Guide to quality control and performance improvement using qualitative (attribute) data —

Part 1: Uses and value of attribute charts in business, industry, commerce and public service

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Contents

Foreword

BS 5701-1 demonstrates the business benefits, and the versatility and usefulness of a very simple, yet powerful, pictorial control chart method for monitoring and interpreting qualitative data. This is done in a practical and largely non-statistical manner. BS 5701-1:2003 partially supersedes BS 5701:1980 and BS 2564:1955 and all four parts of BS 5701 together supersede BS 5701:1980 and BS 2564:1955, which are withdrawn.

This qualitative data can range from overall business figures such as percentage profit to detailed operational data, such as percentage absenteeism, individual process parameters and product/service features. The data can either be expressed sequentially in yes/no, good/bad, present/absent, success/failure format, or as summary measures (e.g. counts of events and proportions). For measured data control charting, refer to BS 5702-1.

The focus is on the application of control charts to monitoring, control and improvement. The roles of associated diagnostic, presentation and performance improvement tools, such as priority (Pareto) analysis, cause and effect diagrams and flow charts are also shown.

Its aim is to be readily comprehensible to the very extensive range of prospective users and so facilitate widespread communication, and understanding, of the method. As such, it focuses on a practical non-statistical treatment of the charting of qualitative data, presenting examples of construction and application using a simple pictorial approach.

Whilst the treatment of charting of qualitative data in this part of BS 5701 is essentially at appreciation level, it is intended to provide adequate information for a gainful first application, by a typical less statistically inclined user, in many everyday situations. BS 5701-2 and BS 5701-3 provide a more rigorous, statistical approach to process control and improvement using qualitative data. BS 5701-4 deals with measuring and improving the quality of decision making in the classification process itself.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 27 and a back cover.

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1 Scope

BS 5701-1 describes, in lay terms, the uses and value of pictorial control chart methods for enhancing the presentation and general understanding of qualitative (attribute) data arranged in a meaningful sequence. It also illustrates the supporting roles of associated business improvement tools. These include process modelling, flow charting, prioritizing (Pareto analysis) and cause and effect diagrams.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS EN ISO 9000:2000, *Quality management systems — Fundamentals and vocabulary.*

BS ISO 3534-1, *Statistics — Vocabulary and symbols — Part 1: Probability and general statistical terms.*

BS ISO 3534-2, *Statistics — Vocabulary and symbols — Part 2: Applied statistics.*

3 Terms, definitions and symbols

For the purposes of this part of BS 5701, the terms, definitions and symbols given in BS ISO 3534-1, BS ISO 3534-2 and BS EN ISO 9000:2000, Clause **3** apply.

4 Qualitative (attribute) data fundamentals

4.1 General

In this technological age, we are awash with data. The challenge is to transform such data into meaningful information on a characteristic. There is a wide range of classes of characteristic, including:

a) physical (e.g. mechanical, electrical, chemical or biological);

b) sensory (e.g. relating to smell, touch, taste, sight or hearing);

c) behavioural (e.g. courtesy, honesty or veracity);

d) temporal (e.g. punctuality, reliability or availability);

e) ergonomic (e.g. linguistic, physiological or relating to safety);

f) functional (e.g. range, speed, or rate of climb of an aircraft).

Typical business application characteristics, shown in Table 1, that are the subject of control and progressive improvement further indicate the wide scope of the subject matter of this standard.

Table 1 — Typical business applicable characteristics

Business application	Characteristic
business	profitability
marketing	market share
staff	absenteeism
personnel	turnover
sales enquiries	results
organization overall	errors/faults
product	non-conformities
service	complaints
incoming phone calls	response delays
invoicing	accuracy
deliveries	lateness
accounts	overdue
vehicles, machines	status
warranty costs	over-run
software	errors/10^3 lines
computers	status
communications	clarity, timeliness

4.2 Types of data

Two general classes of data are distinguished here, *measured data* and *attribute data*. These classes can be otherwise termed *continuous data* and *discrete data* or, even, *quantitative data* as opposed to *qualitative data*. Whereas continuous data is measured on a numerical scale with a continuum of possible values, discrete data is referenced on a scale with only a set or sequence of distinct values.

This standard focuses on attribute data. Attribute data are divided for convenience, into two categories, *classified data* and *count data*.

With *classified data*, each item of data is classified as being one of a number of categories. Frequently the number of categories is two, namely a binary situation where, for instance, results are usually expressed as 0 and 1, or as, good/bad, success/failure, profit/loss, in/out, or presence/absence of a particular characteristic or feature.

Data having two classes are termed "binomial" (binomial = "two names") data. A measure can be inherently binomial, e.g. where a profit or loss is made, or if someone is in or out. Sometimes it is arrived at indirectly by categorizing some other numerical measure. Take, for instance, the case where telephone calls are classified as to whether or not they last more than ten minutes or, perhaps whether or not they are answered within six rings.

Count data relates to counts of events where each item of data is the count of the number of particular events per given time period or quantity of product. Instances are:

— number of accidents or absentees per month;

— number of operations or sorties per day;

— number of incoming telephone calls per minute; or

— number of non-conformities per unit or batch.

A pictorial representation of the different types of data is shown in Figure 1.

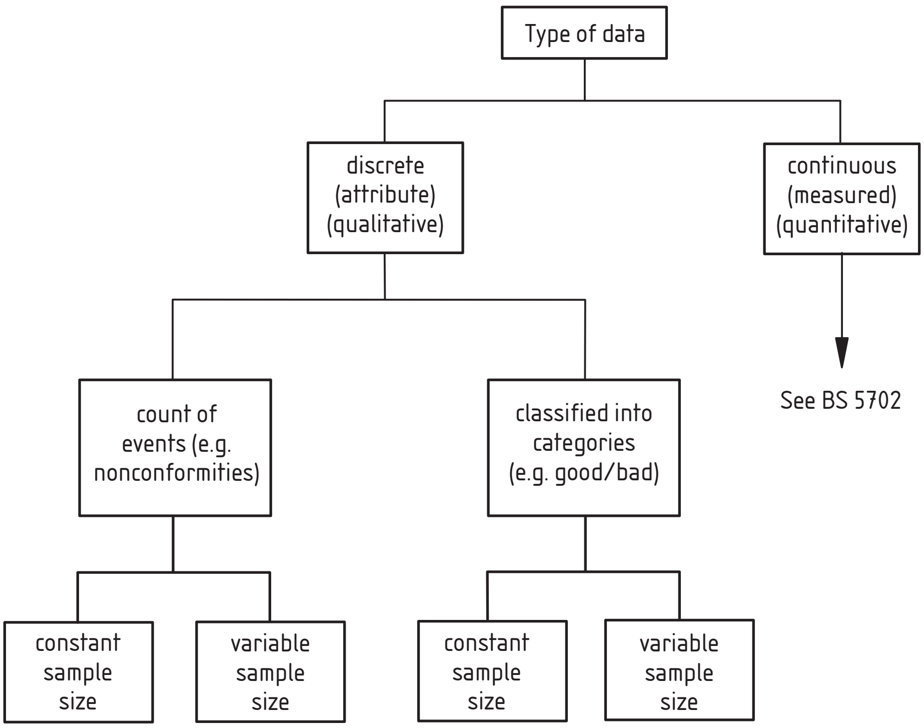


Figure 1 — Different classes of data

4.3 Principles, objectives and rationale of the control charting of qualitative data

4.3.1 *Overview*

Mention of the word statistics invokes a feeling of apprehension in many people. However, everyone should positively respond to, understand and adopt the primary concepts of "statistical thinking". These are as follows:

1) All work occurs in a system of interconnected processes.

2) Variation exists in all processes.

3) Elimination of special cause variation produces process stability and predictability.

4) Reduction in common cause variation is the key to continual improvement.

The first concept highlights that "statistical thinking" should not be confined to a specific function of an organization. It is applicable across the whole spectrum of business activity.

The second concept brings out that variation is present in almost everything. Its existence provides opportunities for better process control and for process performance improvement.

The third and fourth concepts stress the need to clearly distinguish between the variation due to "special causes" and that due to "common causes". The reason for this is that they give rise to two quite different types of action. A special cause is a sporadic source of variation that demands specific action to restore the status quo. A common cause, on the other hand, is an endemic source of variation that is always present, as it is inherent to the process. A reduction demands fundamental changes to the process.

The elimination of special causes brings a process back under control. The process performance or capability is then stable and predictable. A stable process might, or might not, provide the desired performance. A reduction in common cause variation improves process capability or performance.

A control chart is the tool used to differentiate between "special causes" and "common causes". Hence the control chart is a key operational tool in the application of "statistical thinking".

By its very name, a primary role of a control chart, in an operational sense, is to control; namely to inhibit change. The removal of adverse special cause variation to bring a process back into control does not actually improve the process: it only returns it to its original state.

It should be borne in mind, too, that a special cause can be adverse or beneficial. Suppose a supervisor stands in momentarily for an operator in a process and a special cause is indicated on a fault chart. The special cause could be a single reading above the upper control limit indicating an adverse change. Alternatively, it could be a single reading below the lower control limit indicating a beneficial change. The reaction to the two types of special causes would be quite different.

This focus on control, however, should not blind one to the fact that often the objective, in an overall sense, is to improve process performance by inducing change. Such betterment, through common cause reduction does not necessarily have to await special cause removal. However, the prior removal of special causes gives rise to a stable process and so permits a quantitative prediction of process capability. The generic control and improvement sequence is shown in Figure 2.

A significant improvement in process performance is evidenced in a control chart by an "out of control" situation, as is a significant deterioration. Hence the control chart has an in-built statistical test of significance for both improvement and deterioration.

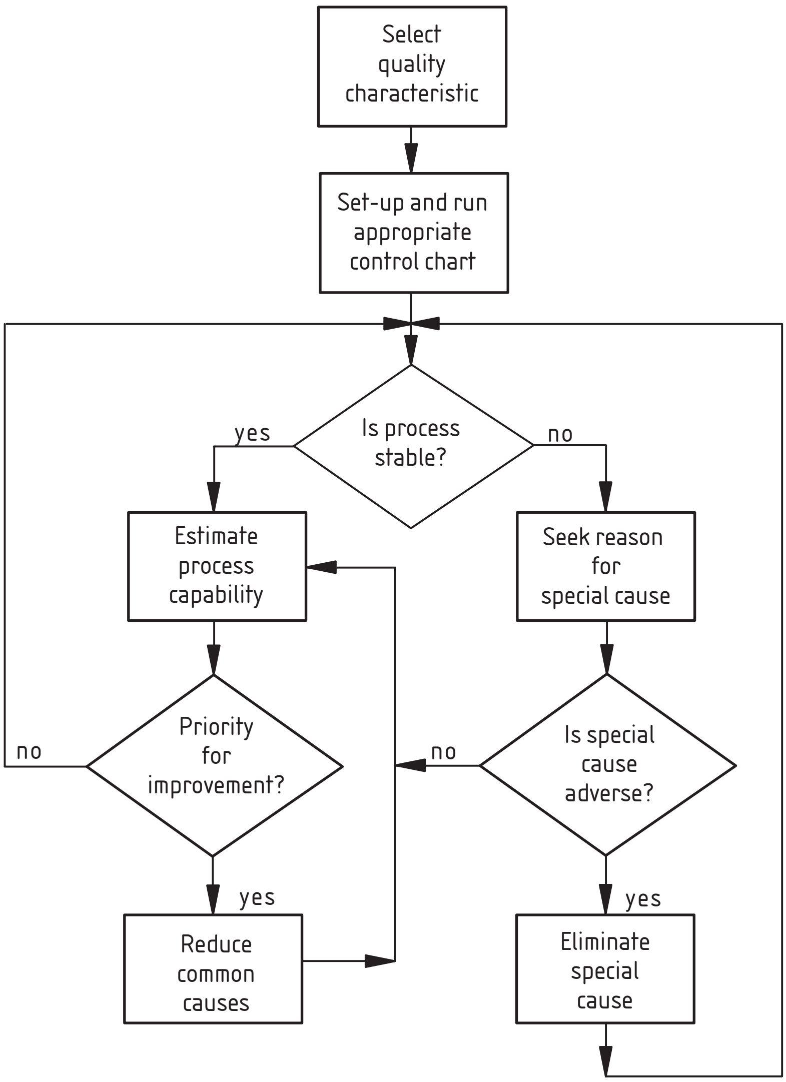


Figure 2 — Process control, capability estimation and improvement sequence

4.3.2 ***Over-control, under-control and control of processes***

A process monitoring system can give rise to:

a) *over-control*: action is taken when it should not be;

b) *under-control*: action is not taken when it should be;

c) *control*: action is taken when it should be and not taken when it should not be. A process is said to be under a state of (statistical) control when no special causes of variation are present. Variation can then be attributed purely to "common causes". Control is not a natural state but it is an achievement, arrived at by elimination, one by one, by determined effort, of special cause variation. To achieve this it is essential to use statistical process control (SPC) charts that set out to provide a signal when a special cause of variation is present, and to avoid giving false signals when a special cause is not present.

Sometimes "assignable cause" is taken to be synonymous with "special cause". However, a distinction should be recognized. In practice, not all special causes are assignable. A state of control does not imply that the common cause variation is large or small, within or outside of specification, but rather that it is predictable using statistical techniques.

4.3.3 ***The control chart***

The control chart is a simple graphical tool that distinguishes between two types of variation:

— *special cause variation*: a source of variation that is not present all the time but which arises from specific circumstances;

— *common cause variation*: a source of variation that is inherent in a process over time.

When no special cause is present, the process is considered to be stable. It is then said to be in a state of statistical control. The capability of a stable attribute process can be calculated directly from the centre-line of the control chart. When a special cause is present, the process is said to be "out-of-control" and needs to be brought back under control.

These process states are readily determined from an attribute control chart. The attribute control chart is essentially a simple run chart with two added features, a centre-line and one or two control limits. The centre-line on an attribute control chart is normally the historical mean of the feature plotted. The control limit, or limits are lines on a control chart placed about the centre-line to evaluate whether, or not, the process is in a state of control. Typical criteria for assessing whether a control chart indicates an "out-of-control" situation are:

a) any point outside of the control limits;

b) any run of seven consecutive points above or below the centre-line;

c) any run of seven consecutive points up or down;

d) any obvious non-random patterns (based on technical and operational knowledge of the process).

4.3.4 ***Case study***

Figure 3 shows a specific example of the use of an attribute control chart in process improvement. It relates to an underwear making-up (assembly) process.

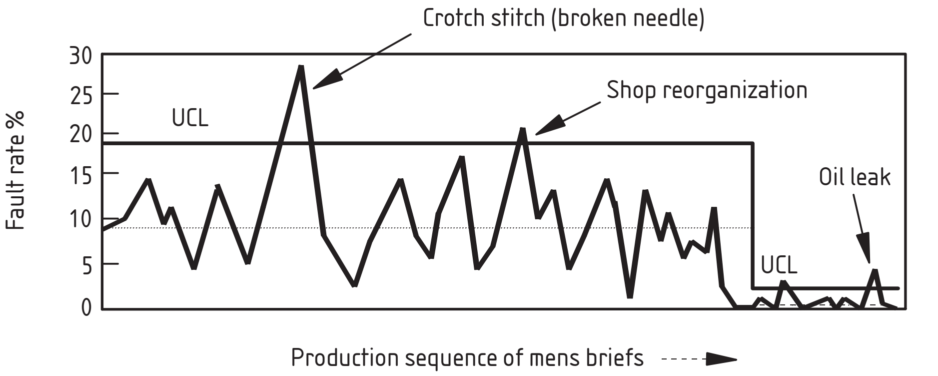


Figure 3 — Control chart for assembly of men's briefs

NOTE Out of control criteria are:

— any point outside the upper control limit (UCL);

— any run of seven consecutive points above or below the centre-line;

— any run of seven consecutive points up or down.

Figure 3 shows the following:

a) There are two quite different stages of performance.

b) The process was running initially at an overall fault rate of around 10 % (indicated by the dashed centre-line). This percentage provides a measure of overall process capability or performance. This is due to common causes endemic to the system of operation of the process: the accepted state of the art as presently performed. The value of 10 % was, and always had been, the expected level of performance and had been budgeted into the system. Hence, it was not considered a concern to operational management. The system had adapted to the situation by introducing aerospace standards of garment inspection with its attendant internal reject levels. As such, it was considered a premier division quality supplier to its major customer, a quality conscious retailer. However, the adverse effect of this state of affairs on company profit margin and product price was considerable.

c) During this period two points contravene the upper control limit (UCL). This indicates two undesirable "out-of-control" situations due to the presence of special causes. These causes were investigated and assigned to a broken needle and a sewing shop re-organization, as indicated on the control chart.

Management got very uptight about the broken needle situation, as a single machinist had worked with it during a whole period of overtime causing perforated crotches on many dozens of briefs. Whilst it is seen that the elimination of these special causes brought the process back into control it had no material effect on the reduction of overall faults.

d) Towards the end of the 10 % run, seven consecutive plotting points are below the original centre-line. This indicates a desirable out-of-control situation. It indicates that the process overall performance has changed significantly for the better. This was due to a management led shake-up and major training and personnel development initiative which gave rise to a reduction in common cause variation from a nearly 10 % fault rate to less than 1 %.

e) This significant improvement in process performance is reflected by a lowering of the upper control limit (UCL) resulting from the decrease in fault rate from 10 % to less than 1 %.

f) An out-of-control situation that causes a blip to nearly 5 % at the new level was caused by an oil leak from one machine causing staining of a number of garments.

This example illustrates why it is important to differentiate between special and common cause variation. The sporadic special cause variation is due to specific activities attributable to a machinist and direct support personnel caused by a weakness in operational control.

The initial overall performance of a 10 % fault rate, however, is a result of common causes endemic in the system, which is a management responsibility. Management should be judged on whether or not their words of dedication to never-ending improvement is actually showing through in improvements in the capability of processes evidenced by the simple but very revealing attribute data control chart.

Summarizing, Figure 3 illustrates that an attribute control chart is no more than a simple run chart with additional guidance in interpretation in the form of centre-lines and control limits. It is easy to create and yet it provides direct visual answers to the three key questions one should be asking of every significant process in any organization, namely:

i) Is the process in control?

ii) What is the performance of the process?

iii) Is there evidence of improvement in performance?

An additional point is that many control systems include reaction procedures only for adverse "out-of-control" situations. It is illustrated here that a process also needs to go "out-of-control", in the favourable sense, for an improvement in performance to occur.

5 Business process focus and management

5.1 Business process focus

In today's business environment, a process focus is essential, as each and every activity, function or task within an organization can be considered to be a process. In focusing on the processes, a number of concepts and principles should be borne in mind. These are as follows.

a) The mindset of today is one of prevention and continuous improvement.

b) Process improvement focuses on the end-to-end (concept to customer) process.

c) Process improvement stems from a disciplined and structured approach.

d) Processes have internal customers (e.g. down-stream recipient), and external customers (e.g. end-users).

e) Customer expectations drive process improvement.

f) Every business is made up of processes.

g) Every person manages a process.

h) Every person is simultaneously both a supplier to someone and a customer of someone else.

i) Every process has inputs and outputs.

j) Every process has resources and controls.

k) Process characteristics affect output.

l) Processes cross organizational boundaries.

m) Processes are often independent of hierarchical organizational structures.

This leads to a concept, a need and three very pertinent business questions that require answers:

— *Concept*: every process generates information (voice of the process) that can be used to control and improve its performance.

— *Need*: to develop informed perceptive observers using appropriate methodology.

— *Questions*:

i) Is the process in control?

ii) What is the performance of the process?

iii) Is there evidence of performance improvement?

Proper application of the control chart within an appropriate process management environment provides the answers to these three questions.

5.2 Business process management

5.2.1 *Four key steps*

Effective process management involves four key steps:

a) identify and define the process (see **5.2.2**);

b) establish responsibilities (see **5.2.3**);

c) define and establish process controls (see **5.2.4**);

d) ensure an ongoing commitment to continual improvement in performance (see **5.2.5**).

These four steps will help everyone to:

i) better understand their processes from start to finish;

ii) focus on the principal elements of each process that help contribute to, or detract from, customer expectations and process efficiency;

iii) continuously monitor, evaluate and improve each process and ensure responsiveness to change;

iv) adopt a structured approach to defining process goals and understanding the best way to go about achieving them.

5.2.2 *Identify and define the process*

The process should be identified and developed as follows.

a) Isolate a discrete set of related activities.

b) Identify this named set in terms of inputs and outputs, resources and controls.

c) Construct a process model. This process model is often best expressed pictorially by developing process flow charts or cascades of block diagrams from simple block diagram models.

This activity will help focus the attention and efforts of process members. It will ensure that they, and others on whom they rely (e.g. suppliers of product and information) and support (e.g. customers), share a common understanding of the nature of the process and the impact of its performance on both the processor, customers and input suppliers.

5.2.3 *Establish responsibilities*

Responsibilities should be defined as follows.

— Ensure that there is someone in charge of the process.

— Ensure that individual responsibilities are established for process control and team responsibilities for process performance improvement.

The primary objectives at this step are to:

a) identify an overall process owner who is ultimately accountable for the process and who manages the process across functional and organizational interfaces;

b) define roles and responsibilities of everyone involved in process control and process improvement;

c) ensure significant interface interests are represented;

d) make it quite clear who is responsible for initiating and managing reaction to out-of-control signals and process improvement projects.

5.2.4 *Define and establish process controls*

Ensure that controls are established to ensure stability of the process and to enable assessment of the degree to which the process is satisfying customer expectations and business objectives. This involves the definition of:

a) *what to control*. Identify control subjects that are relevant. Use selective emphasis. Separate the vital few from the trivial many. For example, key accounts might have preferential treatment; bottlenecks might have special consideration and characteristics generally that receive controls appropriate to their criticality;

b) *dominant influencing factors*. Although a process can be subjected to many sources of variation often a few sources predominate. Once located these predominant factors provide the basis for economic and effective control. Dominant factors to look out for include:

i) information dominant: where non-conformities and other undesirable events arise from frequent job and requirement changes;

ii) time dominant: where process performance changes with time;

iii) set-up dominant: where the characteristic is highly reproducible once correctly set up;

iv) process dominant: where the process output is highly dependent on certain process parameters;

v) processor dominant: where the process is highly dependent on the skill, care and attention of the people performing the task.

c) *the level of control.* Choose the appropriate level of control. Examples are:

i) automatic control, e.g. thermostatic control of temperature, laser scanning of fabric for faults during production, traffic lights and sleeping policemen (humps) in the road;

ii) self-regulation by the person performing the task (e.g. the car driver who drives naturally on the proper side of the road and obeys traffic signals);

iii) independent check/inspection/test/audit;

iv) information control where selected personnel are provided with reports of errors and absenteeism.

Whatever the decisions made in terms of items a) to c) the methods of process control recommended in this standard have universal applicability to attribute data characteristics. The control charts described are easy to construct and interpret. They express a common language readily understandable throughout the world.

5.2.5 ***Assess and improve process performance***

Achieving and maintaining stability of a process is essential. Control, too, in the sense of meeting budgets, quota and specifications is equally important. But holding rejects at a budgeted level of, say, 7 %, particularly if this loss exceeds the profit margin, obviously does not make good business sense.

The conclusion is that a preoccupation with control should not blind one to the needs, expectations and opportunities for process performance improvement.

A number of thought stages are involved in successful process improvement projects. These include:

i) understanding the extent to which process performance affects customer (internal and external) satisfaction and process cost;

ii) appreciating the need to achieve a stable process by applying appropriate controls before assessing process performance;

iii) estimating "first-run" process performance for individual process stages and for the process as a whole;

iv) prioritizing opportunities for improvement;

v) achieving and sustaining improved levels.

6 Supporting techniques for effective process control and performance improvement

6.1 Overview

Process diagnostic and performance improvement activities normally involve the use of supporting techniques such as process modelling and flow charting, Pareto diagrams and cause and effect diagrams. These techniques are frequently used in two principal ways. Firstly, in conjunction with the discrete data control chart in pinpointing and eliminating special causes to resolve adverse out-of-control situations. Secondly, in the assessment of improvement opportunities and the setting of priorities to reduce common cause variation to exploit advantageous out-of-control situations.

6.2 Process modelling and flow charting

6.2.1 ***What is a process?***

A process is a set of inter-related or interacting activities that transforms inputs into outputs. An individual process is best portrayed in simple block diagram form showing inputs, outputs, resources and controls as shown in Figure 4.

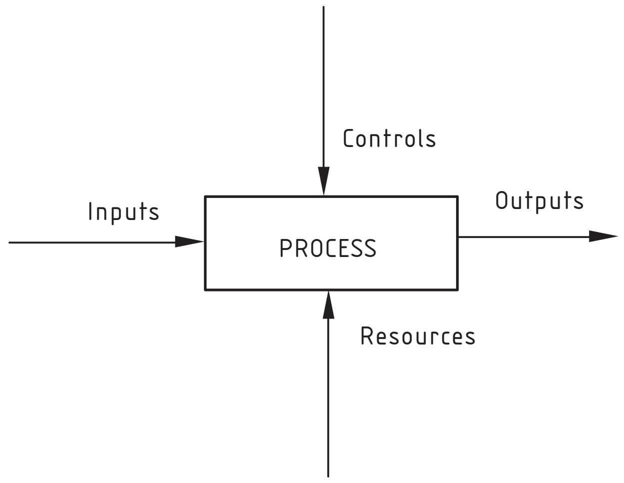


Figure 4 — Basic process model

NOTE 1 *Inputs* are materials and/or data that are transformed by the process to create outputs.

NOTE 2 *Outputs* are the result of transformation of inputs. Outputs can include acceptable customer wants, unacceptable process wants, waste and process information.

NOTE 3 *Controls* are regulators and/or influences on the process. Controls embrace procedures, methods, control plans, standards and legislation.

NOTE 4 *Resources* are people, equipment, material, space, etc. that are not transformed into output.

An application of a typical basic process model is shown in Figure 5.

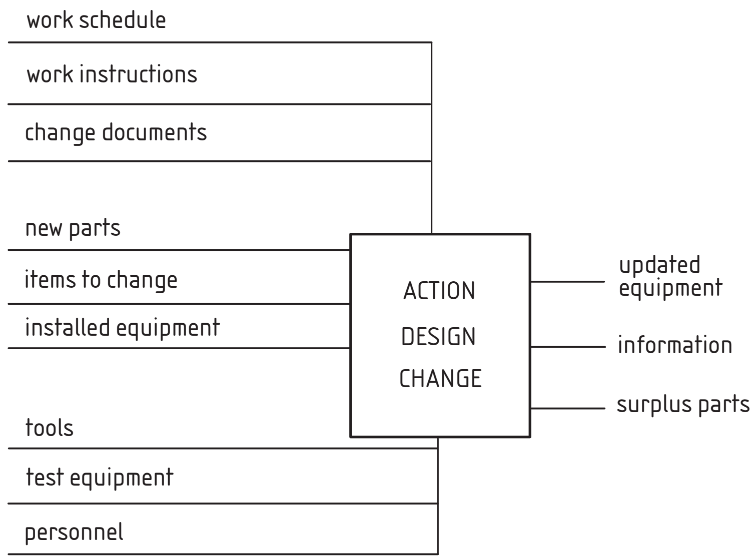


Figure 5 — Application of the basic process model to the actioning of a product design change

A process can relate to a complete organization in macro format; to a single task in micro format (as in Figure 5) or to a set of several processes in cascade form (as in Figure 6).

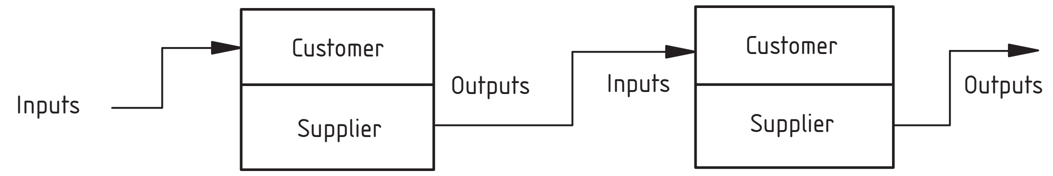


Figure 6 — Business is made up of integrated multistage processes

6.2.2 ***Integrated process flow diagram***

Figure 7 shows a model of an actual integrated process consisting of a number of stages. It shows the opportunities for monitoring at various stages to provide information in order to control, measure and improve process performance.

Such monitoring is most beneficial when it takes place on process parameters that have a significant impact on the output of each stage of the multiple stage process prior to the output being produced. This facilitates the achievement of first run capability at each stage.

Figure 7 illustrates the distinction between the strategy of detection associated with post-process monitoring and the strategy of prevention possible with in-process monitoring. Examples of post-process monitoring, namely "after the event" product characteristic monitoring, include number and types of fault at each stage, and post-process stage inspection information. Examples of in-process monitoring, namely "during the event" process parameter monitoring, include ram velocity, transition pressure, cooling time, pin positions on extrusion, proximity switch position, router choice, extruder type and trimming blade status.

Whilst Figure 7 relates to a manufacturing process, the same approach is applicable to any process in any organization.

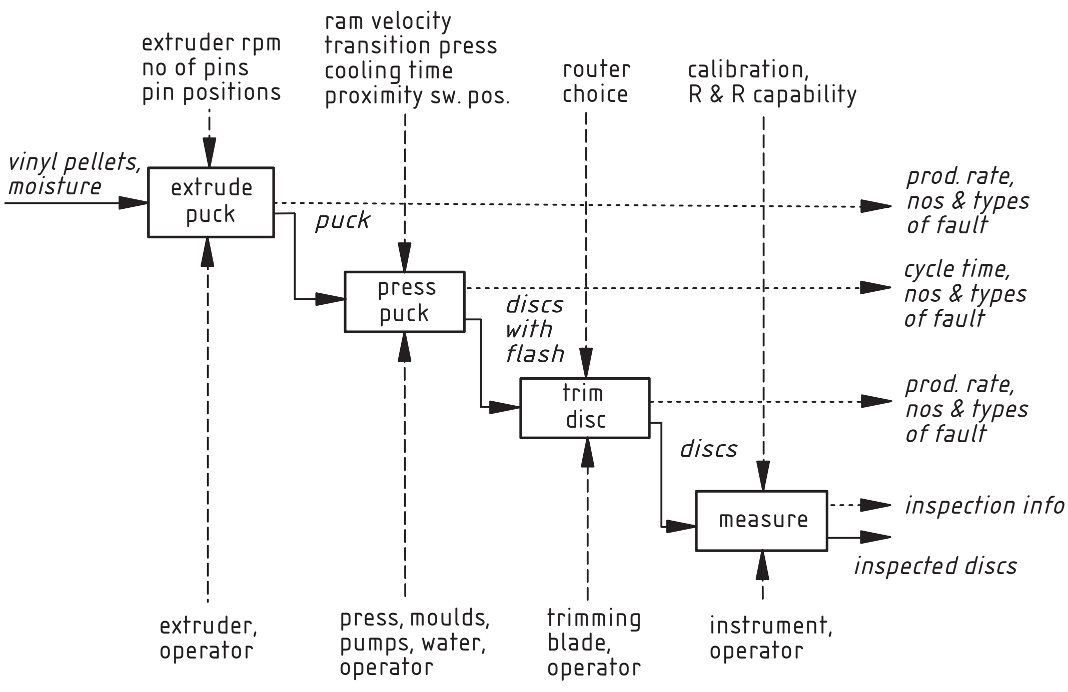


Figure 7 — Video disc pressing: flow diagram of integrated multistage process

6.2.3 *Case study: overall process first time capability*

In a multistage process, many stage decisions are taken by individual functional business units in order to optimize the stage for which they have departmental responsibility. In Figure 7, for example, the extrusion section has operational responsibility for extruding the puck and the press section for pressing the disc. Each section can well be concerned, almost exclusively, with meeting its own departmental requirements without real regard to the effect of this on the line as a whole.

It is essential in such a situation to ensure appropriate management, focus and coordination to optimize overall line performance. An important aspect of this is to have a means of assessing the overall performance of the integrated line in terms of individual stage process performance. From a quality viewpoint, such line performance is estimated from its first time capability rather than its logistic performance.

Figure 8a) shows three scenarios regarding the disposition of faulty items:

Three scenarios: re: disposition of faulty items
Process 1. all scrap
Process 2. all rework
Process 3. some scrap, some rework

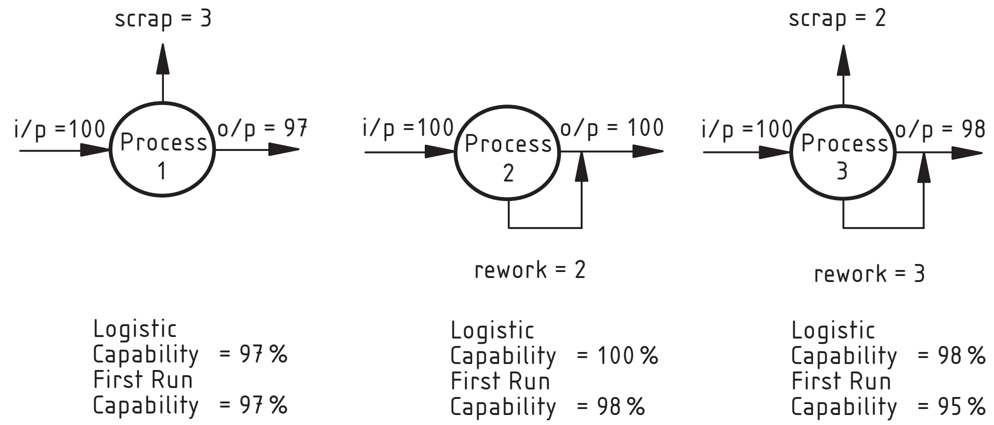


Figure 8a) — Illustration of the calculation of logistic capability and first run capability of a process stage

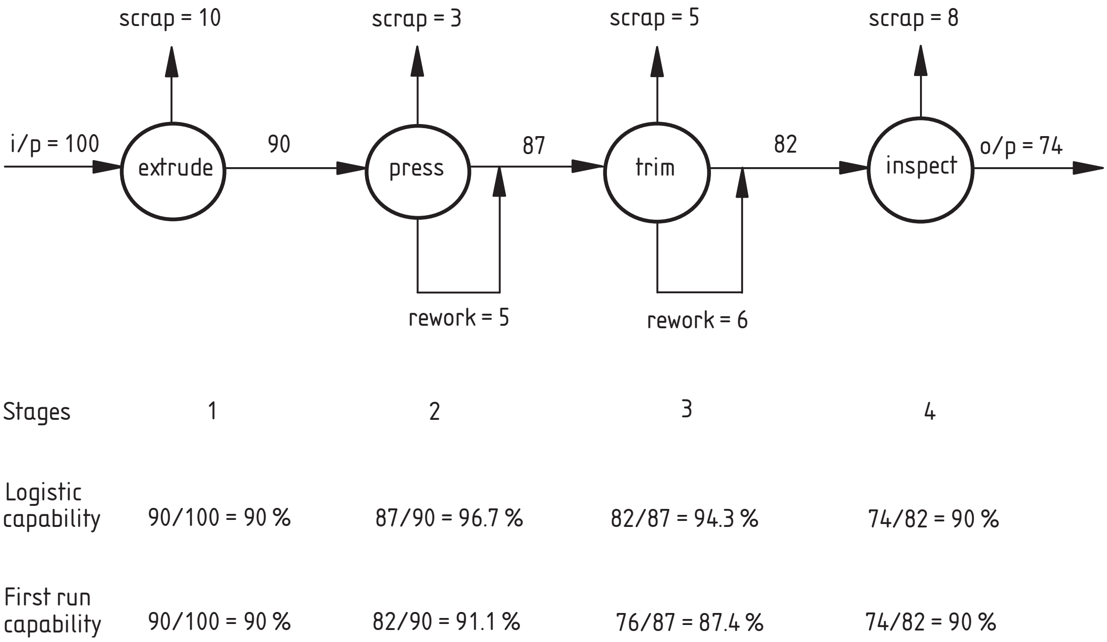
NOTE 1 Logistic capability $= \frac{\text{good output}}{\text{input}} \times 100\ \%$.

NOTE 2 First run capability (FRC) $= \frac{(N-W)}{N} \times 100\ \%$.

N = number of items entering the process.

W = waste = number of items that are not processed right first time whatever the ulitmate disposition (e.g. reworked, scrapped).

In Figure 8b), the principles of Figure 8a) are applied to the integrated multistage process illustrated in Figure 7.



Overall process logistics capability = 74/100 = 74 %

Overall process first run capability = (100 – 10 – 8 – 11 – 8)/100 = 63 %

Figure 8b) — Logistic and first run capabilities of the video disc manufacturing process

Figure 8b) shows that whilst stage capabilities look quite respectable, being in the 90 %'s, overall capabilities of the integrated multistage process are much less attractive. It also shows that the logistic capability, at 74 % overall, is much more optimistic than the actual first run capability, at 63 % overall.

These examples illustrate the value of the use of overall first run capability to identify process improvement opportunities, to exploit these, and to verify the effectiveness of any changes made to the process. They also show the need for an overall management perspective when dealing with multistage processes rather than the narrow stage view that can be taken by discrete functional departments.

6.3 Pareto analysis

Pareto analysis is a simple graphical technique for displaying the relative importance of features, problems or causes of problems as a basis for establishing priorities. It distinguishes between the "vital few" and the "trivial many" and hence focuses attention on issues where maximum quality improvement is secured with the minimum effort. An example is shown in Figure 9.

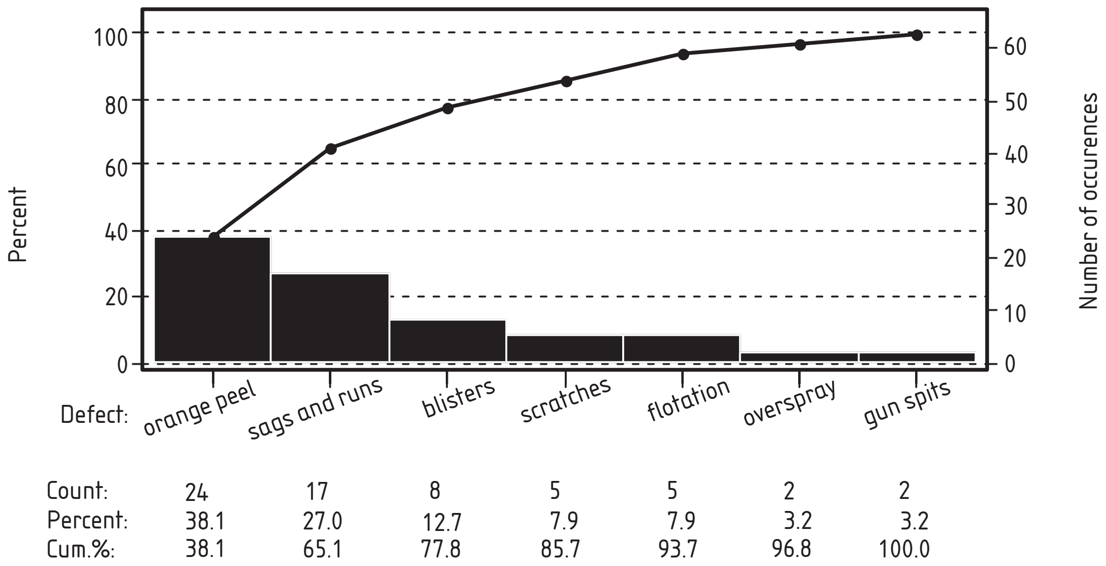


Figure 9 — Example of Pareto diagram for paint process faults

NOTE The faults are arranged in order of incidence in Figure 9. However, other measures of meaningfulness, such as costs, are sometimes used. For instance, one fatal accident insurance claim can be of much greater significance than dozens of claims for minor injuries

6.4 Cause and effect diagrams

The cause and effect diagram is often called an Ishikawa diagram (after its Japanese creator) or a fish bone diagram because of its shape. It displays pictorially possible cause and effect relationships and is intended to help determine the root cause(s) of a problem. An example of a process-based cause and effect diagram is shown in Figure 10.

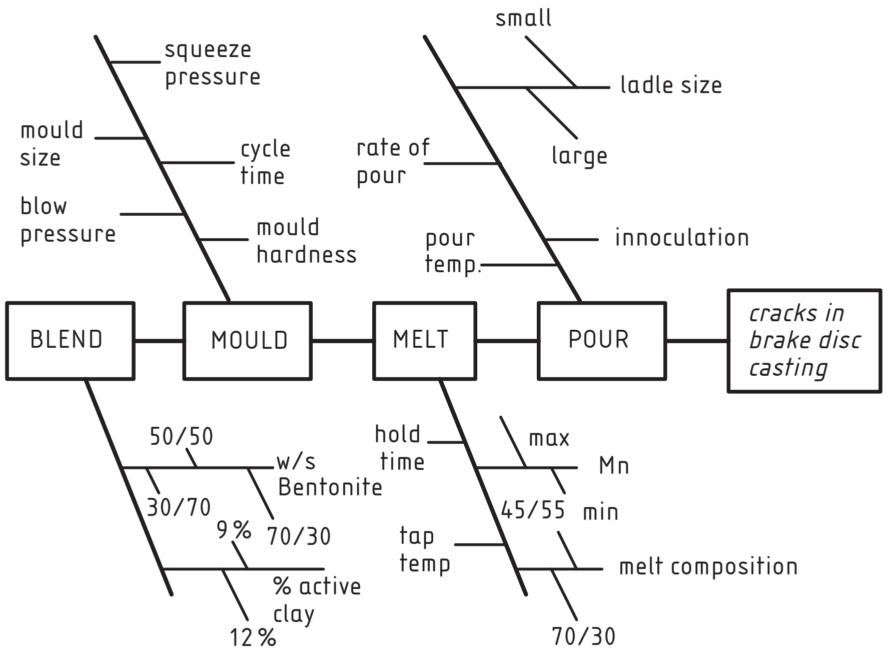


Figure 10 — Process cause and effect diagram for cracks in a brake disc casting

6.5 Check sheets/tables

The object of a check sheet/table is to gather data in the form of frequencies in order to detect patterns. It can be in the form of a tally chart in terms of elements of a concern, or opportunity, (e.g. by type of fault) or by presenting numbers (figures) in a column and row format.

An example of a check sheet/table is shown in Annex A.

7 Relationship with Six Sigma initiatives

A number of organizations have adopted the Six Sigma initiative [1]. The Six Sigma initiative consists of a performance measure, a performance benchmark and an organization-wide continual improvement process. Its relevance to this standard lies in:

a) the setting of a world class benchmark of 3.4 adverse events or non-conformities per million opportunities. This performance level is deemed to be 6 Sigma;

b) the relationship between the Sigma value and non-conformities per million opportunities and equivalent percentage yield as expressed in Table 2;

c) the organization-wide continual improvement initiative that is statistically based.

Table 2 — Relationship between Sigma value, non-conformities per million opportunities and percentage yield

Six Sigma Sigma Value	Non-conformities (or events) per million opportunities	Yield %
1	691 462	30.8
2	308 538	69.1
3	66 807	93.3
4	6 210	99.4
5	233	99.98
6	3.4	99.999 7

This standard provides methods to support the Six Sigma continual improvement initiative in respect of attribute data. However, the principal purposes of this standard are to engender a mindset and provide methods that support the targeting on:

1) "preferred value or condition", rather than something that is "just acceptable" by proposing an offset or relief from a target condition.

2) zero fault rates, rather than an arbitrary finite value.

8 Typical case study

8.1 Overview

A case study illustrates the wide range of application of attribute charting and associated control and improvement tools.

Attribute charting is simpler to apply than measured data charting. However, unlike for measured data where decisions are made against objective criteria, attribute data judgements are frequently taken on a subjective basis. The effective application of attribute data is thus highly dependent on decisions taken on, say, whether an item is classified as acceptable or not acceptable or whether a slight flaw or blemish warrants being termed a non-conformity. This prior need to ensure appropriate decisions are taken is dealt with in Part 4 of this standard.

Another possible concern with attribute data is the need for a larger sample size than that for measured data, particularly on high performance processes.

8.2 Role of attribute control charting in defining and monitoring an improvement project

8.2.1 *Scenario*

Consider the trouser manufacturer who has come under pressure from his principal customer, a high quality retailer, because of the occasional faulty garment getting through 100 % final examination. The initial reaction of the manufacturer was to put in an additional inspection stage in spite of its adverse impact on an already very thin profit margin. The retailer's reaction was quite different: analyse the situation with a view to eliminating the production of sub-standard garments. This case study illustrates the initial stages of this activity.

8.2.2 *First time quality profile of one trouser line*

The quality profile of one of the trouser lines was established over a period of 52 working days. The particular line consisted of 13 discrete operations and 22 machinists were involved. A simple run chart was first constructed by plotting the number of faults per working day. A centre-line and upper and lower control limits were superimposed on this plot. This has the effect of transforming the run chart into an attribute control chart as shown in Figure 11.

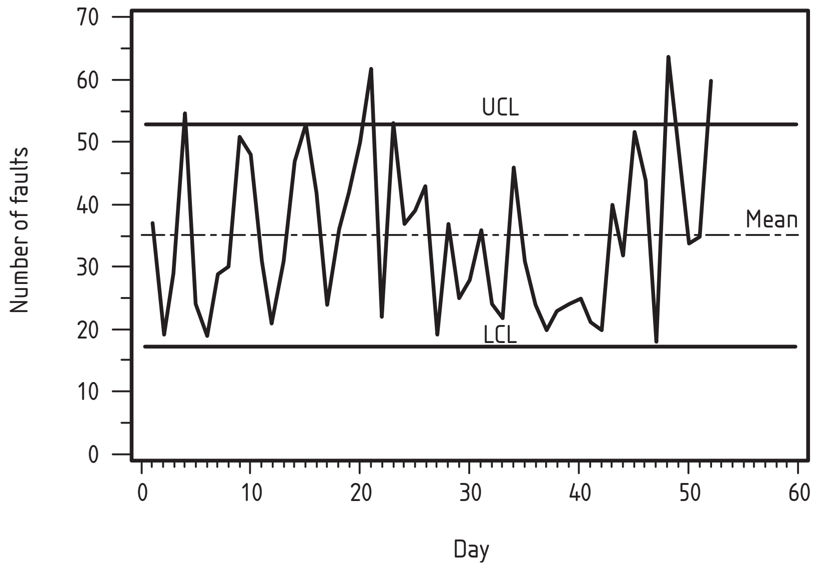


Figure 11 — First time quality profile of trouser line

NOTE 1 Figure 11 is constructed from the data given in Annex A.

NOTE 2 The mean is determined from the total number of faults divided by the total number of working days = 1 830/52 = 35.

NOTE 3 The upper control limit is determined from: mean + 3 $\sqrt{\text{mean}}$ = 35 + 18 = 53.

NOTE 4 The lower control limit is determined from: mean – 3 $\sqrt{\text{mean}}$ = 35 – 18 = 17.

Figure 11 indicates that over this period some 35 faults per day were detected. This excludes those that got through to the retailer and were detected ex-works. There is no evidence of any improvement in overall inherent performance. So this performance is likely to continue into the future unless fundamental issues are addressed. Adverse out-of-control situations arose on four occasions. However, the principal concern here is the ongoing average of some 35 faults per day. Additional inspection to protect the customer can be looked upon as a short term expedient. However, this is unlikely to be wholly effective and, in any case, will have a serious impact on the viability of the business. Quite obviously, there is a need for a drastic review of the whole operation with a view to significantly improving first time quality performance.

The effective use of this data in achieving improvement in line performance is best achieved by first separating out the various potential sources of faults, for example here, by process operation (or type of fault) and by machinist/operator as shown in Annex A.

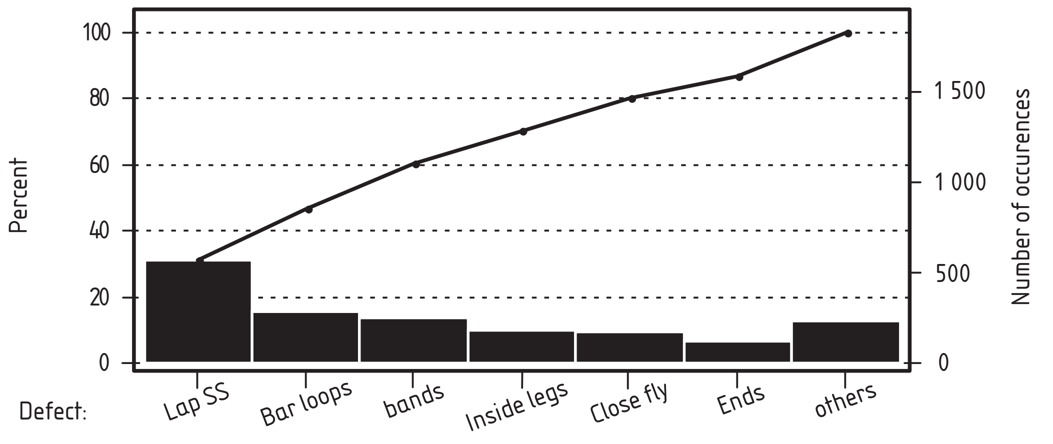
8.2.3 *Principal sources of faults by operation and machinist*

8.2.3.1 *General*

In pinpointing principal sources of faults, it is very important to keep all personnel on-side. One should avoid stating, for instance, that machinist A is responsible for *x* % of the total faults. This makes a gross assumption concerning the cause and can give rise to feelings of antagonism and non co-operation. It is better to state that *x* % of the total faults occur with machinist A. Then ask how machinist A can be helped to increase the quality of her work and hence her earnings and job satisfaction.

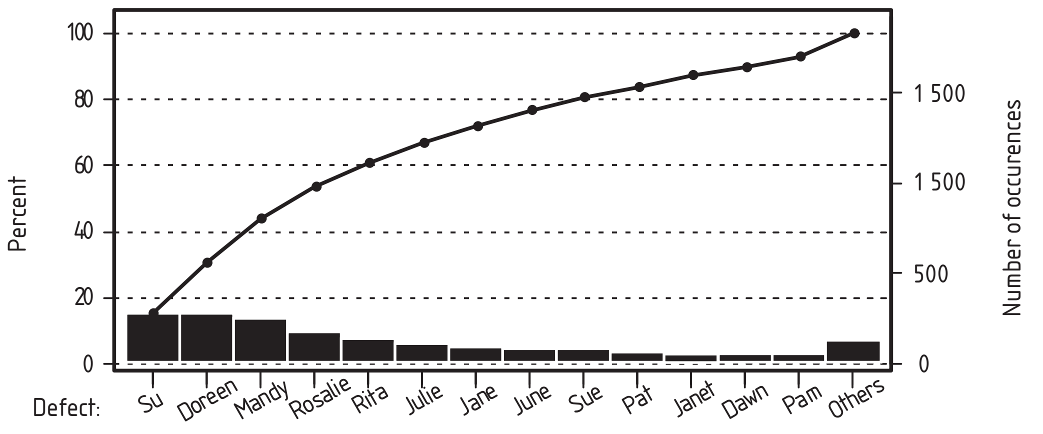
In this case in point, all the machinists are on a bonus system based on good work produced. So it is in everyone's interest to produce fault-free work. The fact that they are not may be due to a number of causes. Machinists work in a system that is not of their making. Isolating the source does not imply responsibility. For example, the effect of previous operations such as panel preparation and cutting, the need to de-skill certain difficult operations, machine settings and capability and workplace and job design can adversely affect the output from a particular machinist's operation.

A preliminary Pareto analysis in terms of operation and machinist is shown in Figure 12 and Figure 13, respectively. These Pareto diagrams provide the key to establishing priorities for improvement. The next step is to plot attribute control charts for those operations and machinists that provide the highest numerical opportunities.



Count:	571	290	250	181	177	124	237
Percent:	31.2	15.8	13.7	9.9	9.7	6.8	13.0
Cum.%:	31.2	47.0	60.7	70.6	80.3	87.0	100.0

Figure 12 — Pareto analysis by process operation



Count	280	275	250	171	138	108	92	83	75	63	60	52	52	130
Percent	15.3	15.0	13.7	9.3	7.5	5.9	5.0	4.5	4.1	3.4	3.3	2.8	2.8	7.1
Cum %	15.3	30.3	44.0	53.4	60.9	66.8	71.8	76.4	80.5	83.9	87.2	90.0	92.9	100.0

Figure 13 — Pareto analysis by machinist/operator

8.2.3.2 *Lap side seam*

Taking the lap side seam operation first where a total of 571 faults have occurred over the period making up over 31 % of the total faults. Four machinists are involved, Doreen, Sue, Jane and Rita. Their control charts are shown in Figure 14, Figure 15, and Figure 16.

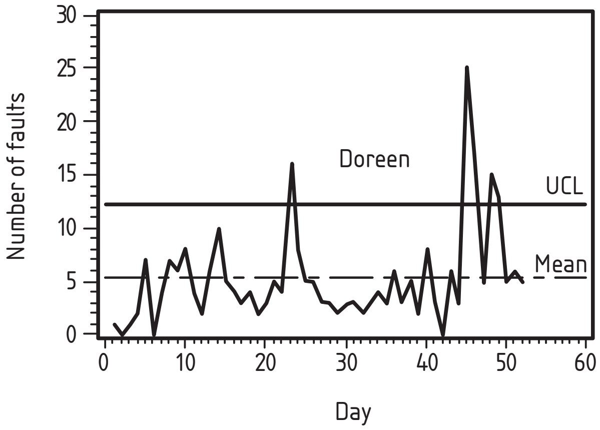


Figure 14 — Doreen lapping side seams (5.3 faults per day); Total 275 faults (15 % of total faults)

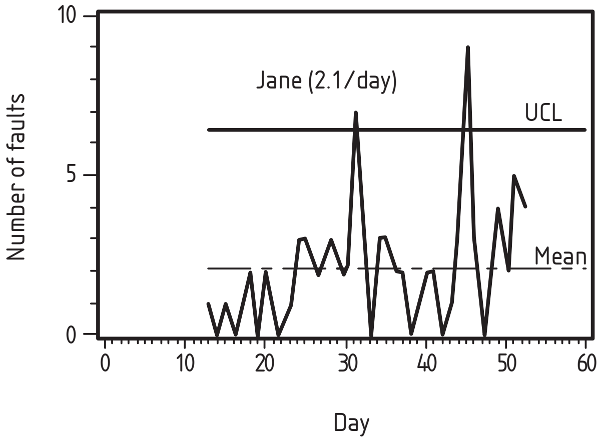


Figure 15 — Jane lapping side seams (2.1 faults per day)

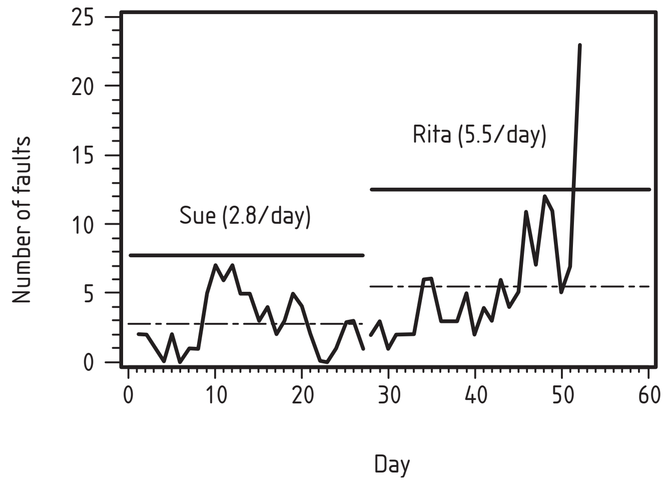


Figure 16 — Sue and Rita lapping side seams

The tentative initial conclusions drawn on lapping side seam performance is that this is the most difficult operation in the assembly of trousers. Even the most skilled machinists, Sue and Jane, suffer a between 2 % and 3 % fault rate. Sue left the company early in the project and Jane followed later. The fault rates borne by Doreen and Rita are about twice that of the other two.

8.2.3.3 *Bar loops*

There is a big contrast between the performance of the two machinists barring the trouser loops as shown in Figure 17 and Figure 18. Brenda is seen to be inherently capable of a virtually fault-free performance. Figure 17 shows that Su initially produced some 8.8 faults per day compared with that of Brenda's 0.19 faults per day. This represents a difference of some 46 times. Following retraining/recalibrating regarding the standard required, Su's performance is seen to improve from 8.8 faults per day to 0.33 faults per day. Apart from the odd special cause concern, Su is now also inherently capable of a zero defect performance. The results from this situation should be sufficient to alert management to the potential for a major breakthrough in business performance. It should be used as an exemplar of what can, and should, be achieved across this and similar lines in the business.

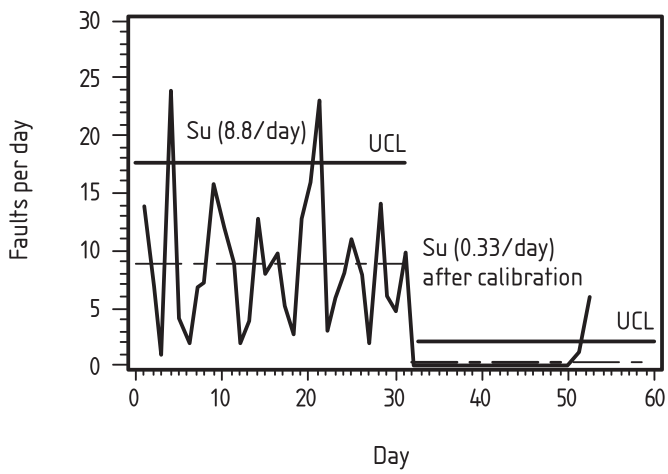


Figure 17 — Su barring loops

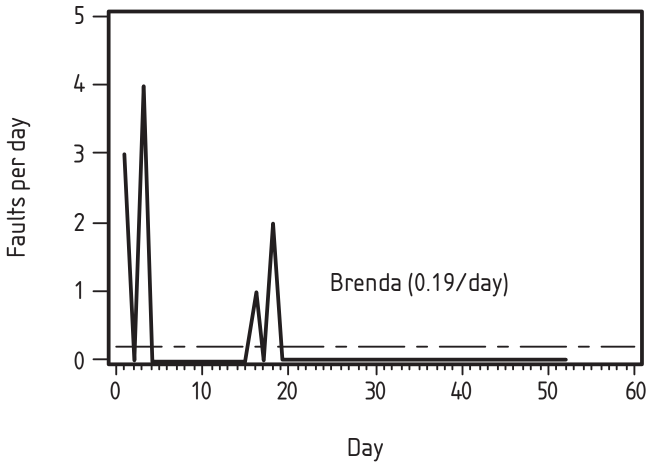


Figure 18 — Brenda barring loops

8.2.3.4 *Bands on*

Mandy is the only machinist on this line putting the bands on. She is looked upon as being a very good operator. However, the control chart in Figure 19 indicates three poor, but quite different, performance levels. An initial performance of 4.9 faults/day is followed by a period of 3.1 faults/day that in turn is succeeded by some 9 faults/day. A similar situation exists on a different line. It appears that shading (variations in colour shade) of the bands, which are supplied in batches, may be a major contributor to the variation in, and sub-standard performance of, this operation. This is to be investigated.

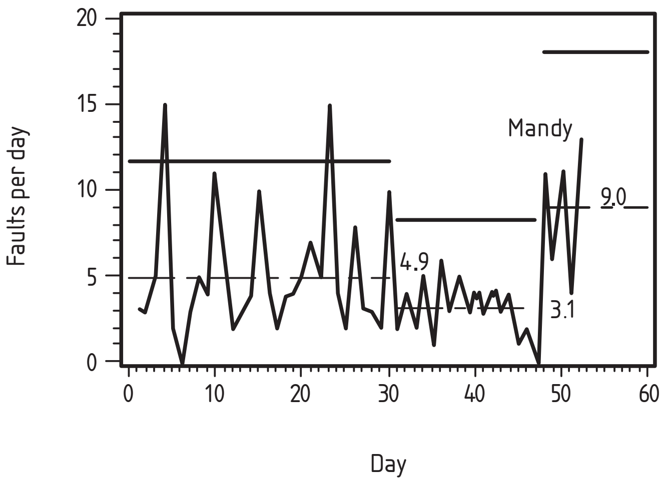


Figure 19 — Mandy putting the bands on

8.2.3.5 *Inside legs*

Three machinists are involved in this operation. Rosalie is known to have problems in getting her centres to meet, as shown in Figure 20, the non-resolution of this has resulted in Rosalie having a long term average output performance of 3.3 faults per day (171/52) making up some 9.3 % of total faults. On the other hand, Delia, and Dorry who took over from Delia when she left, are, apart from the presence of the occasional special cause, inherently fault-free performers.

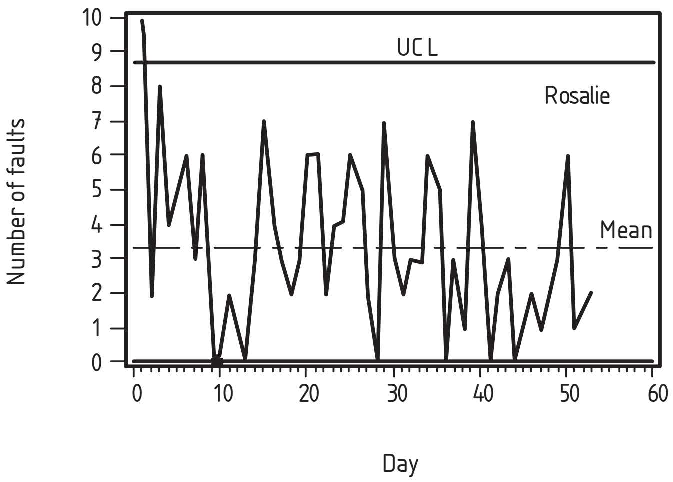


Figure 20 — Rosalie machining inside legs

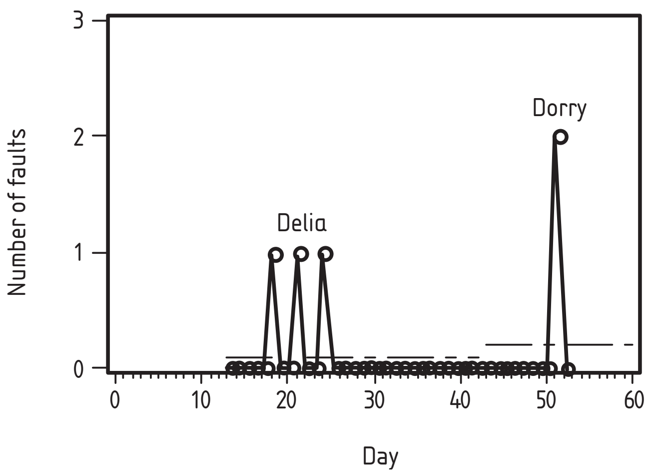


Figure 21 — Delia and Dorry machining inside legs

8.2.3.6 *Close fly*

The consequences of Dawn taking over the job of Shirley, without proper induction, is shown in Figure 22. Fifteen faults were produced on the first day of what was previously a virtually fault-free performance. Janet is seen, in Figure 23, to have a fault rate of 1.5 per day. Jean, in Figure 24, has a different profile. Her performance varies in phases. She appears inherently capable of producing 1.2 faults per day but this can double under certain process conditions.

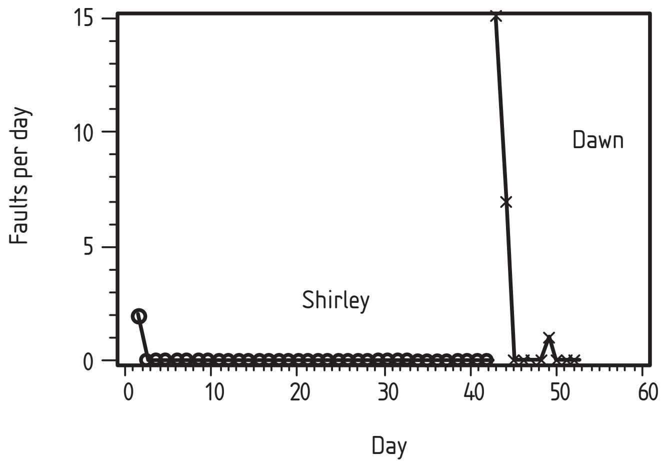


Figure 22 — Shirley and Dawn closing the fly

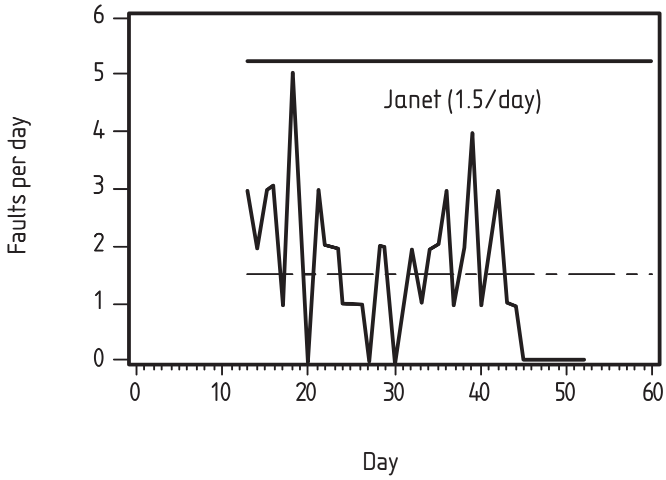


Figure 23 — Janet closing the fly

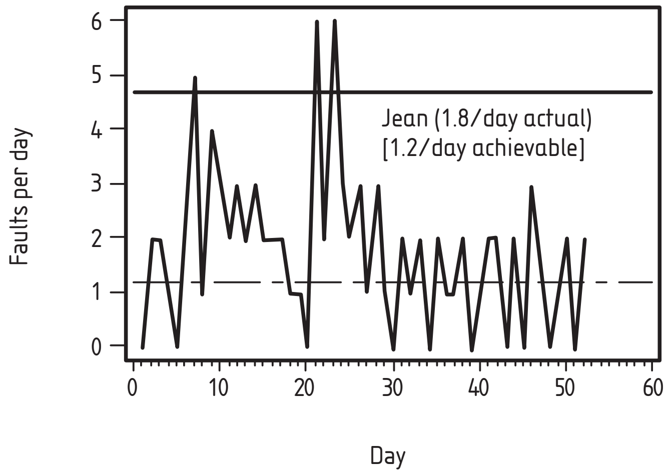


Figure 24 — Jean closing the fly

8.2.3.7 *Situation summary*

This case study illustrates the role of attribute charting in pinpointing opportunities and establishing priorities for significant improvement in business performance. Although dealing with a specific situation, the approach is generally applicable to any business process.

Concentration here has been largely on highlighting ongoing common (inherent) causes where the most substantial scope for improvement occurs. Special causes have not been so addressed in this study as the study was to some extent retrospective. The primary reason for separating out special causes is that they can be dealt with (and are seen to be dealt with) operationally, at source, at the time of the event. The operational value of the control chart in achieving this is obvious from the expectation of a positive reaction, in practice, to each out-of-control situation shown in the control charts portrayed.

Two principal issues are involved, one relating to machinists and the other to management.

A necessary prerequisite is to keep operational personnel and particularly the machinists involved on-board throughout. This is readily achieved if criticism of their relative abilities is avoided and it is put over to them that it is their own interest, financially and job satisfaction wise to seek out and remove the reasons for fault generation. This will, for example, avoid requiring them to undertake the time consuming task of rework with the consequent hassle and loss of bonus involved.

Bringing the data out in the open in such a pictorial manner and by separating out special causes from ones inherent to the operation makes it far less likely for rational management to continue to accept that the currently achieved, and budgeted, norm is really par for the course. It is intended to provoke and stimulate immediate fundamental changes in the way business is conducted. Regardless of the nature of the process the use of simple attribute control charting, in this manner, is supportive of a transparent, focused and decisive style of management aimed at achieving corporate objectives.

Annex A (informative)
Base data for case study of Clause 8

Table A.1 — Base data for case study of Clause 8

Process	Machinist	Day																										
Yokes	Teresa	0	0	0	3	1	0	0	0	1	0	2	0	0	1	1	0	0	0	0	1	0	0	0	0	0	1	0
Bk Seams	Glen	0	0	0	1	2	4	3	1	2	2	0	0	0	1	1	2	0	2	4	3	0	0	0	0	0	0	1
Roll Pkt	Dawn1	0	0	0	0	0	0	0	0	2	1	0	0	0	2	3	1	1	0	0	1	1	0	0	0	2	2	1
Bind	Pam	2	2	3	1	0	2	0	1	0	0	0	0	1	0	0	0	0	1	2	3	2	1	0	0	1	2	1
Serge Fly	Pat	0	0	1	0	0	1	0	0	4	2	0	4	1	1	5	3	3	6	3	2	0	0	0	1	1	0	0
Close Fly	Jean	0	2	2	1	0	2	5	1	4	3	2	3	2	3	2	2	2	1	1	0	6	2	6	3	2	3	1
..	Janet													3	2	3	3	1	5	3	0	3	2	2	1	1	1	0
..	Shirley	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
..	Dawn2																											
Lap SS	Doreen	1	0	1	2	7	0	4	7	6	8	4	2	6	10	5	4	3	4	2	3	5	4	16	8	5	5	3
..	Sue	2	2	1	0	2	0	1	1	5	7	6	7	5	5	3	4	2	3	5	4	2	0	0	1	3	3	1
..	June													1	0	1	0	0	2	0	2	0	0	1	3	3	2	2
..	Rita																											
Bands	Mandy1	3	3	5	15	2	0	3	5	4	11	5	2	3	4	10	4	2	4	4	5	7	5	15	4	2	8	3
Ends	Julie	0	1	0	1	1	2	3	1	7	2	0	0	3	1	3	4	1	0	2	2	3	1	3	0	2	3	2
..	Sharon	0	0	3	3	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	1	3	2	0	0	0	0	0
Barr Loops	Su	14	7	1	24	4	2	7	7	16	12	9	2	4	13	8	10	5	3	13	16	23	3	6	8	11	8	2
..	Brenda	3	0	4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0
Fly Tack	Jeanet	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Zip Stop	Mandy2													0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
..	Heather													0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
..	Jeanet													0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
In Legs	Rosali	10	2	8	4	5	6	3	6	0	0	2	1	0	3	7	4	3	2	3	6	6	2	4	4	6	5	2
..	Delia													0	0	0	0	0	1	0	0	1	0	0	1	0	0	0
..	Dorry																											
Total		37	19	29	55	24	19	29	30	51	48	31	21	31	47	53	42	24	36	42	50	62	22	53	37	39	43	19

Table A.1 — Base data for case study of Clause 8 *(continued)*

Process	Machinist	Day																									
Yokes	Teresa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	12
Bk Seams	Glen	1	0	0	0	0	0	0	0	0	0	0	1	1	1	3	0	3	1	0	0	4	4	0	0	1	49
Roll Pkt	Dawn1	0	0	1	2	3	4	16	3	0	0	1	1	0	1	1	0	0	0	0	1	0	0	0	0	1	52
Bind	Pam	2	0	2	1	1	1	2	2	0	1	2	0	1	2	2	1	0	0	1	2	1	2	0	0	1	52
Serge Fly	Pat	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	3	3	2	0	8	1	0	3	1	63
Close Fly	Jean	3	1	0	2	1	2	0	2	1	1	2	0	1	2	2	0	2	0	3	1	0	1	2	0	2	92
..	Janet	2	2	0	1	2	1	2	2	3	1	2	4	1	2	3	1	1	0	0	0	0	0	0	0	0	60
..	Shirley	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0											2
..	Dawn2																15	7	0	0	0	0	1	0	0	0	23
Lap SS	Doreen	3	2	3	3	2	3	4	3	6	3	5	2	8	3	0	6	3	25	17	5	15	13	5	6	5	275
..	Sue																										75
..	June	3	2	2	7	4	0	3	3	2	2	0	1	2	2	0	1	3	9	3	0	2	4	2	5	4	83
..	Rita	2	3	1	2	2	2	6	6	3	3	3	5	2	4	3	6	4	5	11	7	12	11	5	7	23	138
Bands	Mandy1	3	2	10	2	4	2	5	1	6	3	5	3	4	3	4	3	4	1	2	0	11	6	11	4	13	250
Ends	Julie	3	0	1	4	2	4	2	3	2	2	1	0	0	1	0	4	2	7	3	1	8	6	3	0	1	108
..	Sharon																0	0	0	0	0	0	0	0	0	0	16
Barr Loops	Su	14	6	5	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	280
..	Brenda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
Fly Tack	Jeanet	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	5
Zip Stop	Mandy2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
..	Heather	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0											3
..	Jeanet	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
In Legs	Rosali	0	7	3	2	3	3	6	5	0	3	1	7	4	0	2	3	0	1	2	1	2	3	6	1	2	171
..	Delia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0											3
..	Dorry															0	0	0	0	0	0	0	0	0	7	0	7
Total		37	25	28	36	24	22	46	31	24	20	23	24	25	21	20	40	32	52	44	18	64	52	34	35	60	1 830

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