Application of Statistical Sampling Schemes to Finishing House in Paper Industry

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The article discusses the application of sampling schemes based on statistical considerations for the inspection of paper sheets in the Finishing House. It is shown that without subjecting the paper to 100% inspection and sorting, one could get the identical results about the quality of paper from a sample provided its magnitude and frequency is based on sound statistical considerations. The article offers the possibility of doing away with 100% inspection of paper by adopting a statistical sampling scheme at the cutter-machine.

INTRODUCTION

Finishing of the cut sheets of paper such as sorting, removal of defective sheets, counting, packing, etc., employ a large number of manual labourers in most of the Paper Mills especially in older type of mills. For finishing, labour cost component alone may be around 1 to 2% of the total cost of production of ordinary paper. This high cost is mostly due to 100% inspection and sorting work normally adopted by majority of the mills for the elimination of the defective sheets from reams, ready for despatch. The complete inspection of paper is favoured on the mistaken idea that 100% inspection guarantees a 100% removal of defective sheets. Experience shows, such a notion is far from true. Many human factors such as fatigue, judgemental errors , etc., do not allow accomplishment of 100% defect removal by 100% inspection.

Although of late, electronic counters and sorters have been introduced in increasing number in modern mills for doing the finishing operations, probably the majority of the mills in the world still depend on manual sorting and counting by trained human labour. Due to frightening competition, constantly increasing wages and other elemental costs and also due to shortage of foreign exchange and some times non-availability of dependable equipment along with non-standardisation of paper sizes — especially in many developing countries — one is forced to explore cheaper, but dependable techniques for paper finishing. Statistical sampling schemes, whereas per scientific sample size and frequency, only a part of production is subjected to sorting operation, offers one such possibility to reduce substantially the sorting part of the finishing operations. These schemes have been successfully tried in some of the mills (1).

Since application of statistical sampling schemes and their consequent success depends, to a large degree, on the local conditions, it was thought of interest to undertake this study at the West Coast Paper Mills and publish the findings for nourishing further enquiry and investigations in this unexplored, yet potentially useful field.

Normally, inspection for acceptance purpose, is carried out chiefly by two methods:

a) Acceptance based on the results of a definite sample analysis; and

b) Acceptance based on the inspection of one hundred per cent material.

The adoption of any of the above procedures is based on the quality tested, level of manufacture, inspectional traditions, intuitions, etc. As already stated, experience indicates 100% inspection, is never a 100% guarantee against the acceptance of a defective item. A well chosen sampling scheme, besides being more economical, may actually provide better quality assurance and is consequently utilized in many industries.

In a paper of the present size and description, it is not possible to give details of the theoretical background of statistical sampling schemes — for which standard works on the subject are available (2, 3, 4). However, a concise description on the theory and application of these methods is included to stimulate further interest in the subject.

If sampling inspection for acceptance purpose is carried out without the aid of theoretically worked out rules regarding size and frequency of sample, the inspector often draws informal working rules, based on his knowledge of the past quality history of the product to be sampled. Although this is sound as far as it goes, such an informal working system has obvious limitations such as, the shortness and inaccuracy of inspectors' memory, his non-availability at all times, sharp changes in the current quality, etc. These limitations force the need of definite quality protection rules regarding size and frequency of sample along with basis for acceptance or rejection with a definite known risk.

Sampling is a problem involving the laws of chance and the modern sampling schemes are based on the mathematics of probability. The application of the mathematics of probability are discussed in standard books on acceptance sampling.

The sampling may be of single or double sampling type. In the former case, the decision regarding the acceptance or rejection is made on the evidence of only one sample, while in the latter case "one more sample", is taken from the same lot and decision taken on a worked out procedure.

In sampling plans developed without benefit of statistical analysis,

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even a single defective article in the sample rejects the whole lot. This is basd on the illusion that if the sample is perfect, the lot will also be perfect. Experience indicates such sampling plans seldom provide the protection one is looking for.

Statistical sampling, based on theory of probability allow various sampling plans to be compared over a wide range of possible quality levels of submitted product, by indexing them with a definite distinguishing power, provided by **operating characteristics curve.** This curve of an acceptance sampling plan shows, the ability of the plan to distinguish between good and bad lots to a quantitative extent. The calculation of this curve is fairly simple and is given in majority of the standard texts. Most of the statistical sampling plans are based on this curve.

Study of sampling plans based on statistical principles, have shown the fallacy of many of the popular beliefs prevalent in industry. A common practice in industry is to specify that the sample selected shall be some fixed percentage of the lot such as 1%, 5 per cent, 10 per cent or more which is often based on the mistaken idea that the protection given by a sampling scheme is constant if the ratio of sample size to lot sizes is constant. Actual calculations show that the above procedure is highly misleading. As a matter of fact fixed sample size tends towards constant quality protection and larger absolute sample size provides a more dependable procedure. Further, the operating characteristics of plans which recognize and permit a certain definite number of defectives are superior to those which do not permit any defectives in the sample.

It is, however, recognised that no sampling plan can provide complete protection against the acceptance of defective product (nor does 100% inspection!). This fact needs to be faced by all who specify or use acceptance sampling plan requires a decision on the risks that the user of the plan is willing to accept. This is essentially an economic decision and depends on factors, such as cost of 100% inspection versus protection, dependability of sampling or complete inspection, the extent of rejection and consequent screening etc.

In many industrial concerns, especially where one department is the consumer of the product of another department, the satisfactory lot is approved by sampling and the rejected lot completely screened of defectives. Such schemes called, acceptance/rectification plans, are also based on the operating characteristics curves. In fact these schemes are more extensively used in industry. Ready published tables, based on the above schemes, worked on theory of probability and O. C. curves, are available (3). In the present article, this scheme was applied.

FACTS OF THE CASE

The works where these investigations were undertaken employed sulphate pulping of bamboo for the manufacture of both bleached and unbleached pulp and paper. During the manufacture a routine inspectional procedure was followed both for the pulp, as well as for the finished paper. The inspection of paper was carried out at various places, such as, at the Parent Pope Reel, Rewinder and Sheet Cutter. At the Finishing House the cut sheets were subjected to 100% manual inspection and screening before packing and despatch. Fig. 1 illustrates the operations and inspection followed from the parent reel onward (standward symbols employed in work study techniques have been used in the chart). Since inspections previous to those at the parent reel are not relevant to the present investigation, they are not considered here.

During cutting of the paper, some minor inspection was made regarding size of the cut and other glaring defects. The sample size and frequency was random and not based on statistical considerations. In case some prominent defects were observed at the cutter, the stacks were marked for the attention of the warehouse (at the parent reel and at the re-

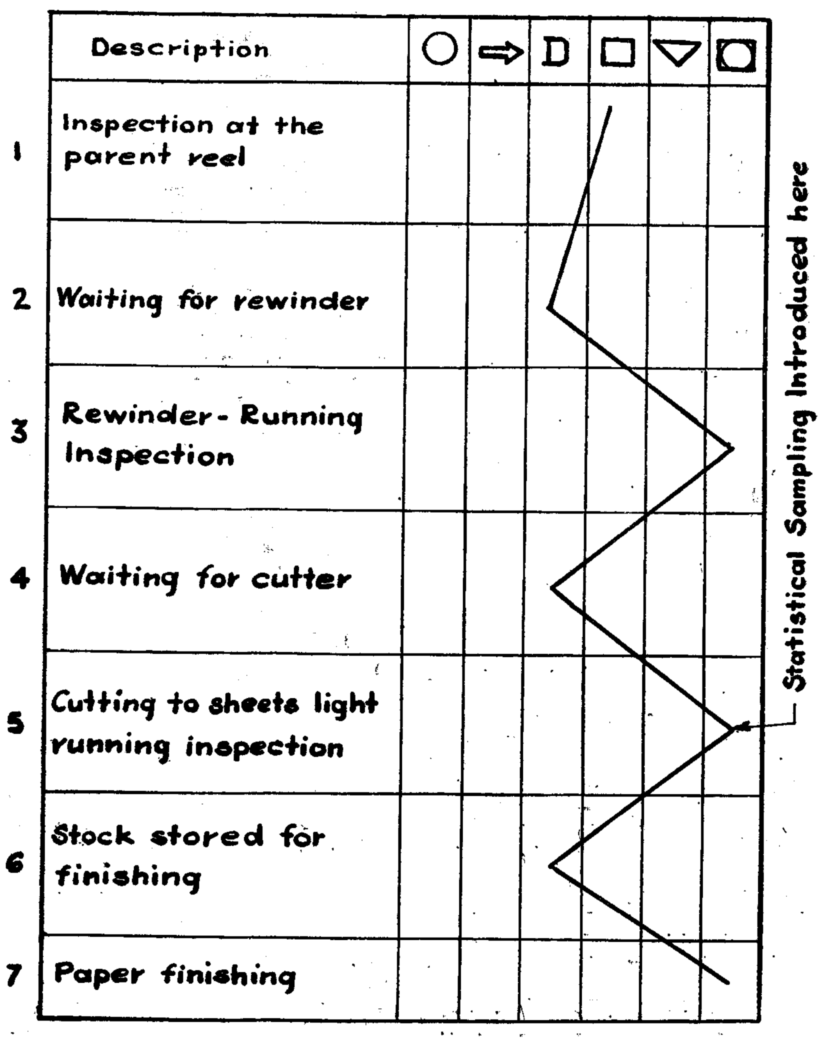

Figure 1 : Various operations on Paper after Parent Reel.

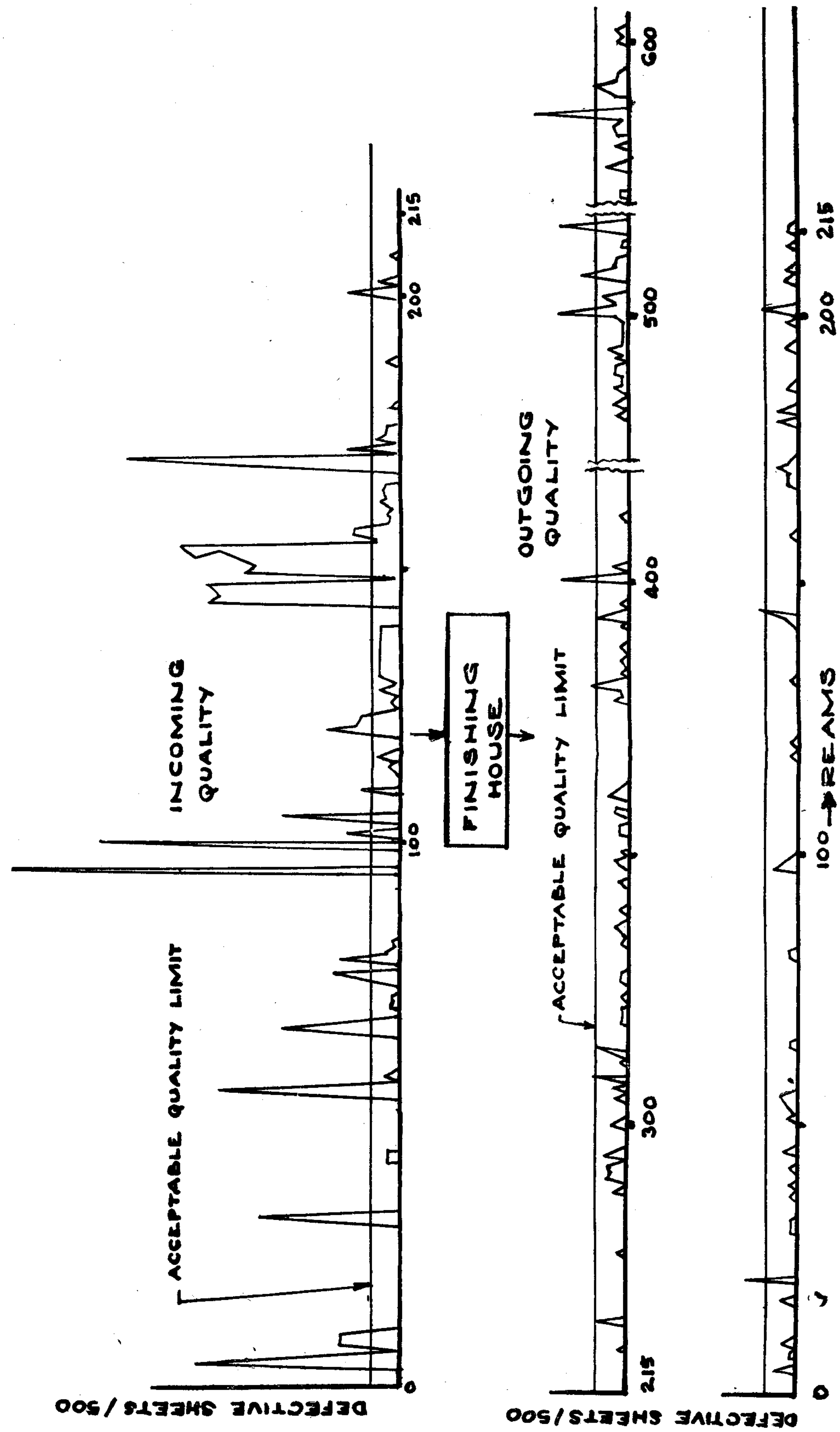

Figure 2 : Incoming quality of Paper to Finishing House and outgoing quality.
Abcissa : Number of reams checked.
Ordinate : Defective sheets per ream.

winder, an attempt was made to mark the reels also as far as possible).

All the stacks were subsequently transported to the finishing house, where they were subjected to 100% inspection, sorting and counting to appropriate reams.

The above procedure, besides possessing some inherent shortcomings such as mixing up of good and bad stacks, uneconomy of operation, etc. was incapable of providing entirely defect free reams. A typical graphic picture representing the quality of incoming and outgoing paper to and from the Finishing House is illustrated in Fig. 2. In order to cancel the actual figures, only the trends are shown in Fig. 2. The actual figures would vary from works to works. The diagram exhibits, firstly 100% defect removal is not being accomplished, secondly around 70-80% of the material is already free of defects and, at least theoretically the sorting expenses are incurred unnecessarily on this 70-80% satisfactory component also.

Statistical sampling scheme was applied at operation no. 5 mainly for the isolation of good from bad stacks (see pg. 9) so that they could be handled separately and more economically at the Finishing House. The bad stacks were planned to be completely screened and good stacks either only fly finished and counted or preferably counted only, thus eliminating a good portion of manual work.

CHOOSING THE CORRECT SCHEME FOR THE WORKS

As already stated in the introduction, no scheme can provide full protection against the ingress of some defectives into the approved material. Further, it would improve matters both psychologically and administratively, if this fact is squarely faced and a tolerance defective ream specified. The selection of tolerance defective is a compromise of factors such as economics, process capability and general prevailing practices in the industry. For choosing the correct sampling scheme, the existing standards of the defectives in the outgoing quality could be taken as a rough aim of the proposed scheme. On a sample analysis by control chart for fraction defective, it was found that the average outgoing quality of many of the Paper Mills varies around 0.2-0.5% with a tolerance limit of 1.0-1.5 per cent. Many paper factories adopt 1% as the defective tolerance limit in their despatches (1). Taking all the factors into account, 5 or 6 defective sheets/ream of 500 sheets may be considered a fairly balanced and satisfactory tolerant limit for the outgoing quality and the inspection scheme was worked for the same defective limit.

OPERATING CHARACTERISTICS OF THE SCHEME 5/500 OR 6/500

Since statistical sampling ideas were being introduced for the first time in the works under study; single sampling schemes, due to their simplicity were chosen and applied.

For working out the operating characteristics of the scheme, a rough estimate of the fraction defective for the material going to the Finishing House was made by preparing control chart of fraction defectives. Acceptance/rectification plans are not so sensitive to slight errors in percentage defective of the material offered for inspection; a rough estimate, serves the purpose. In case the computation of average fraction defectives are not precise, only the number of stacks to be screened may be slightly different from those expected.

The operating characteristics of the schemes, sample size 500 (one ream) and allowable defective limits 5 and 6 is worked out in Fig. 3 from the poisson ratio distribution. The abcissa provides the percentage defect, while the ordinate gives the probability of acceptance. As the percentage defectives are reduced, the chances of acceptance of paper go up, thus as per the proposed scheme 0.2% defective paper has almost 100% chance of acceptance, 1% defect 75% acceptance probability, 1.6 per cent defective, 30 per cent chance, 2.5 % defective, almost a total chance of rejection. This curve was used for the segregation of good and bad stacks.

PROCEDURE OF WORKING OUT THE SCHEME

The paper was cut into sheets from the reels and the same was stacked on a layhboy. Depending upon the size of the cut sheets, one to three stacks were put on one layhboy. On an average one stack of medium weight paper; 60-70 g/m2-contained around 10,000 sheets. Half stack was considered as a lot for decision.

For assessing the quality of the stack with a fair precision, it was desirable to stratify the sample withdrawal as widely as possible. Each half stack was sampled two to three times by withdrawing the appropriate number of sheets from the running machine. In case the number of defective sheets were more than six per 500 sheets, that particular half stack was reserved for screening; if however, the defectives were upto six per 500, the same was considered as satisfactory.

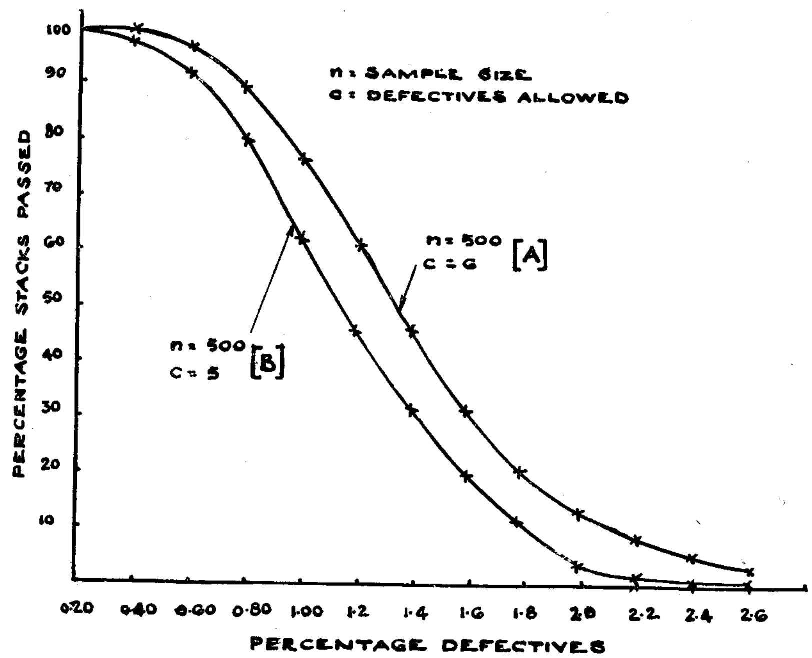

Figure 3 : Operating characteristic curves for sample size 500 and allowable defective sheets 5 and 6.

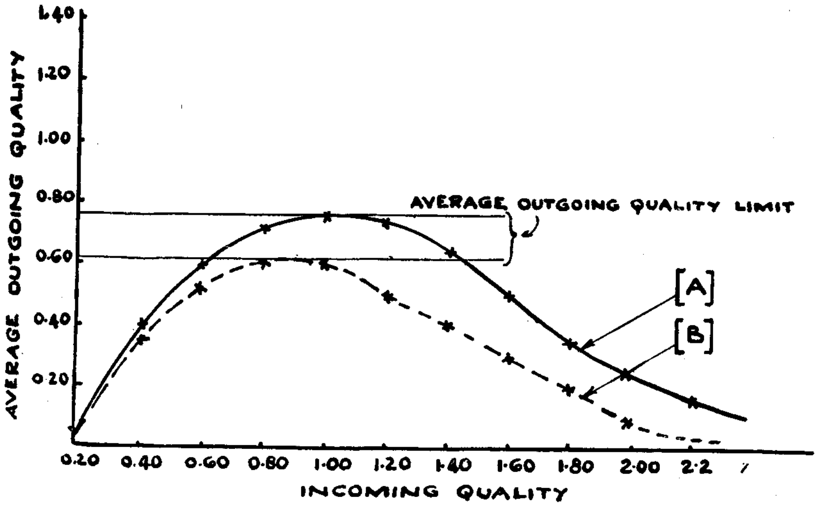

Figure 4 : Average outgoing quality limit for sample size 500 and permissible defective 5 and 6 for acceptance/rectification scheme.

EFFECTIVENESS OF THE SCHEME AND AV. OUTGOING QUALITY

Inevitably some defectives will be found in the material passed by statistical inspection scheme. Its quantitative evaluation is important for considering the merits vis-a-vis 100% inspection data. Lots accepted by sample undergo a partial screening through the elimination of defectives found in samples. Lots failing acceptance by sample are completely screened of defects. The net result is some average percentage defective in the product as it leaves the factory. This is termed as average outgoing quality, which depends on the level of per cent defective for incoming product and the proportion of total defectives screened out. The average outgoing quality — as reflected by per cent defective — increases with the increase in incoming defectives, reaches a maximum and then falls off due to rapid increase in the amount of screening. The highest value, called the average outgoing quality limit, provides an index to the highest average defectives pertaining to a particular incoming quality for a particular scheme.

The average outgoing quality values, computed as per theory of probability for the plans discussed here are plotted against the incoming quality (viz. 5 to 6 defectives per 500) in Fig. 4. The least consumer protection is provided by 1% defective under the present scheme. However, under all cases the average outgoing quality limit remains within one per cent defectives. This shows the plan is sound and within our tolerance of defectives also.

For ascertaining the dependability of the scheme, the sample approved stacks were tested completely by sorting out all the reams and noting the defective sheets per ream. The results obtained are illustrated in Fig. 5. This pilot analysis indicates that the scheme in fact, is able to isolate good reams to the extent of over 90 per cent and is thus practically feasible.

The average value of fraction defective obtained for nearly 1,000 reams from samply passed stacks is around 0.30%. This value is only for the approved stacks, which were approximately 40 to 50% of the produced lot in the shift during the time the observations were recorded. In case; it is assumed that the balance material is to be screened and defectives entirely removed, the average outgoing percentage defective of the whole production may not be more than 0.20 to 0.25 per cent. The highest values projected on 3 sigma control limits on the basis of sub-group size of 500 is around 0.8 per cent. In case the values are considered stackwise, the same is expected not to go beyond 2.0% in most of the stacks. All these values have been computed on 100% quality check of the samply approved material.

Taking all the above facts into consideration, the merits of the scheme are fairly satisfactory. However, one of the snags of statistical sampling over 100% inspection is the administrative difficulties and expenses in their proper execution, especially if the number of rejected stacks for screening are more than 40 per cent. However, experience shows that trial introduction of the schemes leads towards improvement in general quality as rejected lots from incoming material exert pressure towards quality defective removals and make people look for trouble spots quickly. Further, by knowing the quality of the paper going into the Finishing House before hand the planning of the whole section can be improved and put on more rational basis and proper arrangements can be made for the disposal of broke, distribution of work, etc.

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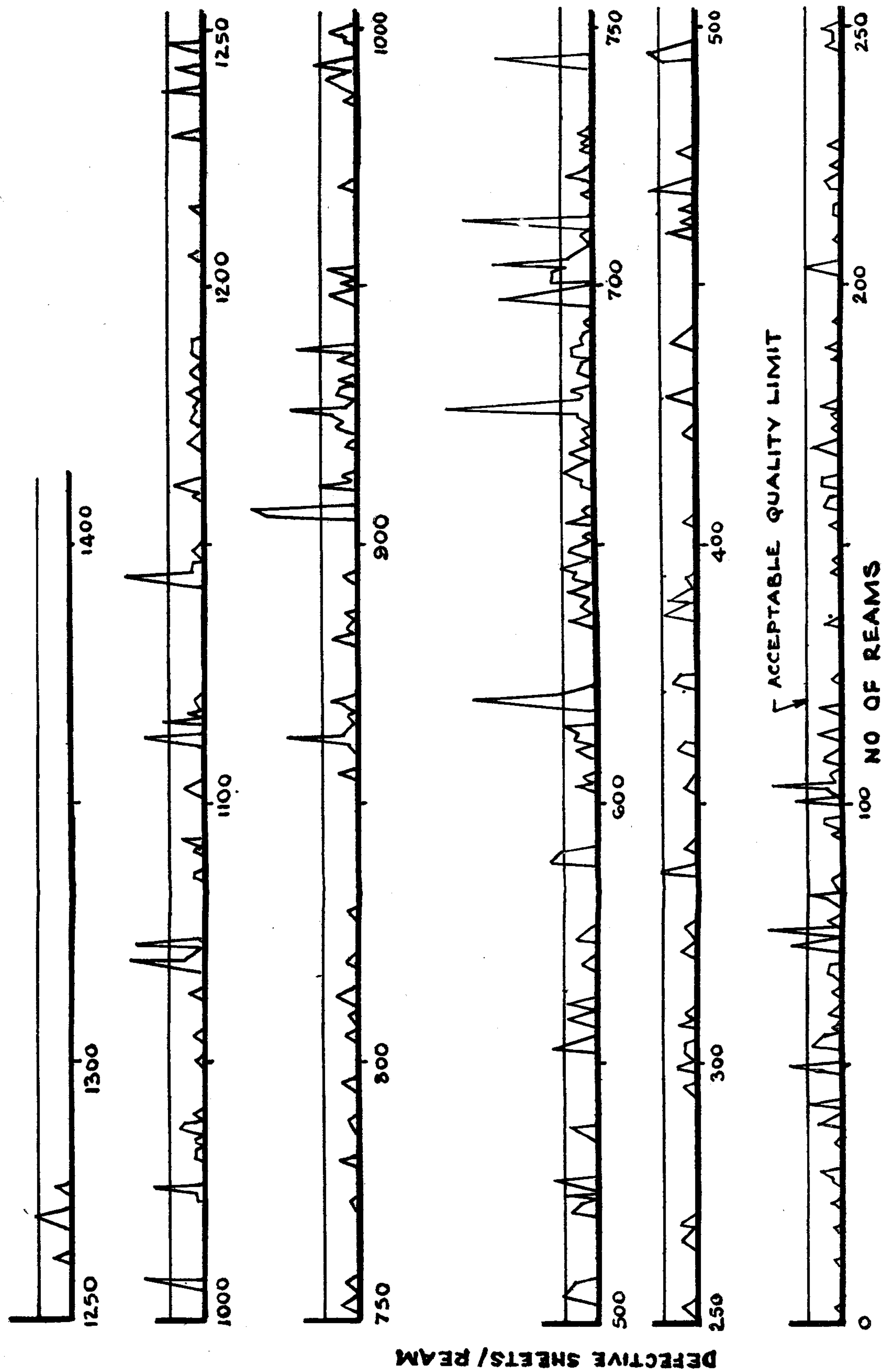

Figure 5 : Defectives from samply passed stacks.
Abcissa : Number of reams checked.
Ordinate : Defective sheets per ream.