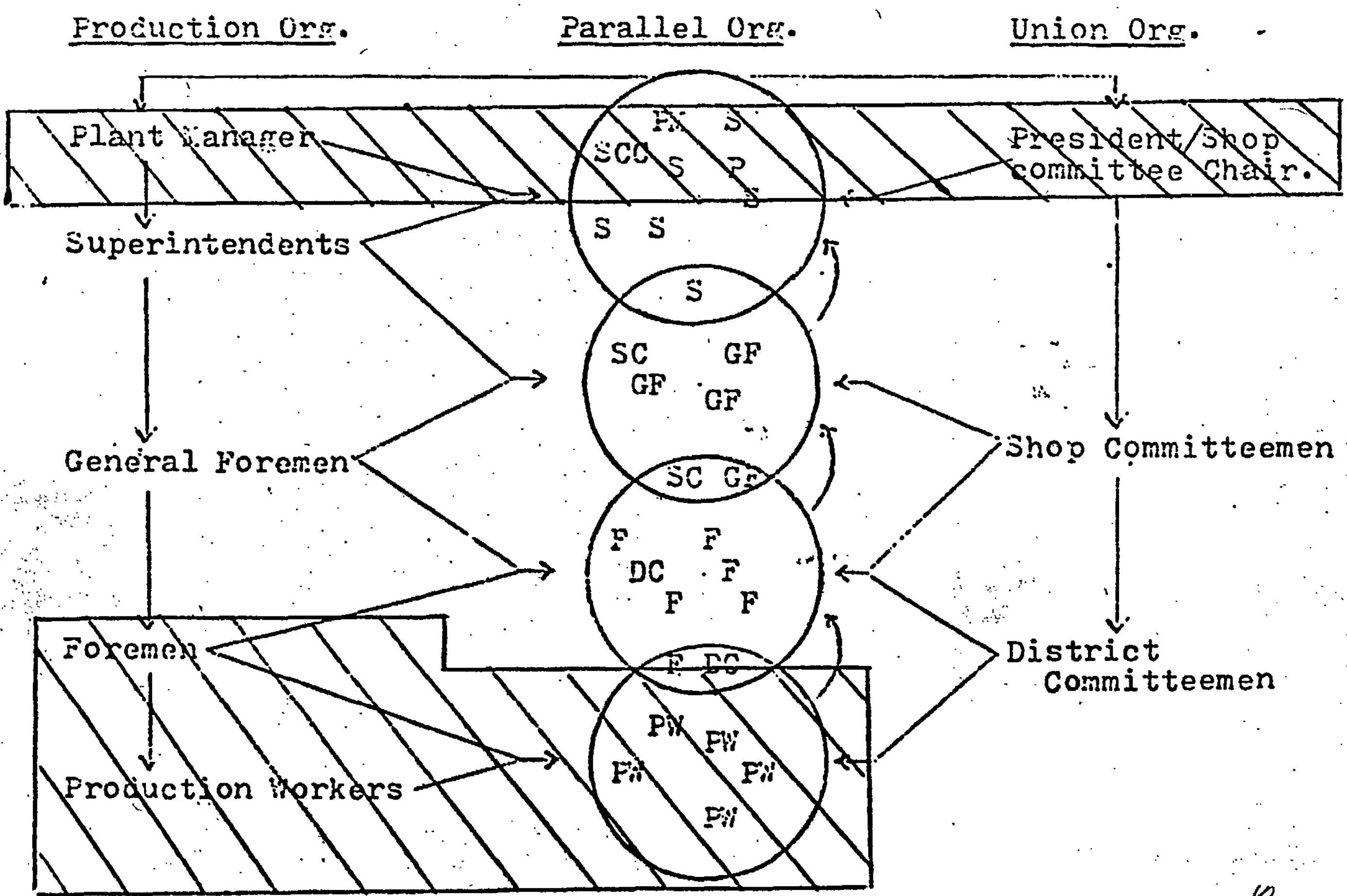

## Employe Participation Groups

This note began with the assertion that EPGs are an intervention aimed at developing parallel groups at the operating core. While the way EPG works is different in each location, we can reflect on the EPG system as a whole by examining the implementation guidelines presently offered during EPG Coordinator Training and anecdotal reports from the field.

The implementation models presently offered call for the development of a joint union-management steering committee at the top of the organization to oversee the implementation and maintenance of EPGs. Then, with the the help of full time EPG Coordinators (often a management and a union coordinatior) groups of hourly workers, with or without foremen, are set up. These groups are trained in group problem-solving and participative leadership skills and encouraged to work on any problems (outside contractual matters) they choose.

In Model IV we can see how EPG, as presently conceived, overlays our model of parallel organization.

Model IV EPG AND PARALLEL ORGANIZATION



Again the boxes demarcate those areas where EPG matches our model of parallel organization. A number of potential difficulties come into sharp relief.

The first has to do with resistance to change. Anecdotal evidence from the field consistently reports general foremen or union reps as being the centers of resistance to EPG. In the EPG structure there is no place for them. Recall the similar phenomena in Model III with superintendents. It may well be that if layers of supervision are not integrated into this type of intervention, resistance and sabotage will be unavoidable and may ultimately lead to failure of the whole program.

A second category of potential problems has to do with the EPG structure's impact on the groups' ability to influence the organization. One aspect of this has to do with linkage of groups to the formal decision-making structure. As it exists now, any decisions an EPG would want to implement that might effect other units must gain sanction from the top steering committee. In the first place this bypasses the normal chain of command which is likely to be perceived as threatening by those who are bypassed and increase resistance.

In the second place, many of those decisions might be more reasonably made (and more easily integrated into the organization) at lower levels of the hierarchy. A top steering committee which constantly has to deal with what appear as trivial decisions may start to question the usefulness of the whole EPG system.

Related to this is the way in which group ideas are brought to the steering committee for decisions. Unlike the parallel organization with its overlapping membership, the steering committee and EPGs are distinct groups. At best, this means that EPGs must make "presentations", thus reinforcing traditional, hierarchical, authority-based role relations. At worst, it means that groups will not know the logic behind steering committee decisions, fostering mistrust and potentially leading to a lessening of member commitment.

Another way in which EPG may sub-optimize the usefulness of parallel organization is that it is unable to address organization wide problems. As it stands, the explicit EPG philosophy is that groups should choose what problems they want to work on for themselves. This is useful for developing committment but neglects the potentially beneficial effects of using the parallel organization to cope with problems that the parallel structure itself creates, problems such as heightened worker aspirations, the cost-benefit ratio of this way of working, the inadequacy of current reward systems and performance appraisal, etc.. Because the EPG system does not integrate middle management and union officials it will, in and of itself, be incapable of addressing such issues in a location.

Further, to the extent that the present EPG structure encourages a narrow focus, looking at only their own areas for problems to solve, there are some questions about how long the groups will remain alive. After they have dealt with all the obvious maintenance and work related problems in their own areas, what else is there for them to do?

Another set of potential difficulties has to do with the EPG's impact on the quality of work life. For our purposes, we'll define QWL as the development and maintenance of a work environment characterized by trust, opennes, cooperation and optimal opportunities for personal and organizational development.

A key ingredient in developing QWL, as our study of that location demonstrated, is the development of trust and cooperation between union and management in day to day activities. The parallel organization at that location has perhaps had its greatest success in doing just that. The EPG system, as presently conceived, has no requirements for union participation other than on the top steering committee. But it has been the experience of foremen, general foremen and committeemen working together in these groups that has helped develop the constructive, open climate at that location. As well, it is questionable whether the present EPG system does anything to enhance the sense of participation and QWL of general foremen and superintendents.

Summarizing the points made so far, the concept of parallel organization allows us one perspective for theoretically defining potential problems with the EPG system as presently conceived. In point form, these are:

- Fosters resistance by exclusion of general foremen and union committeemen.
- Dampens the ability of groups to influence the organization due to lack of linkage to decision-making structure at appropriate points.

- Maintains traditional authority based role relations due to distance between steering committee and EPGs.
- Unable to cope with organization wide problems due to lack of integrative mechanisms for implementing solutions that effect other units.
- Fosters a narrow scope of issues for group consideration.
- Improvements in QWL questionable, particularly in developing union-management cooperation and trust and in enhancing QWL of middle management.

These points provide areas for our further study and refinement of EPG in specific locations. As well, the parallel organization depicted in Model II offers possibilities for experimenting with a different EPG system.

Gervase Bushe