Total Quality Control in a Paper Mill

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SUMMARY

The authors consider adoption of Total Quality Control concept as the only means by which Indian Paper Industry can come out of the prevalent crisis.

Total Quality Control starts right from the Raw-material procurement through process control to the consumer service. These aspects of Quality Control in a paper mill are dealt in the paper.

Statistical methods are necessary tools for a successful TQC programme, a few of which have been used in paper as the illustrations

Quality Control is not the responsibility of Quality Control department only but everybody in the organisation has his share of responsibility. This paper also depicts in a chart the responsibilities of various functional groups.

It is felt that the top Management has the major share of responsibility to shoulder, without the support of which a QC system cannot work. It is the top Management only who takes major quality decisions based on the information provided by various functional groups.

Indian Paper Industry today is passing through a big crisis. Many mills have already closed down and a few others may be at the doorstep of closure mainly because of general recession in the market on account of decline in purchasing power of the general public. The steep hike in the cost of all inputs of papr has further added to the problem of paper industry.

The current situation demands that if the Indian Paper industry has to survive, it has to stand in competition with the foreign market by required improvement in quality and reduction of cost. This aim can be achieved only if the concept of Total Quality Control (TQC) is adopted. Only the Managements' acceptance to this technology will not be sufficient, but everybody in the organisation has to adopt Quality Control as a way of working. They have to be trained on Quality Control methods and be made aware of the gains from it so that they carryout their share of responsibility in a TQC programme.

We have the example of Japan before us. Japan's economy after world war II, was in a very bad shape. It is a nation of scarce resources and import most of the items including the basic necessities. Therefore, its industry has to produce not only for home consumption but also to export its products for necessary imports. This meant that they had to improve their products in terms of quality as well as cost in order to stand in competition in the market. Japan could do it only by adopting the concept of TQC, in which they are even ahead of USA.

Quality control, until recently, was sought to ensure conformity of manufactured products to specified standards of appearance, dimension and durability. With the advent of statistical technology, the concept has undergone a radical change recently. It has enlarged from a mere product control to process control, from a local operation i.e. machine to covering the plant as a whole, from production to distribution, from goods to services and from manufacturing to administration. It now seeks to achieve larger and better output at lower cost with full customer satisfaction. This concept has been termed as Total Quality Control (TQC).

The TQC concept is different from the old concept of Quality Control in that, whereas the old one was inspection oriented Quality Assurance this a production process control oriented. Quality assurance in a TQC system is done by the manufacturing department on the inprocess product and any abnormality is quickly noticed and rectified, thus reducing the chances of substandard quality production, resulting in less

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rejections, better and uniform quality and reduced cost.

In a TQC programme, a single QC specialist or a particular QC group only is not expected to carryout all the control activities, but every department of an organisation has to share specific responsibilities for a quality product. The QC group plays the role of a coordinator.

The responsibilities of various departments have been listed in annexture-I.

VARIOUS INGREDIENTS OF A TQC PROGRAMME

There are two facets of quality, namely Quality of Design and Quality of conformity. Quality of design sets the difference in specification in products meant for the same end use. Quality of conformity relates to the fidelity with which products conform to the specified design. The Quality Control concept discussed in this paper relates primarily with the second one.

The various ingredients of a successful TQC programme in a paper mill are as follows :

RAW MATERIAL CONTROL

The Quality Control starts right from procurement of raw materials, for desired quality of the end product cannot be achieved if these raw materials are not of required and consistent quality. It has been a common experience that material supplied by the same supplier show large variations, sufficient enough to destabilize the quality control efforts in a process. Therefore, variations in all incoming materials should be taken care of for maintaining quality of the end product. Following steps are essential to achieve the above aim.

STANDARDS FOR INCOMING MATERIALS

The management shall decide, by past experience and with the help of experiments and process study, as to what shall be the quality of the incoming materials to achieve desired quality of the end product. These standards shall also be conveyed to the vendors for compliance.

INSPECTION OF INCOMING MATERIALS

All the materials received from various vendors shall be put to strict inspection in the light of laid down standards. Some materials are received in bulk and others in units. The methods of sampling for the two are different. Statistical theory of Bulk Sampling gives a rational basis for proper sampling of a material received in bulk with due consideration to the quality history of the vendor's past supplies such as variation between wagons, variation within wagon, cost of sampling for a wagon from the lot as well as the cost of analysis and sampling of a secondary unit from the wagon. The following equation gives the relationship between the above factors :

$$\text{Var } \bar{\bar{X}} = (M-m)/(M-1) \times \sigma b^2/m + \sigma w^2/mn.$$

where M = No. of wagons in the consignment

m = No. of wagons in the sample

n = No. of secondary samples from a wagon

σb^2 = Variation between wagons

σw^2 = Variation within a wagon.

The precision of the estimate Var $\bar{\bar{X}}$ can be controlled through appropriate choice of m and n, which are to be selected in such a way that cost is minimum in

$$n = \frac{\sigma w}{\sigma b} \sqrt{\frac{C_1}{C_2}}$$

C_1 = cost of sampling a wagon from the lot.

C_2 = cost of sampling a secondary unit from a wagon.

In case of material consisting of clearly distinguishable units, random sampling methods may be used to draw representative samples for analysis and various acceptance sampling plans available in statistical literature can be used for acceptance/rejection of the lot.

Whereas occassional rejection of the materials not meeting standards will keep the vendor vigilant on the quality of his future supplies, too much rejections will have a damaging effect on the morale of the vendor on one hand and may cause shortage of material to the mills on the other hand. Therefore, too much strict standards will not be of much help, especially in prevalent times of scarcity of raw-materials.

VENDOR QUALITY RATING

The materials received might be classified into homogeneous groups depending upon their type and use etc. Individual ratings can be evolved for each group of materials like bamboo/wood, pulping and bleaching chemicals, paper making chemicals and purchased fibres etc. A typical example of Quality Rating performa is given in annexure-II. Mills can give different weightage to different factors in the rating for

various groups of materials.

The inspection data on the supplies from different vendors shall be recorded separately. When sufficient data on each vendor is available, it can be used to grade the vendors as per their Quality Ratings. The ratings might be used for vendor development, for placing more or reduced orders, for offer of premium or penality prices etc. A poor quality rating of a vendor will call for selective attention on that vendor till a positive improvement has been noticed in the quality based on the rating of the current supplies.

This system of Quality Rating also helps the vendors to evaluate and develop the quality of their product.

PROCESS CONTROL

Quality control in a continuous paper making process is cumbersome due to the following three reasons :

a) A representative sample is difficult to draw for analysis and test.

b) The nature of most of the tests is such that there is a long gap between drawing sample and feed back of the test results to the process for required action.

c) There are a large number of factors responsible for variation in each quality characteristic. For example, there are about 1,400 factors contributing to variations in tensile strength of paper. These factors range from the moisture of the finished sheet to the side of the hill on which a particular fibre was grown.

The above reasons make it all the more necessary that all the factors are taken care of and ensured to work within the prescribed limits of operation so that the end product quality is within the specified limits. This means that for an effective process control the operating crew shall be provided with detailed standards/specifications on all the process conditions so that they can take care of them. The operating crew cannot be expected to achieve quality till they have these specifications.

It is important to mention here that before starting a QC system and before asking the process crew to maintain quality, it has to be made very clear as to what is required from them and from the process. At times it has been observed that process crew are expected to maintain a quality which their machine is not capable of producing. Therefore, as a start of a quality control programme, process capability studies have to be carried out in respect of all the characteristics which are expected to be controlled in the paper. Based on these studies, the capability of the machine has to be estimated numerically which shall form the basis for all the standards/specifications for process and the end product. Statistical methods like 'Analysis of variance' etc. are of much help for the purpose of such analysis.

Paper making process can be divided into two stages viz, (1) pulping and (2) paper making. Whereas the quality of the paper is very important and it has to be attained at all costs since it affects the consumer, the quality of pulp has a direct bearing on the paper quality. A poor quality pulp cannot result in better and uniform quality of paper. Therefore, pulp quality control is as essential as paper quality control.

PULP QUALITY CONTROL

Pulping process consists of chipping bamboo/wood to chips and cooking them with alkali under controlled conditions to loosen up the binding materials, bleaching or removing colouring matters with the help of different bleaching agents. Variations in the quality or quantity of the chemicals added will mean variations in the quality of final pulp. Therefore, it is essential that all these factors are properly taken care of. To ensure the uniformity of inputs, quality and quantity as well as that of inprocess product quality, their periodical testing/inspection is most essential. Representative samples shall be collected at regular intervals and tested by control laboratory and the results be promptly fed back to process for use in necessary process control.

As most of the tests connected with pulp are known to take longer time to carryout, such tests cannot be of much help for use in process control. To avoid this, such tests can be replaced by quicker tests. For example, brightness test needs pulp sample to be made into sheet and the same be air dried before measuring its brightness. This means a time gap of atleast 2/3 hours between sampling and reporting of results. Such tests cannot be used for control but only for record purposes. If brightness is to be controlled effectively, a quicker estimate of this characteristic, and other characteristics also, is most essential. Probably the brightness of the pulp in suspension can be measured which will be a quicker method. In case of such characteristics which cannot be measured fast, some other characteristic can be measured and the desired characteristic can be estimated from the measured characteristic with the help of statistical

technique of regression analysis.

PAPER QUALITY CONTROL

Paper making process starts from physical treatment of the pulp through refining/beating and addition of various chemicals/dyes etc. which is known as stock preparation, through formation of paper sheets, its drying and conversion. Though sample in stock preparation is easy to draw, testing takes a little longer time and, therefore, these testing methods need to be replaced with quicker methods such as providing process on line control instruments or to be estimated from some other characteristic with the help of statistical regression equation $Y=a+b$.

But sampling during sheet formation and its drying is a cumbersome process. The only place where a sample can be easily drawn is paper reeling stage. Samples from here also cannot be drawn quite often as it means wastage of production. A statistical analysis of the effect of breaks in the paper roll was carried out at our mill which indicated that number of breaks in a roll has direct relation with percentage of finishing losses. Breaks due to various reasons contributed in the loss of paper as under (number of breaks/100T of production also given) :

Cause	Paper loss/ break	Avg. No. of breaks/100T prod.
Machine break	20 kg	141
Sample break at m/c.	5 kg	267
Rewinder break	91 kg	16
Average :	12 kg	424

The paper loss/break on account of sample break was low because rewinder was slowed down at the time of passing this (sample) break and therefore no paper loss resulted most of the time. This means that sampling of the paper has to be drawn in such a way that it is neither too often to eat up the economy of the process nor it is so rare that it, not representing the lot from which it is taken, becomes meaningless for process control.

For a medium speed machine, hourly samples have been found adequate enough to represent the lot. But the exact frequency of sampling has to be decided depending upon the individual mills process conditions and the product needs for quality. At times, when some disturbances in the process are noticed, more frequent samples than stipulated can also be drawn to lay hands on the exact cause of such distutbances and to segregate the sub-standard product from acceptable ones.

In the event of disturbances inprocess causing variations in the end product, various methods like cause and effect diagram and simple/multiple regression analysis etc. can be of much help in tracing out the exact cause. We have been making use of these methods with benefits in our mill.

Under the stable conditions in a process, the product quality is expected to follow the law of chance and when the results of tests from such process are plotted they form a shape like an inverted bell known as normal distribution. Any deviation in its behaviour can easily be noticed. A control chart is based on this concept only and is of much help in process control indicating the need of adjustment when the process shows lack of control and asking to leave the process untouched when it is under control.

QUALITY ASSURANCE

As has been said earlier paper making is a complex process. In spite of best efforts on the part of process crew to maintain quality there are chances that some portion of the production fails to meet the standards. Even in a best controlled process this is possible due to interference of some factors for short durations e.g., failure of ADKA, disturbence in consistency regulator, fluctuation in machine speed etc. Detection of short duration of such disturbances have chances of going unnoticed in a continuous process like paper making where random samples cannot be possible and only from the top of the roll the samples are usually drawn. A vigilant process crew can reduce such disturbances but cannot completely eliminate them. Therefore, it is necessary that quality of the paper is inspected and assured at various stages of conversion.

AT REWINDER

As the roll is being processed at rewinder it shall be assessed for various characteristic i.e. measurable as well as non-measurable for its overall quality. A Quality Rating system for individual rolls can also be made at this stage as per the proforma given in annexure–III. The feed back of Quality Rating along with any special remarks on quality to the process as soon as the roll has been processed at rewinder will help the process crew to improve the quality in respect of the lapses noticed in the earlier roll.

At the end of each shift a Quality index may be calculated to judge the quality efforts of the

process crew as under :

Quality Index =

$$\frac{\text{Accepted production without action}}{\text{Total production}} \times 100$$

AT CUTTERS

This is the stage where reels are converted into sheets and the paper is available into unit form. Therefore, a better representative sample can be drawn.

An acceptance sampling inspection system at this section can provide a good quality assurance. The results when fed to the process regularly will help in process control efficiently.

Our mill had experimented and established an acceptance sampling plan at this section in which samples of cut sheets, as they are cut and pile up on the pallet, were sampled by a sampler as provided in the plan. Sample drawn from a pallet was inspected visually for various characteristics and good and defective sheets segregated. If the number of defective sheets in a given number of sheets was found to exceed the acceptance number of the plan, the whole pallet from which this sample was drawn was rejected; otherwise it was accepted. The accepted pallets were subjected to no sorting operation but simply counted and packed. The rejected pallets were subjected to mild to vigorous sorting operation depending upon the extent of defectives into them. The results of the checking were immediately fed back to the process for needful action.

The scheme, after experimental stage, was given a trial for more than a year and no complaints were received from the market on this paper.

At Finishing House

Whether or not a TQC programme is in practice in a mill, a quality assurance of the reams made at finishing house for supply to market is very essential and a must. Finishing house is the final stage of a mill process and any defect escaping notice of this section is bound to raise complaints from the market. In every paper mill 100% inspection by the finishers is practiced. But there is no guarantee against defectives passing in the reams since the work fatigue in cent percent inspection limits the effectiveness of this system and because mostly the finishers work on contract basis.

Therefore, a quality assurance of the finished reams should be carried out on sampling basis. Under a Quality Assurance scheme, an acceptance sampling plan can be used and if the reams of any finisher do not meet the requirement of the scheme they shall be required to re-finish.

CUSTOMER SERVICE

Maintaining quality of the product at manufacturing stages and assuring it at conversion stages is not the end of Quality control efforts in a mill but includes to ensure that the paper reaches the customer with this quality and performs at his end without trouble. This means ensuring proper packaging, storage and its transportation to the customer so that it does not get damaged in transit.

In spite of all efforts on quality front, some sporadic complaints may be received from customers since even a best quality paper cannot be good for all end uses or a few defective sheets may escape in the reams. Generally, market complaints on quality arise due to users dis-satisfaction with the product performance. These complaints, therefore, shall be viewed seriously by a mill for corrective action in respect of such defects in the process. Such complaints help the mill to improve the product quality and hence can put it in a better position of competition with other mills.

While analysing the complaints for about ten years, it was observed that rejection of sub-standard paper has a positive relation with number of complaints. The higher the rejections, higher is the number of complaints. It gives a correlation coefficient value (r) of +0.78 against a maximum possible of +1. This is obvious because higher rejection only indicates that more sub-standard paper is being manufactured by machine which is tried to be sorted out at subsequent stages. But no process of sorting can be cent percent effective, meaning thereby that in case of higher proportion of defectives in the paper coming out of the machine has a chance of some defectives escaping to the market. Therefore, to avoid it, it is essential that all the controls are exercised in the process so that ultimate product is defect free.

The ultimate objective of the TQC endeavour in a process is to provide quality assurance for the finished product and to ensure optimum quality cost. To accomplish this objective, a mill needs an integrated programme of quality control right from raw-material procurement to the finished product, including customer service.

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Annexure–I

Responsibility of various departments for quality

Sl. No.	Functional group	Quality function
1.	Design & development	Product design, prototype testing and evaluation.
2.	Process engineering	Selection of materials and their specifications, component tolerances, manufacturing plan.
3.	Production planning	Allocation of machines and processing equipments to different jobs.
4.	Manufacturing	Operator education, proper interpretation of drawings and specifications, process operation to meet these specifications.
5.	Inspection & testing	Inspection of incoming materials, inprocess and final products in the light of laid down standards/specifications and segregation of product not conforming to specifications.
6.	Purchasing	Selection of vendors and ensuring steady Supply of requisite quality materials.
7.	Packing & transportation	Adequacy of containers, safe transportation procedures.
8.	Coating	Cost analysis.
9.	Sales	Quality trends in market, changing needs of customer, timely delivery of goods to the customer.
10.	Quality control	Co-ordination of activities of different departments in relation to "QUALITY".
11.	Management	Has the major share of responsibility. Without their support a quality control system cannot work effectively. All major quality decisions are taken only by management on the basis of information provided by various functional groups.

Vendor Quality Rating
(Calculation procedure)

Sl. No.	Factors	Rating	Max. score
1.	**Quality**	—	35
	No. of lots received	n	
	No. of lots accepted without any defect	A	A/n × 0
	No. of lots accepted with concession	B	B/n × 10
	No. of lots accepted with vigorous sorting	C	C/n × 20
	No. of lots rejected	D	D/n × 35
2.	**Support documents** (receipt of test certificates or categories on literature)		5
	No. of consignments	n	
	No. of lots for which the documents did not accompany the material.	R	R/n × 5
3.	**Quantity discrepancy**		5
	No. of consignments	n	
	No. of consignments for which quantity is different from declared.	K	K/n × 5
4.	**Delivery**		10
	No. of consignments	n	
	No. of consignments received with ±d days on delivery date specified.	M	M/n × 0
	No. of consignments received after d days	K	K/n × 10
5.	**Price**		15
	Minimum of the price	x	
	Price from other suppliers	y	
	Rating		$\frac{Y-X}{X} \times 15$
6.	**Service and business relations**		10
	i) Attends to enquiries or complaints		5
	a) very regular		0
	b) moderate		1
	c) occasionally regular		3
	d) not at all regular		5
	ii) Relations :		5
	a) Very cordial		0
	b) Moderately cordial		1
	c) Cordial just to the point		3
	d) Bad		5
7.	Supplementary criteria		
	1. Facilities		10
	a) No proper equipment b) Technology inadequate c) Inadequate planning		max 5
	d) Quality control		max 5
	i. instruments poor		
	ii. Non-qualified man power		
	iii. Systems and procedures poor		
	2. Product failures after acceptance		10
	Total score		(S)

Overall Quality Rating = 100—S

Note : Demerit scores are assigned for various characteristics. Higher the score, proper is the performance and lower the Quality Rating.

Annexure–III

PAPER QUALITY RATING

Characteristic	Max. score	Actual score	Action
Quality defects	25	20–25	No action
		15–20	Check further
		10–15	Separate and check at further stages.
		<10	Reject
Surface cleanliness	15	12–15	No action
		7–12	Inform the process
		<7	Reject
Shade	10	10	Exact matching—no action.
		8–9	Sl. variation—No action.
		5–7	Distinct variation—inform process.
		<5	Prominent variation—reject.
Sizing	10	8–10	Within standards—No action.
		5–7	Sl. lower than Std.—inform process.
		<5	Much low—reject.
Substance	10	10	$\bar{x} \pm$ specification—No action
		5–9	$\bar{x} \pm$ rejection limit—inform process.
		<5	Beyond rejection limits—reject.
TOTAL	70	X	

$$\text{QUALITY RATING} = \frac{X}{70} \times 100$$