SAMPLING PLAN FOR INCOMING MATERIAL INSPECTION AT SANDEN

THESIS

Presented to the Graduate Council of the

University of North Texas in Partial

Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

By

Luis Puntel, B.S.

Denton, Texas

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Sanden international, an automobile air conditioning compressor manufacturer, was facing a problem in its incoming material inspection procedures. Although the company had designed and was using its own sampling plan, some managers and supervisors where not confident of its reliability. Sanden recently established a goal for its total number of defects per supplier as one part per million. Achievement of this target required reviews of the existing sampling plan.

The purpose of this project was to help Sanden identify the best alternatives for its incoming material inspection procedures. To do that considerations were made about the usefulness of sampling inspections, theoretical aspects of inspection sampling plans were examined, current sampling plans were analyzed and recommendations were made.

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CHAPTER 1

INTRODUCTION

The Company

Sanden International (U.S.A.), a child company of Sanden Corporation was founded in 1943, and is a manufacturer of automotive air conditioning compressors. Its declared mission is to supply the Western Hemisphere with products of ever-increasing quality and efficiency through continual improvements in its processes and products. Sanden is the world's largest air conditioning compressor manufacturer that is not owned or controlled by an automotive manufacturer, and supplies components to the most demanding and respected companies throughout North and South America and around the globe.

The Problem

The former General Manager for Corporate Affairs, Joseph Rigali, and the present Quality Assurance Manager, Norman Davis, recommended that a special study and review of Sanden's incoming inspections methods be undertaken. Their suggestion was based on the following company guidelines:

- Random sampling must occur for all incoming U.S. supplied parts.
- The total number of defects per supplier must be measured in defective parts per million.

- One supplier lot would equal one day's production from the supplier.
- Regardless of container size or shipping method, a system was required to obtain truly random samples.
- Suppliers must show a *Cpk* of 1.67 for all critical dimensions.

To clarify these points, I discussed them with Richard Grieser, who is responsible for incoming material inspection. From this conversation I learned that:

- Sanden recognizes the importance of establishing a relationship with its suppliers based on mutual confidence rather than solely on incoming material inspection. However, the fact is that this condition is a goal that has not yet been achieved. This indicates the need to retain incoming inspection activities while defining a better supplier relationship system.
- The level of confidence provided by the present inspection plan is unknown. Even though the amount of time spent by an inspector is directly related to the sample size, the true value of the incoming inspection effort has not been established.
- The intended Just-In-Time (JIT) production process requires that Sanden receive parts in relatively small lots. This has an impact on the incoming inspection level of activity and efficiency. Because JIT production results in many known operational benefits, it must be taken into consideration in any proposed incoming inspection plan.

- Sanden is aware of the trade off that exists involving sample sizes and risk levels. What the company wants is to have enough information to make the correct decision.
- Even though the use of plans such as Mill Standard 104 is not strictly missed, it is not encouraged. Sadden's goals are based on defective parts per million, whereas Mill Standards reflect defective parts per hundred (percentage).

Before analyzing the existing SIA sampling plan, I think that it is necessry to examine how valid is the acceptance sampling strategy for the company.

CHAPTER 2

VALIDITY OF ACCEPTANCE SAMPLING

Pros and Cons of Sampling Inspection

Scientific sampling procedures have been available for about fifty years. These procedures have been effective for controlling the critical quality characteristics of a wide range of manufactured goods. Many reference books in quality control include scientific plan based on Military Standard 105E, Dodge-Romig methods, Military Standard 114, and other well-known strategies. Journals often provide new sampling methods. Even American Society for Quality Control's certified quality engineer examination includes a variety of questions on sampling inspection.

However, some authors have made a strong argument against the use of sampling inspections as a standard industry practice. The strongest arguments are probably based on various interpretations of W. Edwards Deming's (1950) third point regarding mass inspection policy. Examples of such opposition to sampling inspection are found in books such as *The Deming Guide to Quality and Competitive Position* by Howard Gitlow and Shelly Gitlow (1987) and *Tools and Methods for the Improvement of Quality by Gitlow,* Gitlow, Alan Oppenheim and Rosa Oppenheim (1980). Another strong argument against sampling plans isoffered by W. Edwards Deming in his 1950 book, *Some theory of Sampling,* in which he shows, based on the theorem published by Alexander M. Mood in the Annals of Mathematical Statistics in 1943, that the number of nonconformances in a sample is independent from the number of defectives in the remainder of the lot. More recently, Gabriel A. Pall (1987), in his book Quality Process Control, states that "acceptance sampling is not statistical inference, and it does not lead to statistically valid conclusions about the lot itself". Philip Crosby (1987) also rejects sampling inspections as a quality management tool. In fact, all of the authors mentioned emphasize the use of prevention to eliminate nonconforming products and the need for inspection.

Thus, manufacturing companies are faced with conflicting recommendations. Industry practice has been to use scientific sampling plans, but many leaders in the quality field appear to reject the technology. It seems that this controversy is far from being solved. The deeper one delves into the arguments against sampling inspection, the more complex decision whether or not to use such strategies becomes. Most authors who argue against acceptance sampling advocate the use of process control as a better alternative. However, none of the authors seems to acknowledge that Shewhart charts also involve sampling. Mood's (1943) theorem flags the control charts principles in the same way it does scientific sampling plans.

Alternative for sampling Inspection

Deming (1950) proposed the kp-rule as an alternative to scientific inspection sampling plans. The decision rule is simple: *p* represents the average fraction of nonconforming items in the incoming inspection, k_1 represents the cost to inspect one item, and k_2 represents the cost per unit for allowing a bad part or assembly to enter the production process. When the ratio of k_1 / k_2 is greater than p, no inspection is necessary. When the ratio is less than p, 100 percent inspection should be performed. It is possible that the information needed to use the kp-rule will be available for a given part or assembly. In this situation, it is reasonable to use the kp-rule. Unfortunately, this is seldom the case.

It is important to note that an accurate estimate of p must be known. This implies that an inspection must be conducted before any decision about implementing inspection can be made. Such an initial inspection usually requires more effort than a so-called first-piece inspection practice. This is because an accurate estimate of p is likely to require a larger sample size than that used in first -piece trials. Furthermore, there is no reason to believe that all quality characteristics will exhibit stationary values of p during the process. Hence, periodic estimates of p are necessary to ensure that the original decision concerning inspections is still appropriate.

The computation of the values of k_1 and k_2 is also very complex because it involves multidepartmental data. The same analyst can achieve completely different results by considering slightly different cost components. With the lack of accurate information, this analyst might be tempted to overestimate k_2. Hence, 100 percent inspection tends to become the usual practice. Of course this is not desirable.

Thus, without appropriate cost estimates and an accurate value for p, the kp-rule does not appear to be a viable inspection policy. This is especially true when considering an incoming material acceptance inspection. In this case, the lack of information is even more critical.

Perspectives for Scientific Sampling Plans

Although the goals for any manufacturing operation are effective quality plans, well-designed process control operations, and minimal or no inspection, a role remains for acceptance sampling. Despite the most detailed and careful planning, the world is not perfect and mistakes occur. Well-run processes go out of control occasionally. Reliable and conscientious suppliers have problems from time to time. Transportation providers sometimes damage the product. In all these cases, sampling inspection should be viewed as a defense strategy for management.

There has been a significant movement in the United States in recent years toward a parts-per-million (ppm) specification for acceptable quality levels. Even in such an environment, however, inspection can be useful. For this specification one simply needs expanded tables. Of course, expanded tables show the increased sample sizes needed for protection at lower ppm levels. Depending on the specific characteristic of the situation, the increased sample sizes may be impractical or too expensive.

The JIT process implies the use of smaller lot sizes. The use of such a process in operations makes the achievement of low ppm levels practically impossible. In this situation, 100 percent sampling may be the appropriate policy when inspection is needed.

Inspection practices and capabilities are explicitly examined in the ANSI/ASQC Q90 (1987) series or the equivalent ISO 9000 series standards. This is a demonstration that modern quality management systems still rely on inspection as one of the means for quality asssurance.

CHAPTER 3

ACCEPTANCE SAMPLING THEORY

Acceptance Sampling by Attribute

When a company receives a shipment of goods, it samples the shipment and either accepts it was conforming to its standards or rejects it. If the company rejects the lot as below standard, the shipment may be returned to the supplier or it may be kept, depending on how badly the goods are needed or the arrangements that have been made with the supplier. Frequently a price concession is offered on rejected lots. Some companies do not return rejected lots to a supplier until they are reasonably assured through further inspection of the lot that the quality is, indeed, low. A company's own output is frequently submitted to acceptance sampling at various stages of production. A given lot of a product is sampled and either accepted for further processing or shipment to customers, or rejected.

It is important to emphasize that the purpose of acceptance sampling is to determine a course of action, rather than to estimate lot quality. Acceptance sampling prescribes a procedure that, if applied to a series of lots, gives a specified risk of accepting lots of given quality. In other words, acceptance sampling yields quality assurance.

It is also important to emphasize that acceptance sampling is not an attempt to control quality. The control of quality is the purpose of control charts, which guide the engineer in modifying production so as to turn out better products. This is real quality control. An acceptance sampling plan merely indicates when the lot should be accepted or rejected. If all lots are of the same quality, some will be accepted and others will be rejected. However, the accepted lots will be no better than the rejected ones.

The indirect effects of acceptance sampling on quality are likely to be much more important than the direct effects. When a supplier's product is rejected at a increased rate, one of the two things will happen. The supplier will take steps to improve the production methods used or the customer will be led to seek other, better sources of supply. Acceptance sampling thus indirectly improves quality of production through its encouragement of good quality by a high rate of acceptance and its discouragement of poor quality by a high rate of rejection.

The Operating Characteristic Curve

As noted previously, any acceptance sampling plan involves a specified risk of accepting lots of given quality. The risk incurred by using a specific plan can be better evaluated by its operating characteristic curve (OCC). In essence, an OCC shows the probability Pa of accepting a lot that has a certain fraction of nonconforming units p. Each sampling plan has its own OCC. A sampling plan is nothing more than the definition of the sample size n and the acceptance number c. For example, under a particular sampling plan, a sample of 100 is taken from a given lot. If two or less nonconforming units are found, the lot is accepted; if three or more nonconforming units are found, the lot is rejected. The sampling plan for such condition would be designated as a plan $n = 100$, $c = 2$.

The OCC also reveals the discriminatory power of a sampling plan. The discriminatory power of a sampling plan is its ability to differentiate a "good lot" from a "bad lot". A good lot is a lot that has a fraction of nonconforming products that is smaller than a specified value. This is possible because the OCC shows how the probability of accepting a lot varies with the quality of the material offered for inspection.

This can be mathematically explained as follows. If a process is operating in a random manner to turn out *100p'* percent nonconforming items. The product of this process is of quality p'. If lots of size N are made up this product, the fractions of nonconforming parts of the lots follow a binomial distribution. If each lot is submitted to a sampling inspection plan, the probability that a lot will be accepted is the proportion of the lots from the given process that is, in the long run, accepted under the plan. The OCC for the sampling plan is the curve that shows how this probability of acceptance varies with the product quality p'. More precisely, this is know as a OCC of Type B.

The computation of the ordinates of a Type B OCC is a simple matter. To draw lots of N items at random from a (theoretically infinite) process and then to draw random samples of n from these lots is, in essence, the equivalent of drawing random samples of n accepting a lot from a process of product quality p' is the probability that a random sample of size n from an infinite universe with fraction nonconforming p' contains c or less nonconforming items. This is a probability given by the binomial distribution and can be computed from the binomial formula:

$$P(c/n) = \Sigma_{(x=0,c)} \frac{n!}{x!(n-x)!} p'^{x}(1-p')^{n-x}$$

The Type B OCC for the sampling plan $n = 100$, $c = 2$ is shown in Figure 1. As shown in this figure, for example, if product quality is 0.02, the probability of lot acceptance is 0.68. Whenever p′ is small and p′n<5, the binomial distribution can be approximated by the Poisson distribution, which makes the computation of the probabilities easier. Of course, with the availability of powerful computerized packages, this approximation is no longer needed.

The Type A OCC is distinguished from the Type B OCC by the fact that it gives the probability of accepting an isolated lot in opposition to an infinite process, as it the case for the Type B OCC. In this case the probabilities of acceptance are given by the hypergeometric distribution, with the formula:

$$P(X/n) = \frac{\frac{(N-m)!}{(n-X)!(N-m-n+X)!} \cdot \frac{m!}{X!(m-X)!}}{\frac{N!}{n!(N-n)!}}$$

where m is the number of nonconforming in N. As noted, a Type A OCC depends on the lot size involved, whereas the Type B does not. This is shown in Figure 2.

To simplify subsequent discussion I shall consider Type B OCC, since this is the case in Sanden.

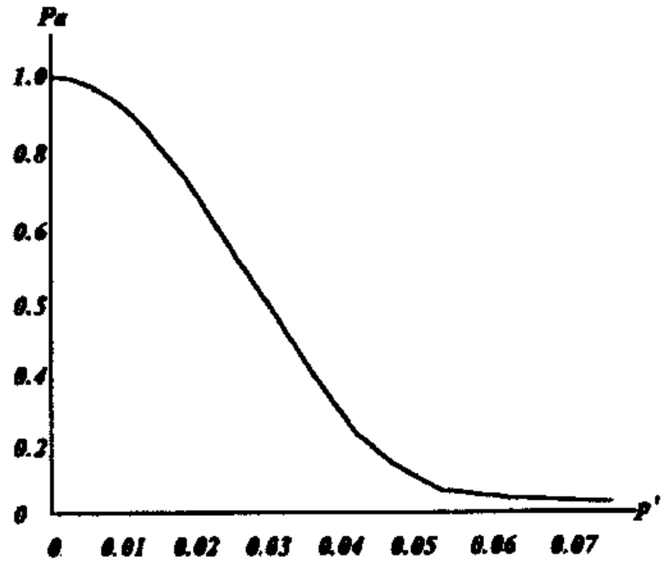

Figure 1 - Type B OCC for sampling plan $n = 100$, $c = 2$

Variation in OCC with n and c

Looking at the Binomial formula, it is evident that the acceptance probability *Pa* for some specific p' depends uniquely upon the values of n and c. Examination of the formula also reveals that a sampling inspection plan that discriminates perfectly between good and bad lots would have a Z-shape. This would run horizontally at a $Pa = 1$ until p' is such that $p'n = c$, at which point it would drop vertically, and then for higher values of p' would run horizontally again at a Pa = 0. Under such a program, all lots with a p' smaller or equal to the maximum allowable fraction of nonconforming units would be accepted, and all the lots with a p' greater than the maximum allowable fraction of nonconforming units would be rejected. Such a plan would give perfect control over the quality of inspected material. Unfortunately, a Z-shaped OCC can only be attained by perfect 100 percent inspection. It can be approached, however, by increasing the sample size. For large lots, this tendency is illustrated in Figure 3, where c is kept proportional to n. Thus the precision with a plan that separates good and bad lots increases as the size of the sample increases. The best size of the sample is always a compromise between the greater precision of larger samples and their greater cost.

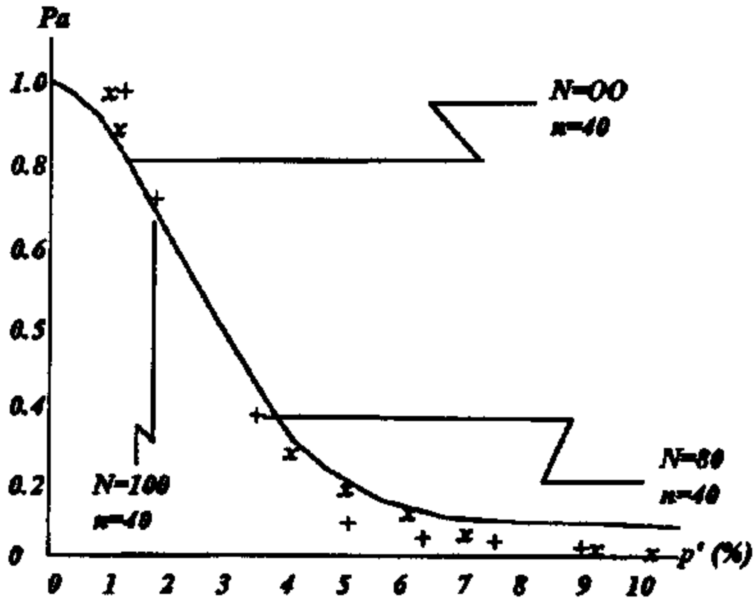

Figure 2 - Type A OCC for sampling plan $n = 40$, $c = 1$

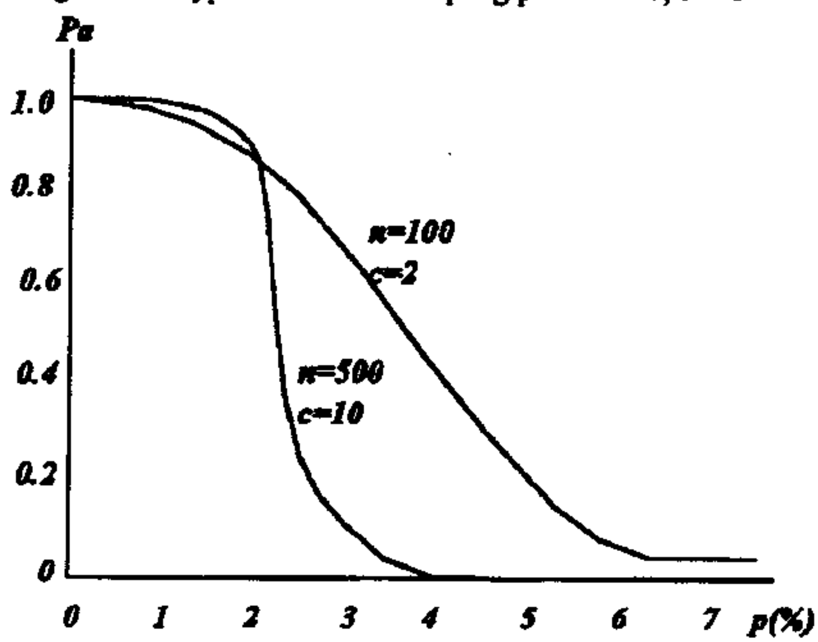

Figure 3 - OCC for samples of different size

How the OCC for a plan varies with the acceptance number c alone is shown in Figure 4. As c diminishes, the plan is tightened up and the effects is to lower the OCC. As c is increased, the plan becomes more lax and the effects is to raise the OCC. From Figure 4 it is clear that a sampling plan with $c = 0$ shows a fast drop in the Pa. This makes the plan yield in a low Pa even for very small values of p′. In other words, a plan with c = 0 makes it easier to reject a lot with a small fraction of nonconforming units.

Characterization of an Acceptance Sampling Plan

Although the complete story is only told by the full OCC a sampling plan, interest sometimes centers on certain parts of the curve. Sometimes it is important to know what lot or product quality will yield a high probability of acceptance. A producer would be particularly interested in this aspect because it indicates the target required to achieve a high rate of acceptance. A sampling plan is thus characterized by its 0.95 or 0.99 point. These may be designated the $p'_{0.95}$ and $p'_{0.99}$ points. At the other end, a consumer might be particularly interested in identifying the lot or product quality that will yield low probabilities of acceptance. The consumer might thus be interested in the $p'_{0.10}$ and $p'_{0.01}$ point.

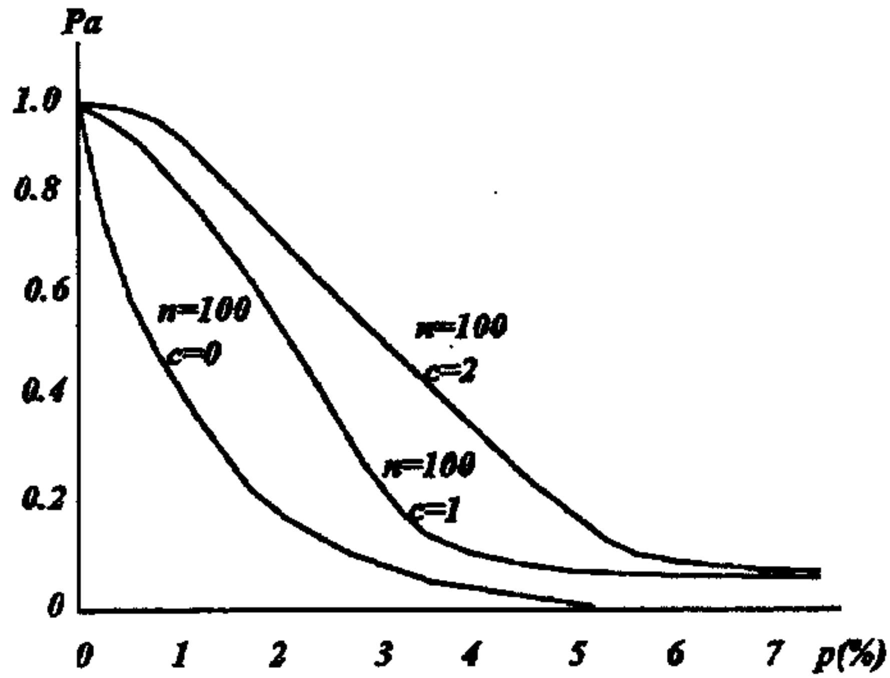

Figure 4 - OCC for Different Acceptance Numbers

When a consumer establishes a sampling plan for a continuing supply of material, he or she commonly does so with reference to what is called an acceptable quality level (AQL). This is the poorest level of quality or maximum fraction of nonconforming units that the consumer considers acceptable as a process average for the purposes of acceptance sampling. The AQL is a characterization of the supplier's process and not of the sampling plan used by the consumer. It is possible, of course, to design a sampling plan such that its $p'_{0.95}$ point or some other particular point is the AQL.

The consumer may also use the Lot Tolerance Fraction Nonconforming (LTFN). The LTFN is an aspect of consumer's standards of acquisition and, as defined, is not a characterization of a sampling plan. It is possible of course to design a sampling plan so that its $p'_{0.10}$ point coincides with a specified LTFN.

Two aspects of a sampling plan that are very useful in the design and analysis of a sampling plan are the procedure's risk or α, and the consumer's risk or β. The procedure's risk is the probability of rejecting a good lot. It is usually used in reference to the rejection of lots from a process with an average which equals AQL. The consumer's risk is the probability of accepting a lot with a quality which is equal to the LTFN.

To design any sampling plan, it is first necessary to define the basic point through which the OCC must pass. For a single sampling plan, two points are needed. In a single sampling plan the decision of accepting or rejecting a lot is based on only one sampling process. Usually, a consumer desires a plan in which the probability of acceptance is 1-α for material of AQL quality and is β for material of LTFN quality. To find a plan that meets these requirements, the Binomial formula or any table or nomograph available in the literature can be used.

Acceptance Sampling by Variables

Discussion to this point has been related to acceptance sampling by attributes. This means the evaluation of the product quality is based merely on its classification as good or bad. However, when a quality characteristic is measurable on a continuous scale and is know to have a distribution of a specific type, usually normally distributed, it is often possible to use as a substitute for an attributes sampling plan a sampling plan based on sample measurements such as the mean of the sample or the mean and standard deviation of the sample. Such plans are called variables sampling plan.

The principal advantage of variables sampling plans is that the same OCC can be obtained with a smaller sample than is required by an attributes plan. Of course, the precise measurement required by a variables plan usually costs more the simple classification of items required by an attributes plan, but the reduction in sample size may more than offset this extra expense. The principal disadvantage of this type of plan is that a separate plan must be employed for each quality characteristic that is being inspected.

There are many different kinds of variables sampling plans. Some are based on the fact that the process standard deviation is not known. Others do not require that the process standard deviation is known. To know the process standard deviation it is necessary to control this process statistically. If this is done, sampling inspection is not needed to decide about the quality of a lot - it is already known. Therefore, the only variables sampling plans that make practical sense in incoming material inspection are those that do not require the process standard deviation to be known.

The OCC of a specific variable sampling plans depends on two parameters - the sample size *n* and the acceptance criterion *k* (there are other methods but they are not considered here), which can be obtained using the following formulas:

$$k = \frac{Z_\alpha Z_2 + Z_\beta Z_1}{Z_\alpha + Z_\beta}$$

$$n = \left(1 + \frac{k^2}{2}\right)\left(\frac{Z_\alpha + Z_\beta}{Z_1 - Z_2}\right)^2$$

To evaluate the acceptance of a lot a sample of n pieces is taken. The lot is accepted if:

$$Z_L = \frac{M-L}{s} \geq k$$

or

$$Z_U = \frac{U-M}{s} \geq k$$

where:

$Z\alpha$, $Z\beta$	> the normal deviate the probabilities of exceeding which are α and β, respectively.
Z_1, Z_2	> the normal deviate the probabilities of exceeding which are AQL and LTFN, respectively.
L, U	> the Lower specification limit and the Upper specification limit, respectively.
s, M	> the sample standard deviation and the sample mean, respectively.

Everything mentioned about OCC and the characterization of an acceptance sampling plan for attributes also applies to acceptance sampling plans for variables.

CHAPTER 4

ANALYSIS OF THE CURRENT SYSTEM

Sanden's Sampling Plan

Sanden formulated its sampling plan many years ago, and named it Supplier Quality Assistance Sampling Procedure (SQASP). Since its formulation, the procedure has been reviewed many times, but its original format has been retained.

the current SQASP is shown in Table 1.

Lot Size	Sample Size			Accept Number	Reject Number
	Normal	Severe	Critical		
0-50	20	25	100%	0	1
51-150	20	40	65%	0	1
151-500	25	45	85%	0	1
501-3200	25	50	90%	0	1
3201-35000	30	70	90%	0	1
35000-Over	35	75	100%	0	1

Table 1 - Sanden Sampling Plan

In Table 1, three levels of inspection are considered: (1) normal, which is used as a general rule, unless the following conditions apply; (2) severe, which is imposed when field failure or customer complaints dictate that a more critical inspection is required; and

(3) critical, which is used when customer requirements dictate a safety-related characteristic.

Rick Grieser confirmed that the severe and critical levels of severity where rarely used, but that an evaluation of their effectiveness would be helpful. He also provided the Table 2, which illustrates the number of lots received that corresponds to each of Sanden's lot size categories:

Lot Size	Total	Mass Prod.	Validation	Frequency
	# of Lots	# of Lots	# of Lots	
0-50	96	31	65	0.04
51-150	99	73	26	0.04
151-500	224	175	49	0.1
501-3200	893	820	73	0.39
3201-35000	818	752	66	0.36
35000-Over	154	154	0	0.07
Total	2,284	2,005	279	1

Table 2 - Receiving Lot Sizes

As shown in Table 2, approximately 75% of the received lots had between 501 and 35000 units. Therefore, most of the analyses are performed considering a lot be made up of 501 to 35000 units.

Analysis of the SQASP

SAS was used for the computation of the OCC and the risks incurred by Sanden using the sampling plan showed in the Table 1. SAS was also used to produce the results of all simulations performed. The coding and the output printout are provided in appendix A and appendix B, respectively.

The probability of accepting a lot that has *100p* percent of nonconforming items, for different values of p and for each one of the sample sizes considered in the SQASP, is shown in Table 3 From Table 3, it is apparent that the sampling plan used by Sanden does not provide a high level of assurance for the quality of incoming material.

n	c	p=.001	p=.005	0.01	0.02	0.05
20	0	0.98	0.96	0.82	0.67	0.36
25	0	0.98	0.95	0.78	0.6	0.28
30	0	0.97	0.94	0.74	0.55	0.21
35	0	0.97	0.93	0.7	0.49	0.17

Table 3 - *Pa* for different n and p

For the largest sample size (35), the probability of accepting a lot with 1 percent nonconforming units is approximately 70 percent. When the most used sample sizes (25/30) are considered, the *Pa* goes as high as 74 to 78 percent for p=1 percent, and 21 to 28 percent. These numbers show the high risk rate of receiving lots of poor quality incurred by Sanden. For someone targeting a rate of 1/1,000,000, the current plan was obviously not the most appropriate.

To achieve a better discriminatory power using an attributes sampling plans, it is necessary to increase the sample size n, because the acceptance number c is already in its smallest value. As shown in appendix, $n = 220$ results in a $Pa = 11$ percent for a $p = 1$ percent and a $Pa = 0.001$ percent for a $p = 5$ percent. For a p as small as 0.001, the Pa is only 64 percent. Of course, a sample size of 220 units is beyond any practical possibility. Nevertheless, this is the sample size that could turn the SQASP into a more reliable Sampling Plan.

If Mil.Std. 105D was used, the sample size code for lots with 501 to 35,000 units would be J, K, L and M, assuming the General Inspection Level II. Such codes result whenever the normal inspection is used in sample sizes of 125 (for J, K, L) and 500 (for M) units, respectively. The sampling plans formed by $n = 125$ and $c = 0$ yields approximately in a $Pa = 88$ percent for $p = 0.1$ percent, $Pa = 28$ percent for $p = 1$ percent and $Pa = 0.2$ percent for $p = 5$ percent. The sampling plan formed by $n = 500$ and $c = 0$ yields approximately in a $Pa = 61$ percent for $p = 0.1$ percent, $Pa = 0.7$ percent for $p = 1$ percent and $Pa = 0$ for $p = 5$ percent. These values indicate that there would be no especial reason to use the sampling plan (220;0) rather than the standardized plan (125;0/500;0). The impracticability of the sample size, however, would not allow the use of Mil. Std. 105D.

One alternative to reduce the required sample size is to use a variables sampling plan instead of the attributes sampling plan. To make it possible to compare its effectiveness, many simulations were run. In the SAS printouts one can see that a variables sampling plan (n=98; k=2.598) corresponds to the attributes sampling plan (n=220; c=0). This is still a large sample size, but it shows that there is a potential reduction in the value of n that justifies further studies.

Assuming that the producer's risk is intended to be related to a value of p=1/1,000,000, it does not matter too much if the *Pa* is relatively small for $p = 0.1$ percent. In this case, a variable sampling plan with $n = 16$ and $k = 3.076$, which results in a $Pa = 51$ percent for a $p = 0.1$ percent, $Pa = 10$ percent for a $p = 1$ percent and a $Pa = 0.7$ percent for a $p = 5$ percent, represents a feasible alternative for the SQASP, because its $Pa = 99.8$ percent for $p = .1/1{,}000{,}000$.

Analysis of Mil. Std. 414 reveals that there is no plan in it that is similar to the one previously mentioned. Therefore, it is important to define a specific variable sampling plan to accomplish Sanden's target of one nonconforming part per million received.

Other alternatives that could lead to a significant reduction in the sample size, include, the use of attributes sampling plans. However, all alternative plans require some sort of knowledge about the process capability. This information is usually limited to suppliers and therefore, is generally unavailable. In fact, if a company knows that much about a supplier's process, it probability does not need to inspect incoming material for this supplier. For this reason, none of those alternatives are considered here.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

The sampling Plan currently used by Sanden does not assure that the quality of the incoming materials meets the company's needs. The risk of receiving lots of bad quality is very high and the target of 1/1,000,000 is far from being achieved.

To improve the reliability of its sampling plan, Sanden should either increase its sample size while still using attributes sampling plans or change to variables sampling plans, in which case the sample size could be decreased. Using the attributes sampling plan, the sample size would be in hundreds of pieces. This sample size would require a much larger group of inspectors than the existing one. In addition, the tendency of the just-in-time production process would result in 100 percent inspection most of the time.

Using variables sampling plans, the required sample size would be around twenty pieces, which is less than that required by the present plan. This type of sampling plan also allows better knowledge about the supplier's process capability, than does an attribute sampling plan. A disadvantage of such sampling plans is that the time consumed to inspect one piece is usually greater than the time consumed for an inspection under an attribute sampling plan. Another disadvantage is that each one of the quality characteristics requires a separate sampling plan.

Based on the analysis the following actions should be undertaken by Sanden:

Short term:

- Design variables sampling plans for all of the main quality characteristics;
- Define the forms and documents for the new inspection methodology;
- Train inspections on the new methodology;
- Orient the suppliers to the new criteria for the incoming material inspection;
- Implement the new methodology;

Long term:

- Formulate a new supplier's quality assurance policy which considers the long-term relationship;
- Negotiate the implementation of this policy with the main suppliers in order to validate all expectations;
- Establish a systematic approach for the suppliers' evaluation based on their measured capability index and on their system assessment;
- Integrate the incoming material quality tasks with the in-process quality control in order to better identify opportunities for improvement.

APPENDIX A

SAS CODE

```
/*Thesis Project*/

/*Program used to identify the OCC for a given Sample Plan*/

/*and to perform some simulations with the data*/

OPTIONS PS=50 nonumber;

data ESP;

INPUT LSI LSF SS AC P1 P2 P3 P4 P5 P6;

R1=PROBBNML(P1,SS,AC);

R2=PROBBNML(P2,SS,AC);

R3=PROBBNML(P3,SS,AC);

R4=PROBBNML(P4,SS,AC);

R5=PROBBNML(P5,SS,AC);

R6=PROBBNML(P6,SS,AC);

LABEL LSF='LOT SIZE'

    SS='SAMPLE SIZE'

    AC='ACCEP. NUMBER'

    R1='P=1/1,000'

    R2='P=2/1,000'

    R3='P=5/1,000'

    R4='P=1/100'

    R5='P=2/100'

    R6='P=5/100';
```

```
CARDS;
1    50    20    0 .001 .002 .005 .01 .02 .05
51   150   20    0 .001 .002 .005 .01 .02 .05
151  500   25    0 .001 .002 .005 .01 .02 .05
501  3200  25    0 .001 .002 .005 .01 .02 .05
3201 35000 30    0 .001 .002 .005 .01 .02 .05
35001 .    35    0 .001 .002 .005 .01 .02 .05
;
RUN;
DATA ESP1;
SET ESP;
KEEP LSF SS AC R1 R2 R3 R4 R5 R6;
RUN;
TITLE 'EXISTING SAMPLING PLAN ';
TITLE2 'Pa for some p';
PROC PRINT DATA=ESP1 NOOBS LABEL;
RUN;
DATA SSP;
Z_VALUE=PROBIT(.999998);
TITLE 'SIMULATIONS';
TITLE2 'PROCESS CAPABILITY FOR ACHIEVING P=1/1,000,000';
PROC PRINT DATA=SSP NOOBS;
```

```
RUN;
DATA SSP1;
TITLE1 'PROBABILITY OF ACCEPTING THE LOT WITH SPECIFIC n, c AND p';
TITLE2 'LOT=500 TARGET P=99.99% FOR p=2/1000 AND P=10% FOR p=1/100';
DO n=10 TO 500 BY 10;
DO c=0 TO 5;
R1=PROBBNML(.002,n,c);
R2=PROBBNML(.01,n,c);
R3=PROBBNML(.05,n,c);
OUTPUT;
END;
END;
LABEL R1='p=2/1,000'
   R2='p=1/100'
   R3='p=5/100'
   C='c'
   N='n';
PROC PRINT DATA=SSP1 NOOBS LABEL;
RUN;
DATA ESP2;
DO p=.001 TO .050 BY .001;
n_20=PROBBNML(p,20,0);
```

```
n_25=PROBBNML(p,25,0);
n_30=PROBBNML(p,30,0);
n_35=PROBBNML(p,35,0);
OUTPUT;
END;
PROC PLOT DATA=ESP2;
PLOT n_20*p='*';
PLOT n_25*p='x';
PLOT n_30*p='+';
PLOT n_35*p='.';
TITLE 'OCC FOR THE EXISTING SAMPLING PLAN';
TITLE2 'FOR n=20,25,30,35 c=0 AND p=.001 TO .050 BY .001';
RUN;
DATA SSP2;
DO n=10 TO 100 BY 5;
p_1000=PROBBNML(.001,n,0);
p_100=PROBBNML(.01,n,0);
OUTPUT;
END;
PROC PLOT DATA=SSP2;
PLOT p_1000*n='*';
PLOT p_100*n='x';
```

```
TITLE 'PROBABILITY OF ACCEPTING A LOT WITH p=1/1,000 AND p=1/100';
TITLE2 'FOR n= 10 TO 100 BY 5 AND c=0';
RUN;
DATA SSP3;
TITLE 'SIMULATION FOR A VARIABLE SAMPLING PLAN';
TITLE2 'THE INTENTION IS TO ACCEPT 99% OF THE LOTS THAT HAVE LESS
   THAN';
TITLE3 '1/1,000 DEFECTIVES AND REJECT 90% OF THE LOTS THAT HAVE
   MORE THAN 1/100';
TITLE4 'DEFECTIVES. THE CORRESPONDENT ASP IS N=220 FOR ALFA=36%
   AND BETA=11%.';
ZALFA=PROBIT(.99);
ZBETA=PROBIT(.90);
ZP1=PROBIT(.999);
ZP2=PROBIT(.99);
K=(ZALFA*ZP2+ZBETA*ZP1)/(ZALFA+ZBETA);
N=(1+K**2/2)*(((ZALFA+ZBETA)/(ZP1-ZP2))**2);
DIV=SQRT(1/N+K**2/(2*N));
DO p=.001 TO .050 BY .001;
ZP=PROBIT(1-P);
ZA=(K-ZP)/DIV;
Pac=1-PROBNORM(ZA);
```

```
OUTPUT;
END;
RUN;
DATA SSP4;
SET SSP3;
IF _N_ = 1;
RUN;
PROC PRINT DATA=SSP4 NOOBS;
VAR N K;
TITLE5 '>>>VSP FOR THE SPECIFIED CONDITION<<<';
RUN;
PROC PLOT DATA=SSP3;
PLOT Pac*p='*';
TITLE5;
RUN;
DATA SSP5;
TITLE 'SIMULATION FOR A VARIABLE SAMPLING PLAN';
TITLE2 'n AND k FOR DIFFERENT VALUES OF PROB. OF ACCEPTANCE.';
TITLE3 ;
TITLE4 ;
TITLE5 ;
DO ZAL=.01 TO .50 BY .02;
```

```
DO ZBE=.05 TO .15 BY .05;

ZALFA=PROBIT(1-ZAL);

ZBETA=PROBIT(1-ZBE);

ZP1=PROBIT(.999);

ZP2=PROBIT(.99);

k=(ZALFA*ZP2+ZBETA*ZP1)/(ZALFA+ZBETA);

N=(1+K**2/2)*(((ZALFA+ZBETA)/(ZP1-ZP2))**2);

DIV=SQRT(1/N+K**2/(2*N));

p1=.001; p2=.01; p3=.000001; p4=.05;

ZP1=PROBIT(1-p1);

ZA1=(K-ZP1)/DIV;

Pac1THO=1-PROBNORM(ZA1);

ZP2=PROBIT(1-p2);

ZA2=(K-ZP2)/DIV;

Pac1HUN=1-PROBNORM(ZA2);

ZP3=PROBIT(1-p3);

ZA3=(K-ZP3)/DIV;

Pac1MIL=1-PROBNORM(ZA3);

ZP4=PROBIT(1-p4);

ZA4=(K-ZP4)/DIV;

Pac5HUN=1-PROBNORM(ZA4);

OUTPUT;
```

```
END;
END;
RUN;
PROC PRINT DATA=SSP5 NOOBS;
VAR N K Pac5HUN Pac1HUN Pac1THO Pac1MIL;
RUN;
```

APPENDIX B

SAS OUTPUT

EXISTING SAMPLING PLAN

Pa for some p

17:46 Tuesday, December 6, 1994

LOT SIZE	SAMPLE SIZE	ACCEP. NUMBER	P=1/1,000	P=2/1,000	P=5/1,000	P=1/100	P=2/100	P=5/100
50	20	0	0.98019	0.96075	0.90461	0.81791	0.66761	0.35849
150	20	0	0.98019	0.96075	0.90461	0.81791	0.66761	0.35849
500	25	0	0.97530	0.95118	0.88222	0.77782	0.60346	0.27739
3200	25	0	0.97530	0.95118	0.88222	0.77782	0.60346	0.27739
35000	30	0	0.97043	0.94171	0.86038	0.73970	0.54548	0.21464
.	35	0	0.96559	0.93233	0.83909	0.70345	0.49307	0.16608

SIMULATIONS 17:46 Tuesday, December 6, 1994
PROCESS CAPABILITY FOR ACHIEVING P=1/1,000,000

Z_VALUE

4.61138

PROBABILITY OF ACCEPTING THE LOT WITH SPECIFIC n, c AND p
LOT=500 TARGET P=99.99% FOR p=2/1000 AND P=10% FOR p=1/100
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n	c	p=2/1,000	p=1/100	p=5/100
10	0	0.98018	0.90438	0.59874
10	1	0.99982	0.99573	0.91386
10	2	1.00000	0.99989	0.98850
10	3	1.00000	1.00000	0.99897
10	4	1.00000	1.00000	0.99994
10	5	1.00000	1.00000	1.00000
20	0	0.96075	0.81791	0.35849
20	1	0.99926	0.98314	0.73584
20	2	0.99999	0.99900	0.92452
20	3	1.00000	0.99996	0.98410
20	4	1.00000	1.00000	0.99743
20	5	1.00000	1.00000	0.99967
30	0	0.94171	0.73970	0.21464
30	1	0.99832	0.96385	0.55354
30	2	0.99997	0.99668	0.81218
30	3	1.00000	0.99978	0.93923
30	4	1.00000	0.99999	0.98436
30	5	1.00000	1.00000	0.99672
40	0	0.92304	0.66897	0.12851
40	1	0.99703	0.93926	0.39906
40	2	0.99993	0.99250	0.67674
40	3	1.00000	0.99931	0.86185
40	4	1.00000	0.99995	0.95197
40	5	1.00000	1.00000	0.98612
50	0	0.90475	0.60501	0.07694
50	1	0.99540	0.91056	0.27943
50	2	0.99985	0.98618	0.54053
50	3	1.00000	0.99840	0.76041
50	4	1.00000	0.99985	0.89638
50	5	1.00000	0.99999	0.96222

60	0	0.88681	0.54716	0.04607
60	1	0.99344	0.87877	0.19155
60	2	0.99975	0.97758	0.41744
60	3	0.99999	0.99688	0.64728
60	4	1.00000	0.99965	0.81966
60	5	1.00000	0.99997	0.92128
70	0	0.86924	0.49484	0.02758
70	1	0.99117	0.84472	0.12921
70	2	0.99960	0.96665	0.31374
70	3	0.99999	0.99457	0.53387
70	4	1.00000	0.99929	0.72794
70	5	1.00000	0.99992	0.86277
80	0	0.85201	0.44752	0.01652
80	1	0.98860	0.80916	0.08605

PROBABILITY OF ACCEPTING THE LOT WITH SPECIFIC n, c AND p
LOT=500 TARGET P=99.99% FOR p=2/1000 AND P=10% FOR p=1/100
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n	c	p=2/1,000	p=1/100	p=5/100
80	2	0.99941	0.95345	0.23062
80	3	0.99998	0.99134	0.42845
80	4	1.00000	0.99871	0.62888
80	5	1.00000	0.99984	0.78922
90	0	0.83512	0.40473	0.00989
90	1	0.98574	0.77267	0.05673
90	2	0.99917	0.93806	0.16643
90	3	0.99996	0.98706	0.33580
90	4	1.00000	0.99783	0.52968
90	5	1.00000	0.99970	0.70519
100	0	0.81857	0.36603	0.00592
100	1	0.98261	0.73576	0.03708
100	2	0.99888	0.92063	0.11826
100	3	0.99995	0.98163	0.25784
100	4	1.00000	0.99657	0.43598
100	5	1.00000	0.99947	0.61600
110	0	0.80234	0.33103	0.00354
110	1	0.97921	0.69885	0.02407
110	2	0.99853	0.90133	0.08294
110	3	0.99992	0.97496	0.19447
110	4	1.00000	0.99486	0.35151
110	5	1.00000	0.99912	0.52673
120	0	0.78644	0.29938	0.00212
120	1	0.97556	0.66227	0.01553
120	2	0.99811	0.88036	0.05751
120	3	0.99989	0.96702	0.14441
120	4	0.99999	0.99262	0.27819
120	5	1.00000	0.99862	0.44155
130	0	0.77085	0.27075	0.00127
130	1	0.97167	0.62629	0.00997
130	2	0.99763	0.85793	0.03948
130	3	0.99985	0.95776	0.10576
130	4	0.99999	0.98977	0.21653
130	5	1.00000	0.99792	0.36343
140	0	0.75557	0.24487	0.00076
140	1	0.96756	0.59114	0.00637
140	2	0.99708	0.83423	0.02687

140	3	0.99980	0.94718	0.07652
140	4	0.99999	0.98626	0.16602
140	5	1.00000	0.99700	0.29415
150	0	0.74060	0.22145	0.00046
150	1	0.96322	0.55698	0.00405
150	2	0.99646	0.80948	0.01815
150	3	0.99974	0.93531	0.05477

PROBABILITY OF ACCEPTING THE LOT WITH SPECIFIC n, c AND p
LOT=500 TARGET P=99.99% FOR p=2/1000 AND P=10% FOR p=1/100
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n	c	p=2/1,000	p=1/100	p=5/100
150	4	0.99999	0.98201	0.12559
150	5	1.00000	0.99579	0.23444
160	0	0.72592	0.20028	0.00027
160	1	0.95868	0.52396	0.00257
160	2	0.99576	0.78388	0.01218
160	3	0.99967	0.92216	0.03882
160	4	0.99998	0.97698	0.09385
160	5	1.00000	0.99426	0.18422
170	0	0.71153	0.18113	0.00016
170	1	0.95393	0.49215	0.00162
170	2	0.99498	0.75762	0.00812
170	3	0.99959	0.90779	0.02728
170	4	0.99997	0.97112	0.06936
170	5	1.00000	0.99236	0.14291
180	0	0.69742	0.16381	0.00010
180	1	0.94900	0.46164	0.00102
180	2	0.99412	0.73089	0.00539
180	3	0.99949	0.89226	0.01901
180	4	0.99996	0.96439	0.05075
180	5	1.00000	0.99004	0.10954
190	0	0.68360	0.14814	0.00006
190	1	0.94389	0.43246	0.00064
190	2	0.99318	0.70386	0.00356
190	3	0.99937	0.87565	0.01316
190	4	0.99995	0.95678	0.03679
190	5	1.00000	0.98726	0.08306
200	0	0.67005	0.13398	0.00004
200	1	0.93861	0.40465	0.00040
200	2	0.99216	0.67668	0.00234
200	3	0.99924	0.85803	0.00905
200	4	0.99994	0.94825	0.02645
200	5	1.00000	0.98398	0.06234
210	0	0.65677	0.12117	0.00002
210	1	0.93317	0.37819	0.00025
210	2	0.99105	0.64950	0.00153
210	3	0.99909	0.83950	0.00618
210	4	0.99993	0.93882	0.01886

210	5	0.99999	0.98016	0.04636
220	0	0.64375	0.10958	0.00001
220	1	0.92757	0.35310	0.00016
220	2	0.98985	0.62245	0.00100
220	3	0.99892	0.82015	0.00420
220	4	0.99991	0.92848	0.01336
220	5	0.99999	0.97576	0.03418

PROBABILITY OF ACCEPTING THE LOT WITH SPECIFIC n, c AND p
LOT=500 TARGET P=99.99% FOR p=2/1000 AND P=10% FOR p=1/100
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n	c	p=2/1,000	p=1/100	p=5/100
230	0	0.63099	0.09910	0.000008
230	1	0.92183	0.32935	0.000099
230	2	0.98857	0.59564	0.000647
230	3	0.99873	0.80007	0.002843
230	4	0.99989	0.91725	0.009400
230	5	0.99999	0.97075	0.025000
240	0	0.61849	0.08963	0.000005
240	1	0.91595	0.30691	0.000061
240	2	0.98719	0.56918	0.000419
240	3	0.99852	0.77936	0.001914
240	4	0.99986	0.90514	0.006573
240	5	0.99999	0.96511	0.018150
250	0	0.60623	0.08106	0.000003
250	1	0.90995	0.28575	0.000038
250	2	0.98573	0.54317	0.000271
250	3	0.99828	0.75812	0.001282
250	4	0.99983	0.89219	0.004571
250	5	0.99999	0.95882	0.013086
260	0	0.59421	0.07331	0.000002
260	1	0.90382	0.26583	0.000024
260	2	0.98417	0.51767	0.000174
260	3	0.99802	0.73644	0.000856
260	4	0.99980	0.87842	0.003161
260	5	0.99998	0.95185	0.009374
270	0	0.58243	0.06630	0.000001
270	1	0.89758	0.24711	0.000015
270	2	0.98252	0.49276	0.000112
270	3	0.99773	0.71443	0.000569
270	4	0.99976	0.86388	0.002176
270	5	0.99998	0.94420	0.006674
280	0	0.57089	0.05996	0.000001
280	1	0.89123	0.22954	0.000009
280	2	0.98078	0.46850	0.000072
280	3	0.99741	0.69216	0.000377
280	4	0.99972	0.84862	0.001491
280	5	0.99997	0.93585	0.004726
290	0	0.55957	0.05423	0.000000

290	1	0.88478	0.21307	0.000006
290	2	0.97895	0.44492	0.000046
290	3	0.99707	0.66974	0.000249
290	4	0.99967	0.83268	0.001017
290	5	0.99997	0.92682	0.003328
300	0	0.54848	0.04904	0.000000
300	1	0.87823	0.19765	0.000003

PROBABILITY OF ACCEPTING THE LOT WITH SPECIFIC n, c AND p
LOT=500 TARGET P=99.99% FOR p=2/1000 AND P=10% FOR p=1/100
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n	c	p=2/1,000	p=1/100	p=5/100
300	2	0.97702	0.42206	.0000293
300	3	0.99669	0.64723	.0001641
300	4	0.99962	0.81611	.0006908
300	5	0.99996	0.91710	.0023321
310	0	0.53761	0.04435	.0000001
310	1	0.87160	0.18323	.0000022
310	2	0.97501	0.39997	.0000186
310	3	0.99628	0.62473	.0001077
310	4	0.99955	0.79898	.0004675
310	5	0.99996	0.90669	.0016266
320	0	0.52695	0.04011	.0000001
320	1	0.86488	0.16976	.0000013
320	2	0.97290	0.37864	.0000118
320	3	0.99584	0.60230	.0000705
320	4	0.99949	0.78133	.0003153
320	5	0.99995	0.89562	.0011295
330	0	0.51651	0.03628	.0000000
330	1	0.85809	0.15719	.0000008
330	2	0.97069	0.35811	.0000075
330	3	0.99537	0.58001	.0000461
330	4	0.99941	0.76323	.0002119
330	5	0.99994	0.88391	.0007810
340	0	0.50627	0.03281	.0000000
340	1	0.85123	0.14548	.0000005
340	2	0.96840	0.33838	.0000048
340	3	0.99486	0.55792	.0000300
340	4	0.99932	0.74475	.0001420
340	5	0.99993	0.87156	.0005379
350	0	0.49624	0.02967	.0000000
350	1	0.84430	0.13456	.0000003
350	2	0.96602	0.31945	.0000030
350	3	0.99431	0.53609	.0000195
350	4	0.99923	0.72592	.0000948
350	5	0.99991	0.85861	.0003691
360	0	0.48640	0.02683	.0000000
360	1	0.83731	0.12441	.0000002
360	2	0.96354	0.30132	.0000019

360	3	0.99373	0.51458	.0000127
360	4	0.99913	0.70683	.0000631
360	5	0.99990	0.84509	.0002524
370	0	0.47676	0.02427	.0000000
370	1	0.83027	0.11496	.0000001
370	2	0.96098	0.28399	.0000012
370	3	0.99311	0.49342	.0000082

PROBABILITY OF ACCEPTING THE LOT WITH SPECIFIC n, c AND p
LOT=500 TARGET P=99.99% FOR p=2/1000 AND P=10% FOR p=1/100
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n	c	p=2/1,000	p=1/100	p=5/100
370	4	0.99902	0.68751	.00004194
370	5	0.99988	0.83102	.00017196
380	0	0.46731	0.02195	.00000000
380	1	0.82318	0.10619	.00000007
380	2	0.95832	0.26744	.00000076
380	3	0.99245	0.47266	.00000529
380	4	0.99889	0.66804	.00002778
380	5	0.99986	0.81645	.00011680
390	0	0.45805	0.01985	.00000000
390	1	0.81604	0.09804	.00000004
390	2	0.95558	0.25166	.00000048
390	3	0.99175	0.45234	.00000341
390	4	0.99876	0.64847	.00001836
390	5	0.99984	0.80140	.00007909
400	0	0.44897	0.01795	.00000000
400	1	0.80886	0.09048	.00000003
400	2	0.95275	0.23663	.00000030
400	3	0.99100	0.43249	.00000220
400	4	0.99861	0.62884	.00001210
400	5	0.99982	0.78592	.00005340
410	0	0.44007	0.01623	.00000000
410	1	0.80165	0.08347	.00000002
410	2	0.94983	0.22235	.00000019
410	3	0.99022	0.41313	.00000141
410	4	0.99846	0.60921	.00000796
410	5	0.99980	0.77004	.00003595
420	0	0.43135	0.01468	.00000000
420	1	0.79441	0.07697	.00000001
420	2	0.94683	0.20878	.00000012
420	3	0.98939	0.39429	.00000090
420	4	0.99828	0.58963	.00000522
420	5	0.99977	0.75380	.00002414
430	0	0.42280	0.01328	.00000000
430	1	0.78713	0.07095	.00000001
430	2	0.94375	0.19591	.00000007
430	3	0.98852	0.37598	.00000058
430	4	0.99810	0.57015	.00000342

430	5	0.99974	0.73725	.00001617
440	0	0.41442	0.01201	.00000000
440	1	0.77984	0.06538	.00000000
440	2	0.94058	0.18371	.00000005
440	3	0.98761	0.35822	.00000037
440	4	0.99790	0.55080	.00000224
440	5	0.99970	0.72042	.00001080

PROBABILITY OF ACCEPTING THE LOT WITH SPECIFIC n, c AND p
LOT=500 TARGET P=99.99% FOR p=2/1000 AND P=10% FOR p=1/100
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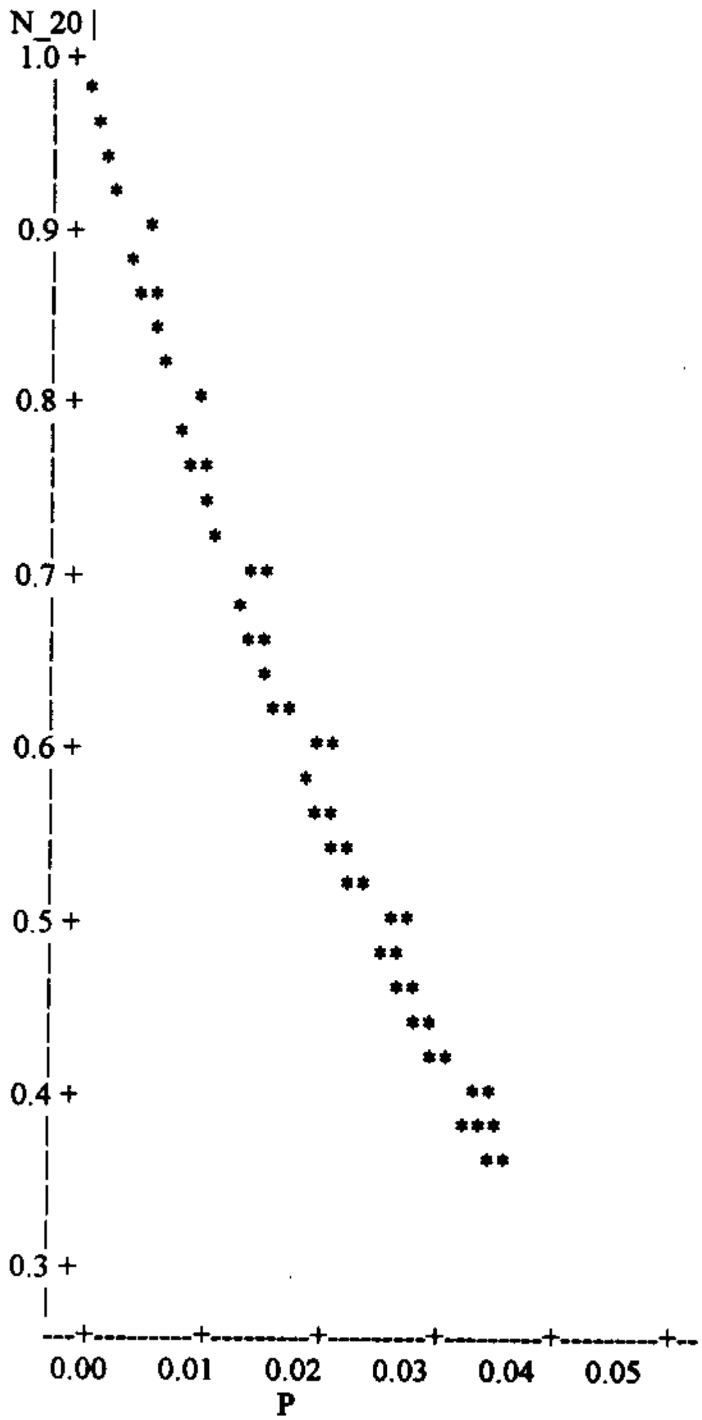
n	c	p=2/1,000	p=1/100	p=5/100
450	0	0.40620	0.01086	.0000000001
450	1	0.77252	0.06022	.0000000023
450	2	0.93732	0.17217	.0000000288
450	3	0.98665	0.34102	.0000002367
450	4	0.99769	0.53163	.0000014598
450	5	0.99966	0.70336	.0000072016
460	0	0.39815	0.00982	.0000000001
460	1	0.76519	0.05546	.0000000014
460	2	0.93399	0.16125	.0000000180
460	3	0.98564	0.32439	.0000001510
460	4	0.99746	0.51267	.0000009508
460	5	0.99962	0.68611	.0000047899
470	0	0.39026	0.00888	.0000000000
470	1	0.75784	0.05105	.0000000009
470	2	0.93058	0.15094	.0000000112
470	3	0.98458	0.30834	.0000000962
470	4	0.99722	0.49396	.0000006182
470	5	0.99958	0.66870	.0000031789
480	0	0.38252	0.00803	.0000000000
480	1	0.75048	0.04698	.0000000005
480	2	0.92709	0.14121	.0000000070
480	3	0.98348	0.29286	.0000000612
480	4	0.99696	0.47553	.0000004013
480	5	0.99953	0.65118	.0000021055
490	0	0.37494	0.00727	.0000000000
490	1	0.74312	0.04322	.0000000003
490	2	0.92352	0.13203	.0000000044
490	3	0.98233	0.27795	.0000000389
490	4	0.99668	0.45740	.0000002601
490	5	0.99948	0.63359	.0000013917
500	0	0.36751	0.00657	.0000000000
500	1	0.73576	0.03975	.0000000002
500	2	0.91988	0.12339	.0000000027
500	3	0.98113	0.26362	.0000000247
500	4	0.99639	0.43961	.0000001683
500	5	0.99942	0.61596	.0000009182

OCC FOR THE EXISTING SAMPLING PLAN
FOR n=20,25,30,35 c=0 AND p=.001 TO .050 BY .001
17:46 Tuesday, December 6, 1994

Plot of N_20*P. Symbol used is '*'.



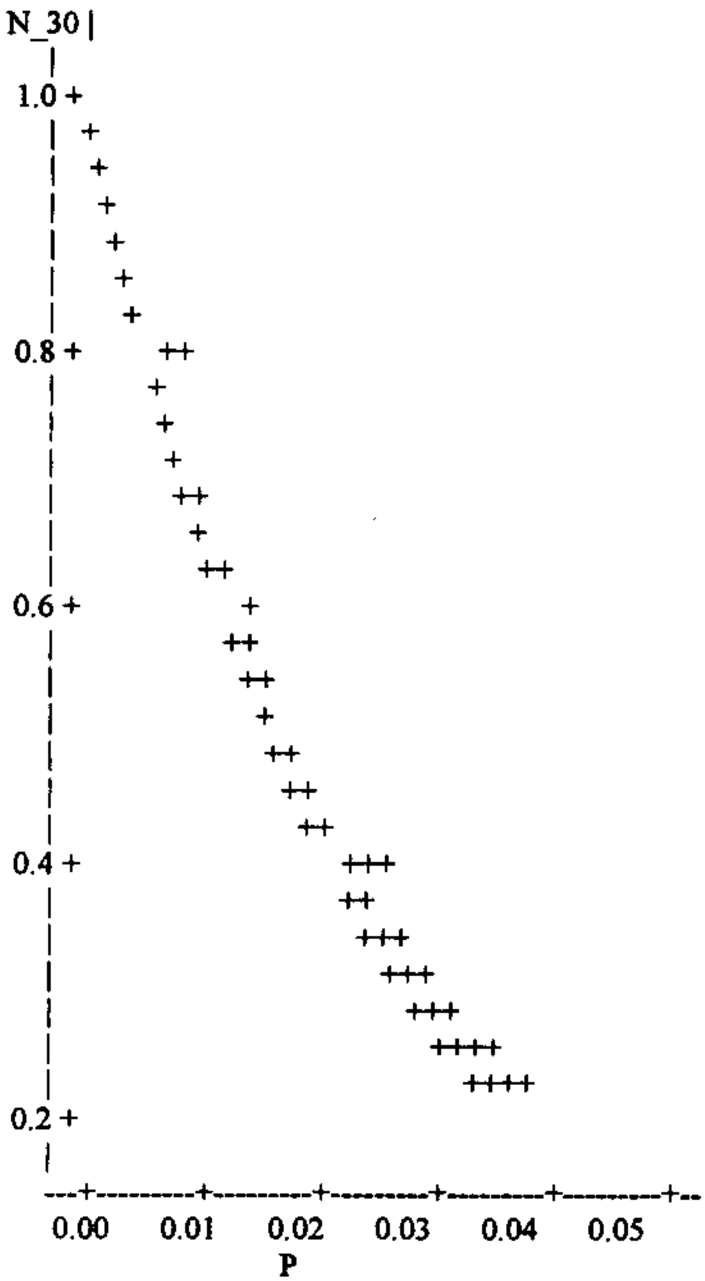
OCC FOR THE EXISTING SAMPLING PLAN
FOR n=20,25,30,35 c=0 AND p=.001 TO .050 BY .001
17:46 Tuesday, December 6, 1994

Plot of N_25*P. Symbol used is 'x'.

```
N_25 |
     |
 1.0 +
     |  x
     |   x
     |    x
 0.9 +       x
     |     x
     |      xx
     |       x
 0.8 +          x
     |         x
     |         xx
     |           x
 0.7 +              x
     |            xx
     |             x
     |              xx
 0.6 +                  xx
     |                 x
     |                 xx
     |                   xx
 0.5 +                      xx
     |                     xx
     |                       xx
     |                        xx
 0.4 +                            xxx
     |                            xx
     |                             xxx
     |                               xxx
 0.3 +                                    xxx
     |                                   xx
     |
     |
 0.2 +
     |
     ---+---------+---------+---------+---------+---------+--
       0.00      0.01      0.02      0.03      0.04      0.05
                             P
```

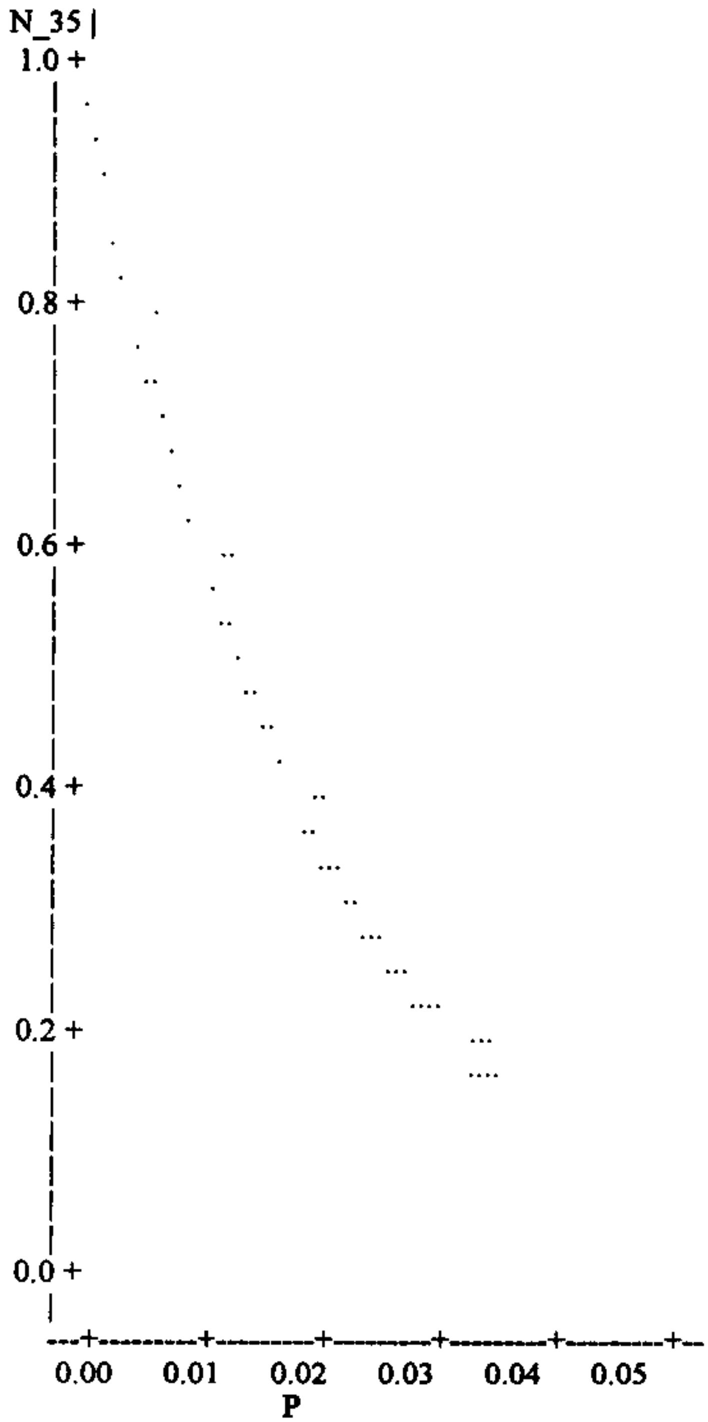
OCC FOR THE EXISTING SAMPLING PLAN
FOR n=20,25,30,35 c=0 AND p=.001 TO .050 BY .001
17:46 Tuesday, December 6, 1994

Plot of N_30*P. Symbol used is '+'.



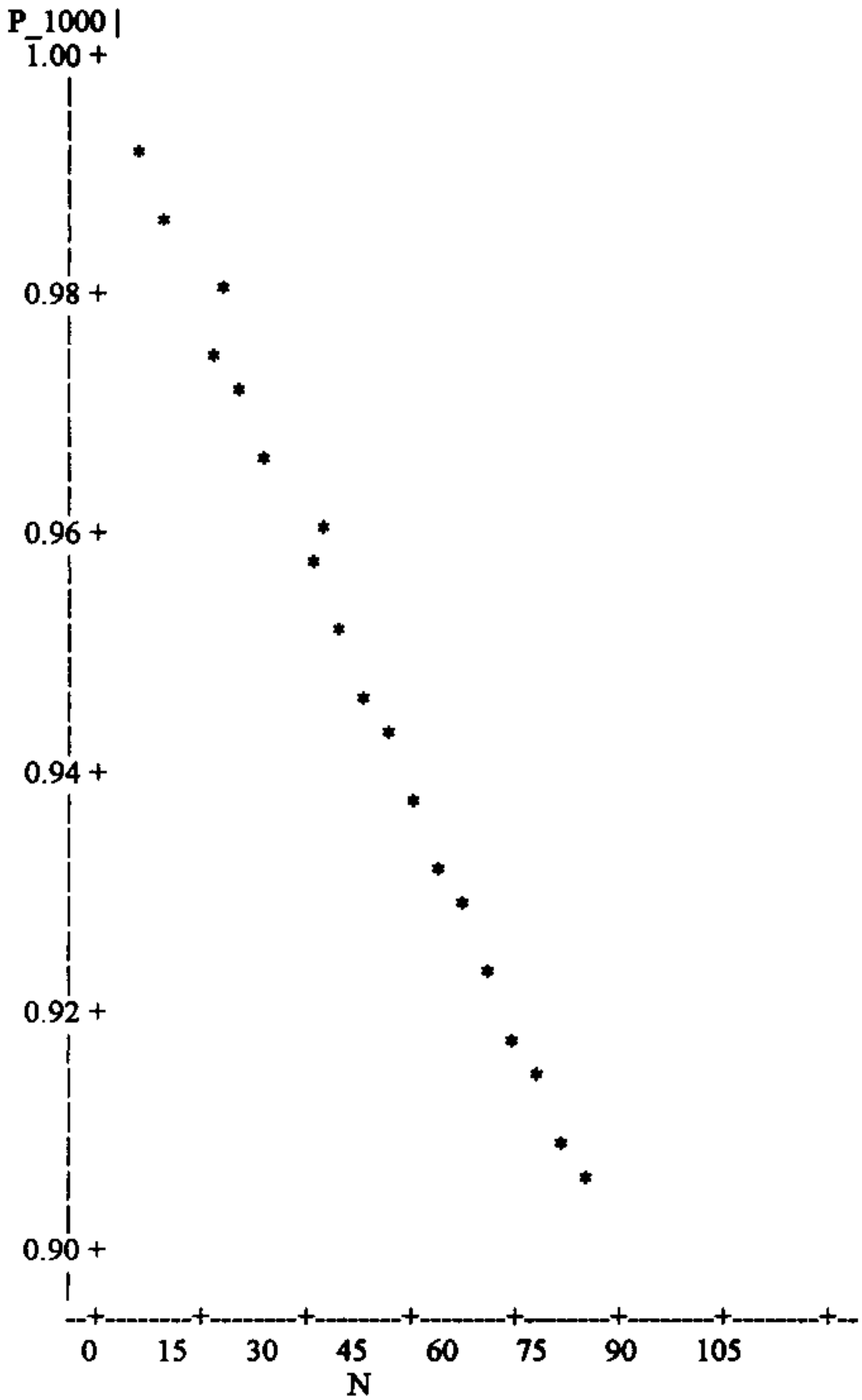
OCC FOR THE EXISTING SAMPLING PLAN
FOR n=20,25,30,35 c=0 AND p=.001 TO .050 BY .001
17:46 Tuesday, December 6, 1994

Plot of N_35*P. Symbol used is '.'.



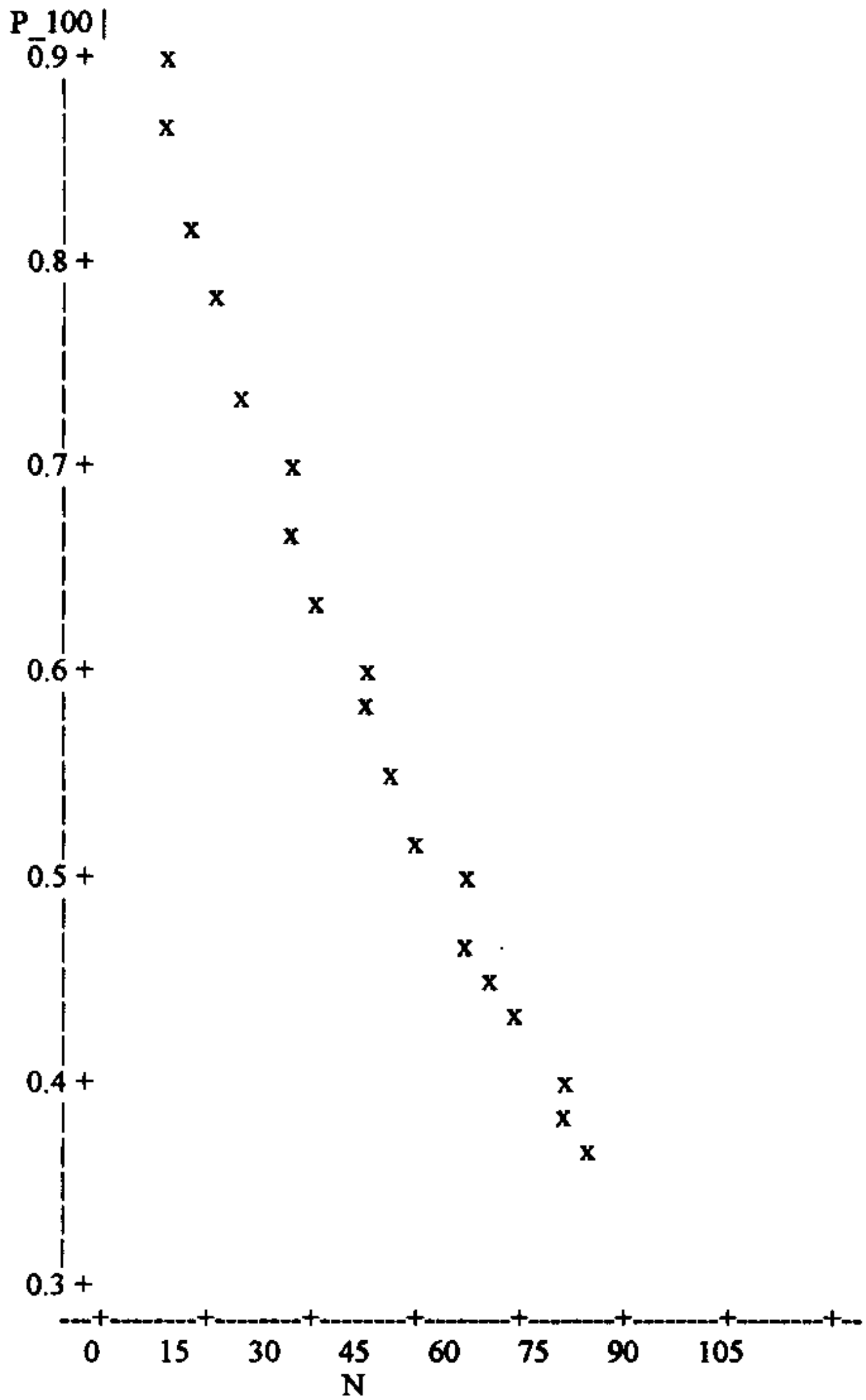
PROBABILITY OF ACCEPTING A LOT WITH p=1/1,000 AND p=1/100
FOR n= 10 TO 100 BY 5 AND c=0
17:46 Tuesday, December 6, 1994

Plot of P_1000*N. Symbol used is '*'.



PROBABILITY OF ACCEPTING A LOT WITH p=1/1,000 AND p=1/100
FOR n= 10 TO 100 BY 5 AND c=0
17:46 Tuesday, December 6, 1994

Plot of P_100*N. Symbol used is 'x'.



SIMULATION FOR A VARIABLE SAMPLING PLAN
THE INTENTION IS TO ACCEPT 99% OF THE LOTS THAT HAVE LESS THAN 1/1,000 DEFECTIVES AND REJECT 90% OF THE LOTS THAT HAVE MORE THAN 1/100
DEFECTIVES. THE CORRESPONDENT ASP IS N=220 FOR ALFA=36% AND BETA=11%.
>>>VSP FOR THE SPECIFIED CONDITION<<<
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N	K
97.5732	2.59769

SIMULATION FOR A VARIABLE SAMPLING PLAN
THE INTENTION IS TO ACCEPT 99% OF THE LOTS THAT HAVE LESS THAN 1/1,000 DEFECTIVES AND REJECT 90% OF THE LOTS THAT HAVE MORE THAN 1/100
DEFECTIVES. THE CORRESPONDENT ASP IS N=220 FOR ALFA=36% AND BETA=11%.

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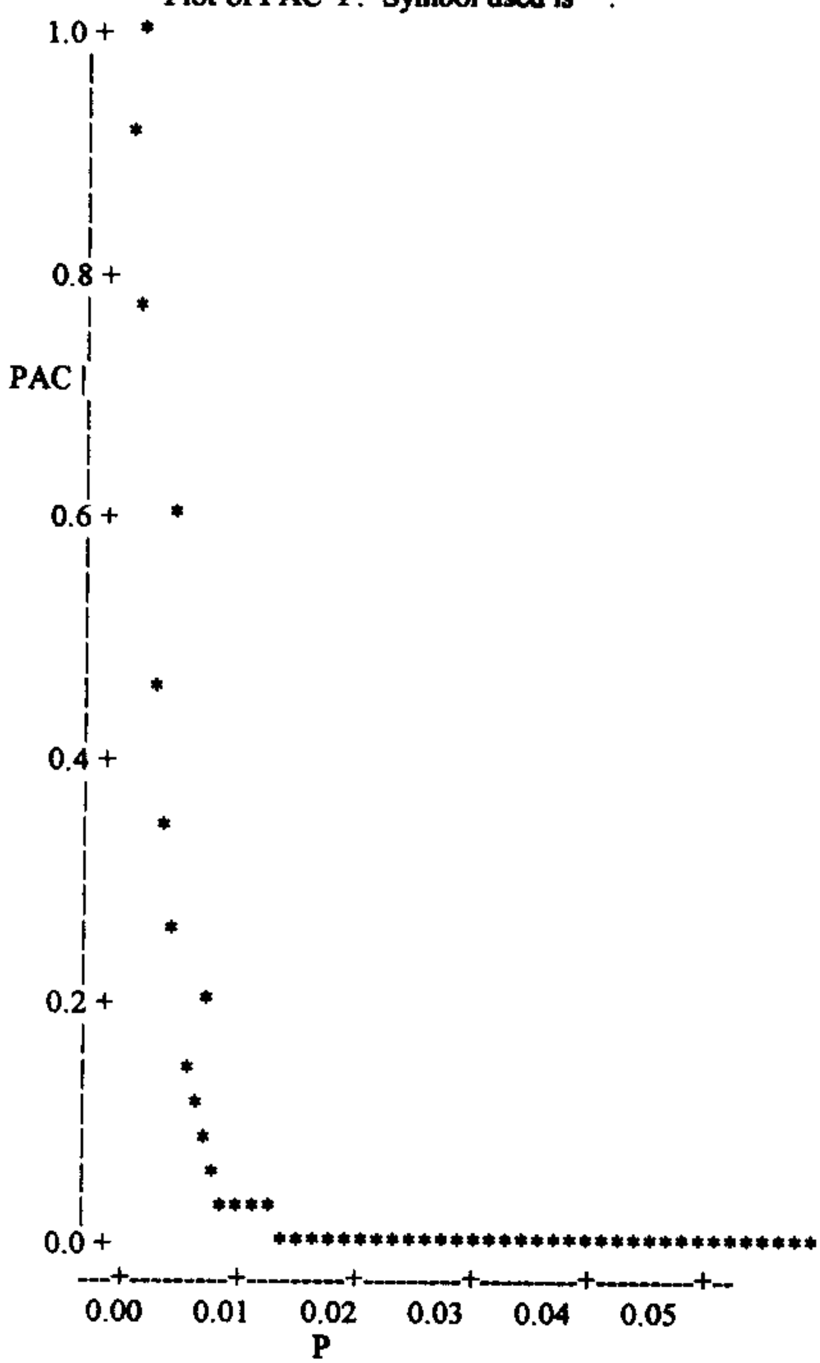
Plot of PAC*P. Symbol used is '*'.



SIMULATION FOR A VARIABLE SAMPLING PLAN
n AND k FOR DIFFERENT VALUES OF PROB. OF ACCEPTANCE.
17:46 Tuesday, December 6, 1994

N	K	PAC5HUN	PAC1HUN	PAC1THO	PAC1MIL
121.404	2.64275	.0000001	0.05	0.99	1.00000
97.573	2.59769	.0000034	0.10	0.99	1.00000
82.971	2.56178	.0000271	0.15	0.99	1.00000
97.958	2.68273	.0000008	0.05	0.97	1.00000
76.676	2.63591	.0000204	0.10	0.97	1.00000
63.794	2.59774	.0001368	0.15	0.97	1.00000
86.564	2.70829	.0000023	0.05	0.95	1.00000
66.632	2.66087	.0000496	0.10	0.95	1.00000
54.660	2.62162	.0003034	0.15	0.95	1.00000
78.834	2.72898	.0000047	0.05	0.93	1.00000
59.869	2.68138	.0000915	0.10	0.93	1.00000
48.550	2.64149	.0005233	0.15	0.93	1.00000
72.921	2.74719	.0000082	0.05	0.91	1.00000
54.728	2.69967	.0001467	0.10	0.91	1.00000
43.930	2.65939	.0007964	0.15	0.91	1.00000
68.099	2.76393	.0000130	0.05	0.89	1.00000
50.561	2.71667	.0002165	0.10	0.89	1.00000
40.203	2.67621	.0011241	0.15	0.89	1.00000
64.009	2.77975	.0000192	0.05	0.87	1.00000
47.043	2.73290	.0003020	0.10	0.87	1.00000
37.073	2.69240	.0015086	0.15	0.87	1.00000
60.443	2.79496	.0000271	0.05	0.85	1.00000
43.992	2.74868	.0004047	0.10	0.85	1.00000
34.369	2.70829	.0019526	0.15	0.85	1.00000
57.272	2.80979	.0000369	0.05	0.83	1.00000
41.292	2.76422	.0005262	0.10	0.83	1.00000
31.986	2.72408	.0024592	0.15	0.83	1.00000
54.410	2.82441	.0000490	0.05	0.81	1.00000
38.865	2.77968	.0006681	0.10	0.81	1.00000
29.854	2.73992	.0030321	0.15	0.81	1.00000
51.794	2.83893	.0000636	0.05	0.79	1.00000
36.658	2.79520	.0008324	0.10	0.79	1.00000
27.923	2.75596	.0036754	0.15	0.79	1.00000
49.380	2.85346	.0000811	0.05	0.77	1.00000
34.631	2.81088	.0010211	0.10	0.77	1.00000
26.157	2.77231	.0043934	0.15	0.77	1.00000
47.135	2.86809	.0001020	0.05	0.75	1.00000

32.755	2.82683	.0012365	0.10	0.75	1.00000
24.529	2.78909	.0051913	0.15	0.75	0.99999
45.034	2.88289	.0001266	0.05	0.73	1.00000
31.006	2.84312	.0014813	0.10	0.73	1.00000
23.018	2.80639	.0060743	0.15	0.73	0.99999
43.054	2.89793	.0001555	0.05	0.71	1.00000
29.367	2.85986	.0017582	0.10	0.71	1.00000

SIMULATION FOR A VARIABLE SAMPLING PLAN
n AND k FOR DIFFERENT VALUES OF PROB. OF ACCEPTANCE.
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N	K	PAC5HUN	PAC1HUN	PAC1THO	PAC1MIL
21.6075	2.82434	0.007049	0.15	0.71	0.99997
41.1804	2.91329	0.000189	0.05	0.69	1.00000
27.8220	2.87713	0.002070	0.10	0.69	0.99999
20.2851	2.84304	0.008121	0.15	0.69	0.99994
39.3991	2.92904	0.000229	0.05	0.67	1.00000
26.3607	2.89502	0.002421	0.10	0.67	0.99999
19.0397	2.86261	0.009298	0.15	0.67	0.99987
37.6989	2.94525	0.000274	0.05	0.65	1.00000
24.9728	2.91365	0.002815	0.10	0.65	0.99997
17.8625	2.88321	0.010588	0.15	0.65	0.99975
36.0704	2.96199	0.000327	0.05	0.63	1.00000
23.6503	2.93311	0.003255	0.10	0.63	0.99994
16.7464	2.90497	0.012000	0.15	0.63	0.99954
34.5058	2.97934	0.000388	0.05	0.61	1.00000
22.3862	2.95353	0.003747	0.10	0.61	0.99988
15.6850	2.92807	0.013543	0.15	0.61	0.99917
32.9980	2.99740	0.000458	0.05	0.59	0.99999
21.1746	2.97505	0.004296	0.10	0.59	0.99978
14.6733	2.95272	0.015229	0.15	0.59	0.99856
31.5413	3.01626	0.000538	0.05	0.57	0.99998
20.0107	2.99782	0.004908	0.10	0.57	0.99960
13.7069	2.97914	0.017069	0.15	0.57	0.99758
30.1305	3.03602	0.000631	0.05	0.55	0.99997
18.8900	3.02202	0.005591	0.10	0.55	0.99929
12.7819	3.00763	0.019077	0.15	0.55	0.99604
28.7609	3.05681	0.000738	0.05	0.53	0.99993
17.8087	3.04786	0.006351	0.10	0.53	0.99878
11.8952	3.03851	0.021268	0.15	0.53	0.99372
27.4286	3.07876	0.000860	0.05	0.51	0.99987
16.7636	3.07558	0.007198	0.10	0.51	0.99795
11.0438	3.07219	0.023659	0.15	0.51	0.99026

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