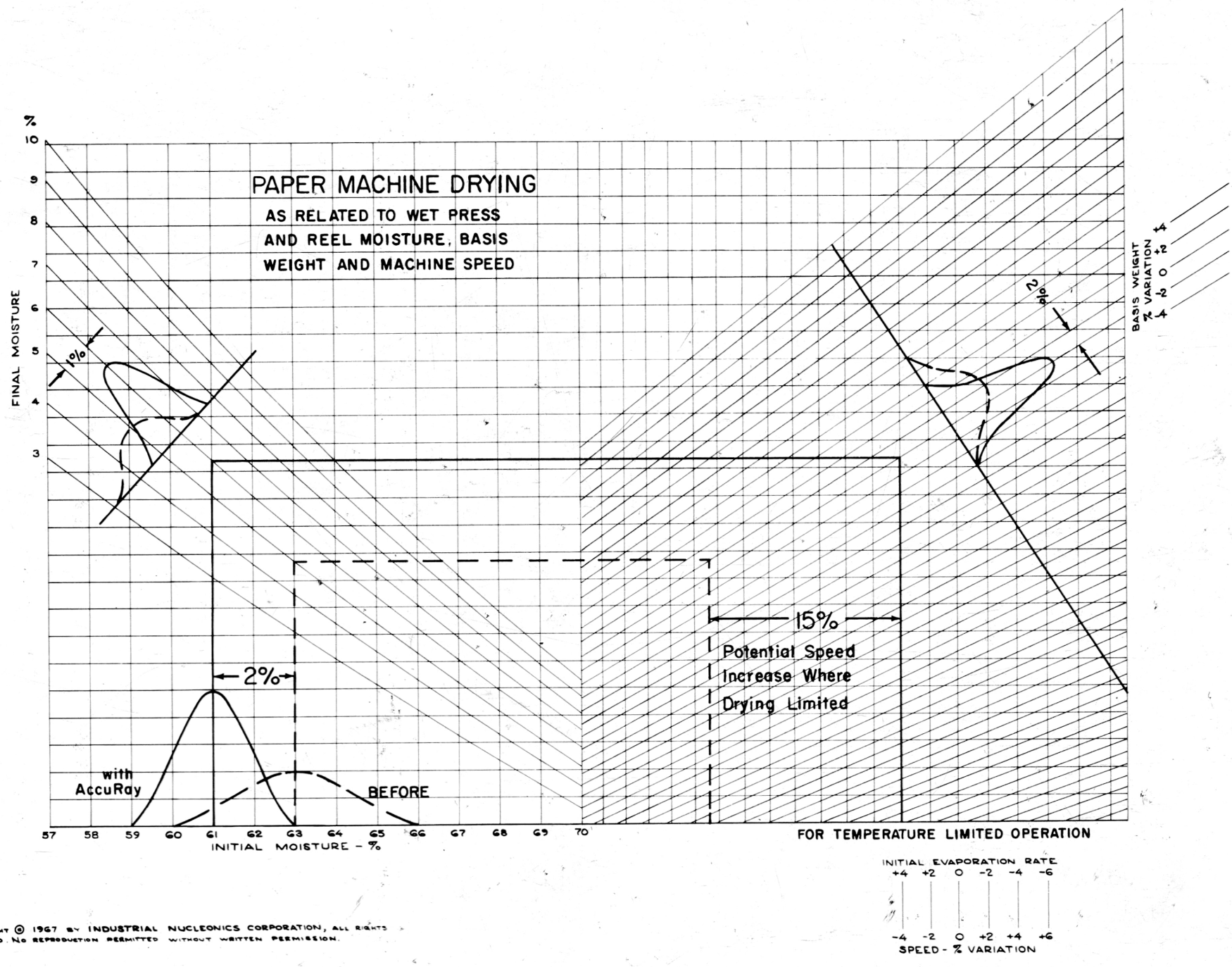
METROLOGY CAN INCREASE PAPER INDUSTRY PROFITS



FORWARD

This group of articles was originally written for publication as a part of the Fourdrinier Series in Pulp and Paper magazine. The purpose of this series was to cover the steps necessary to actually achieve a reasonable percentage of the potential economic benefits available from on-line product measurements. The articles also attempt to express the Industrial Nucleonics philosophy of systems application evolved over the years as the result of experience drawn from over 500 units installed in the paper industry.

This is a new and complex industry, frequently viewed with misgivings and misunderstanding by the paper industry. Opinions expressed by those utilizing these new tools range from near euphoria to frustration and bitterness. A somewhat similar situation has occurred as a result of the installation of digital process computers. The acceptance and results from these systems will continue to grow as greater industry efforts are applied to master and capitalize on these new technologies.

The first article introduces the series and lists the areas of potential economic benefit. An economic model is cited which allows greater precision in the projection of improved operating profits as a result of process changes or improved product quality.

The second article is a layman's discussion of the statistics of reel sampling. Accurate continuous measurement is a requirement if a uniform product is to be obtained. Article number three presented the program necessary to augment the system hardware if results are to be achieved.

The fourth in the series was devoted to the relationship of paper drying to tonnage produced. Useful paper machine drying graphs have been developed. The power of the AccuRay WATER BALANCE® system is indicated. Number five recognizes that none of the preceding is meaningful without high accuracy and uptime. The requirements to obtain these are stressed.

Metrology is a difficult, dynamic and potentially powerful field. We hope this document will allow your company to better capitalize on the significant economic and quality opportunities it offers.

George I. Doering

Metrology* opens door to improved profits

Despite the growth of the paper industry, new methods are needed to counteract eroding profit margins. On-line instrumentation is one answer, as shown in this first of a six part series-within-a-series.

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Like the straw that broke the camel's back, the paper industry is faced with ever increasing managerial, technical and research problems.

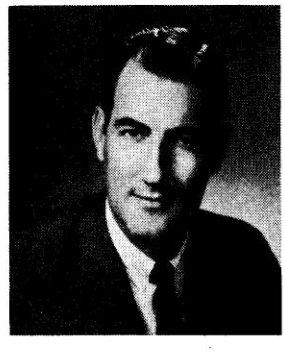
The net effect of all of these problems and changes in the industry can be seen in the performance of the top twenty paper companies. The enviable record of increased sales is unfortunately accompanied by an erosion of net profit as a per cent of assets or sales. All other accomplishments will mean little to owners and employes if the skid of these crucial business indicators is not halted. To a great extent, how well the industry succeeds in meeting today's challenges will depend upon its ability to reverse this trend of return on sales and investment.

No panacea is presented here but attention is focused on one of the more promising areas to improve papermaking profits.

This is the first of a series of six articles which will offer some guidance for maximizing profits through the installation and proper use of on-line analytical instrumentation. We can only present in this first article the highlights of potential results which may be achieved. The remainder of this series will point the way to how modern day technology is applied to achieve those results.

The second article will present a statistical foundation for controlling a process by manual sampling of basis weight at the reel as compared with on-line continuous measurement. It may be a revelation to some that continuous measurement of process variables offers considerable reduction in process spread even if control action is only performed once per reel as in the case of manual sampling.

The mere installation of process measurement and control equipment will produce only a small percentage of the total benefits available. The third article will describe a Results Operation Program which teaches how to properly utilize these systems to reap an annual reward of two to ten times the dollars invested.



Mr. Doering, a BSEE graduate of Case Institute of Technology, joined Industrial Nucleonics, Columbus, Ohio, in 1953. Prior to becoming general manager of the paper industry division, his 14 years of experience include engineering, sales and management.

Since a major function of the Fourdrinier machine is the removal of water from the furnish, it is important to understand the mechanics and economics of the drying cycle. A fourth article will explain the interaction of moisture and basis weight variations entering the dryers as well as those present in the final product. These properties not only have made a major impact on the process economics but also on the quality and saleability of the finished sheet.

The fifth article will discuss the incorporation of theory into hardware and a software program. Actual examples of results achieved and future potentials available will be described in detail so that each papermaker can draw a parallel with his own operation.

We all know that instrumentation and control systems

*The science of measurement.

can produce results only when they are working and reading accurately. The last article in the series will spell out the requirements based on actual experience to maintain 99+ per cent system uptime. The concepts included here will be new to most readers and could be a pattern for the proper maintenance of other equipment.

In total, then, we will show how, through increased fiber yield, reduction of scrap, reduction of operating costs, increase in throughput, and improvement of product quality, a company can significantly increase profits and earnings per share.

Basis weight and moisture control equipment have been available for more than a decade. Why is it that these benefits have not been more universally obtained? To answer this question one could look at the distribution of the sales dollar for a typical paper manufacturer. It would be noted that over half of the sales dollar is in the value of the material entering the headbox of a paper machine. A small percentage in material savings or fiber yield can make a dramatic improvement in profit before taxes. But the paradox is that the least amount of top management time is spent in controlling the utilization of this costly raw material. In contrast the machine tender and backtender have control over a tolerance of at least ± 5 per cent in the utilization of fiber and water in the end product. So the first requirement for results achievement is a corporate-wide program, headed by a top manager charged with the responsibility for optimizing the use of raw materials. This program must involve marketing, technical, manufacturing, quality control and the accounting functions.

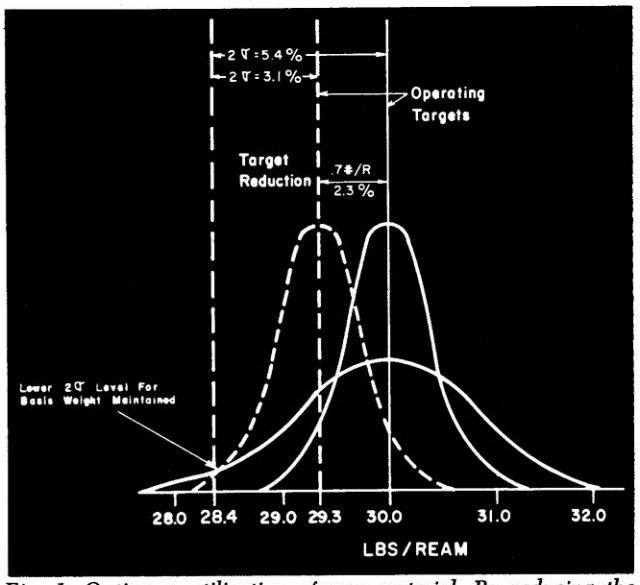


Fig. 1. Optimum utilization of raw material. By reducing the basis weight spread, one can reduce target and save 2.3 per cent of material.

Paper products consumed on area basis

Next there must be a recognition that all paper products are consumed on an area basis. Even if the mill sells its output on a tonnage basis, the value to the customer is determined by how many magazines, cartons, cups, forms, newspapers, or even dresses can be produced from a ton of paper. Regardless of where this bulk-to-area conversion takes place in the accounting system, it physically occurs at the slice of the paper machine. Therefore, the control to produce from a ton of pulp the maximum possible number of sq. ft. of paper which will meet the required performance standards must be applied as close to this point as possible.

Once this concept is adopted by top management then sweeping changes must be instigated throughout the organization.

For example:

1. The marketing department should be converted to sell all products on the basis of emphasizing the maximum usable square footage per customer dollar.

2. Incentive programs throughout the mill from the mill manager to the machine crew must be based on producing the maximum area as opposed to tonnage.

3. Continuous training programs must be conducted for all personnel to indoctrinate them in utilizing the available machines, equipment, and instruments for maximizing the area throughput.

4. The management information system must be restructured to reflect the change in profitability as a function of area production.

5. All paper machines must incorporate gauging and control systems to maximize the area throughput while minimizing the material input. New methods and procedures must be instituted throughout to utilize these systems properly.

6. There must be a continuous accuracy verification and preventive maintenance program to insure that these systems are always working properly.

7. Finally, the product should be accepted or rejected based on the information from these systems.

It will take the greatest ingenuity and creativity throughout the organization to take advantage of the benefits that can be offered by on-line basis weight and moisture control. As we will see, however, the rewards are high and well worth the effort.

The profit opportunities presented by on-line basis weight and moisture control systems originate from numerous areas:

1. Historically, the chief justification for basis weight gauging at the output of the paper machine has been the ability to reduce the process variations and thereby reduce the operating target (Fig. 1). In this example, a manufacturer of publication rawstock was using a target of 30 lbs./ream. By manual sampling at the end of each reel the lower 20 process limit reached 28.4 lbs./ream. By continuous basis weight measurement and control the process spread is sharpened allowing the operating target to be lowered to 29.3 lbs./ream and still maintain the lower 20 limit at 28.4 lbs./ream. The end result is a reduction of 0.7 lbs./ream or 2.3 per cent of the original fiber usage. In addition there is less production below 28.4 lbs./ream.

2. Conventional methods of taking hand samples to determine moisture profile at the reel leave much to be desired. Not only is there a lack of information regarding the moisture profile but also it is a virtual certainty that the sample will pick up moisture from the humidity in the room before a valid determination can be made. As a result, the tendency is to over-dry the paper to insure that moisture streaks do not exceed the tolerable limit.

By the installation of a continuous moisture measurement and presentation of moisture profile at the reel, the backtender has the information available to reduce his moisture variations and raise the average moisture to a point that his peak moistures will be just under the tolerable limit. An increase in end moisture will permit an equivalent reduction in fiber content and still maintain the same basis weight. The probable fiber savings will range from a minimum of one per cent to that achieved by basis weight control described above.

3. In changing grades or basis weight the machine tender has an immediate indication when he has reached the proper basis weight specification without having to wait for the results of a tear sheet. Also, once he is on specification vernier adjustments can be made before tolerances

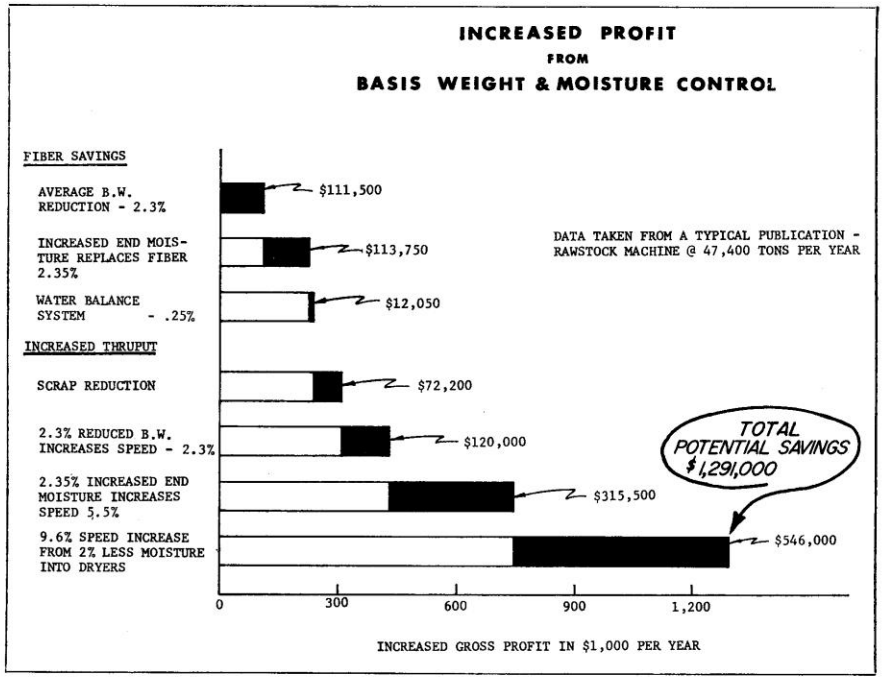


Fig. 2. The potential increase in profit from basis weight and moisture control are substantial.

PAPER MACHINE ECONOMIC MODEL SUMMARY

Product: Publication Rawstock

DATE: November 20, 1967
BY: G. I. Doering

Manual Sampling of Basis Weight and Moisture

Material In
Average Cost
100 $/Ton

Annual Operating Hours 8,000
Average Throughput 6 Tons/Hr.
Variable Process Cost 150 $/Hr.
Fixed Process Cost 1,300,000 $/Yr.
PROCESS

Recycled Scrap Rate 0.6 Tons/Hr.
Reprocessing Cost 10 $/Ton

Average Product Sales Value 220 $/Ton
Saleable Production Rate 5.4 Tons/Hr.
Process Efficiency 90 %

Definitions:

Throughput = Production + Scrap

Process Efficiency = Production / Throughput

Annual Process Costs

Material Cost	$ 4,320,000
Fixed Process Cost	$ 1,300,000
Variable Process Cost	$ 1,200,000
Scrap Process Cost	$ 48,000
TOTAL PROCESS COST	$ 6,868,000

Present Annual Sales	$ 9,500,000
Total Process Costs	$ 6,868,000
Gross Income	$ 2,632,000
Sales Ex/. G.and A.	1,425,000 - 15%
Pr fit before Taxes	$ 1,207,000 - 12.7%

On-Line Measurement of Basis Weight and Moisture at Reel

Material In
Average Cost
100 $/Ton

Annual Operating Hours 8,000
Average Throughput 6.45 Tons/Hr.
Variable Process Cost 150 $/Hr.
Fixed Process Cost 1,300,000 $/Yr.

Recycled Scrap Rate 0.55 Tons/Hr.
Reprocessing Cost 10 $/Ton

Average Product Sales Value 225 $/Ton
Saleable Production Rate 5.9 Tons/Hr.
Process Efficiency 91.8 %

Annual Process Costs

Material Costs	$ 4,630,000
Fixed Process Costs	$ 1,300,000
Variable Process Costs	$ 1,200,000
Scrap Process Costs	$ 42,400
Control System Costs	$ 60,000
TOTAL PROCESS COST	$ 7,232,400

Predicted Annual Income	$ 10,667,844
Total Process Costs	$ 7,232,400
Gross Income	$ 3,435,444
Sales Exp.,G. and A.	$ 1,600,000 - 15%
Profit Before Taxes	$ 1,835,444 - 17.2%

Profit Before Taxes

$1,835,444 On-line Measurement
1,207,000 Manual Sampling
$ 628,444 - 52.1% Increased Profit

Fig. 3. This paper machine economic model shows that with on-line measurement of basis weight and moisture at the reel a 52.1 per cent increase in profit can be achieved.

are exceeded thereby minimizing the probability of producing paper which will be rejected for quality reasons. This reduction in scrap results in a higher process efficiency and the elimination of reprocessing cost of the scrap eliminated.

4. The decrease in basis weight described in paragraph one above will permit an equivalent speed increase without requiring any greater pulp, pump, drainage, or dryer capacity. The resulting production increase will improve profits by the amount of the product value at the reel minus the cost of material at the headbox.

5. It is readily recognized that increasing the reel moisture will permit a sizeable increase in machine speed without increasing the dryer steam.* In fact a one per cent increase in end moisture will permit a three per cent to 15 per cent speed increase depending upon the particular paper machine and the degree of overdrying.

6. By incorporating a gauge at the press section in a Water Balance System,** one can determine the moisture level and profile entering the dryers. Experience has shown that when the presses are adjusted to level the profile at this point a decrease in the moisture level will result and thereby reduce the dryer load per unit area of sheet. A one per cent reduction in sheet moisture will result in a four per cent to five per cent reduction in drying requirements or permit a four per cent to five per cent speed increase in a dryer limited machine. Experience has shown that the increased profit from this factor may be as large as the increased profits from all other causes.

7. In most machines the dryer is usually the limiting factor on the speed of some production. However, in cases where the dryer is not the speed limitation, the savings from the production increase above can be translated into a steam reduction. However, it should be remembered that many older paper machines have undergone remodeling or even a complete rebuild to increase the production rate and product quality. The resulting profit increases have come about from a careful examination of the process limitations and modernizing these parts of the machine. The inclusion of on-line basis weight and moisture measurement will go a long way to enhance the creativity of the process engineer to isolate and eliminate these process limitations.

8. Perhaps the greatest advantage of on-line basis weight and moisture control is the resulting improvement in product quality. It is well known*** that quality factors such as Mullen, tensile strength, printability, porosity, shrink, caliper, and others are strongly dependent upon uniform and proper basis weight and moisture. When the market is soft these factors become of prime importance to maintaining and increasing a company's market share.

A summation of the above potential savings for a typical publication rawstock machine production 47,400 tpy is shown in Fig. 2.

An increasingly important outgrowth of work done during World War II is the use of modeling as a technique to predict how a complex system will react under various conditions. Most of the early applications utilized the analog computer to aid engineering design. In recent years the high speed digital computer has further enhanced modeling utility as an approach to solve a variety of problems. One project currently receiving much attention is a model developed to simulate the U.S. economy. Also, an economic model has been developed which accurately reflects the profitability of a Fourdrinier machine as certain operating costs and basic parameters are varied. In order to speed the calculations and expand its scope, this model has been programmed to run on a 360 computer. It responds as the actual process would under stipulated conditions. To assure accurate data is obtained as input for this model, experienced engineers work with the paper company staff to conduct a technical audit of the process.

Table
Data and assumptions for economic model

1.	Product sold by area		
2.	AccuRay control of basis weight and moisture		
3.	Throughput is dryer limited		
4.	Increase speed 2.3% for 1% increase in reel moisture		
5.	Reduced order change time: 85 hrs./yr.		
6.	Reduced scrap from off-spec moisture: 58 hrs./yr.		
7.	Basis weight	Before	After
	2 σ variations	5.4%	3.1%
	lower 2 σ limit	28.4#/ream	28.4#/ream
	average	30.0#/ream	29.3#/ream
	% shift		2.3%
8.	Reel moisture	Before	After
	2 σ variations	1.5%	1.2%
	upper limit	6.5%	6.5%
	average	3.0%	5.35%
	% shift		2.35%

The complete calculations of the model are far too extensive to be included here. Fig. 3 illustrates a summary of the model results for a typical machine producing publication rawstock. This example is the same one used to calculate the savings shown in Fig. 2. Data and assumptions used in this case are listed in the table, here.

The results show that improved basis weight and moisture control can increase annual salable production from 43,200 to 47,400 tons. With manual sampling the profit before taxes is calculated at $1,207,000 or 12.7 per cent of sales. Utilizing on-line measurement at the reel and after allowance for system rental expense and increased G&A, a new profit is calculated to be $1,835,444 or 17.2 per cent of the new sales volume. This $628,490 increase in profits compares to $732,950 from Fig. 2. Even this lower figure represents a 52.1 per cent addition to the original profit.

These calculations do not include the profit potential which can result from adding additional equipment to level and reducing the moisture profile entering the dryers. These Water Balance Systems are quite new but promise substantial speed increases or alternatively modest steam savings where speed is otherwise limited. Fig. 2 shows the Water Balance System can add an additional $546,000 to achieve the overall total of $1,291,000.

These measurement systems provide an alternative method to increase production in many cases. This flexibility can be invaluable as market demand and operating capacity go through periodic cycles. The 4,200 tons annual increase in production would require $1,200,000 of capital if these tons were achieved by building new capacity. It is certainly a great advantage to be able to extract maximum production from existing machines.

This first article of the series has attempted to show that on-line analytical instrumentation can make a significant improvement in profit margins. The equipment alone will not produce these goals. Top management must become involved in a corporate wide metrology program which will produce new operating standards and methods to result in a better quality product and higher profits. □

*Montgomery, A. E., Tappi; 37(1):1(1954).
**Trademark of Industrial Nucleonics Corp.
***Gardner, T. A., Tappi: 50(7); 110A(1967).

Figure 1

The composite performance of the largest 20 paper companies shows that over the last 17 years a 4:1 increase in sales has been accomplished by a decline in profits as a percent of sales and assets.

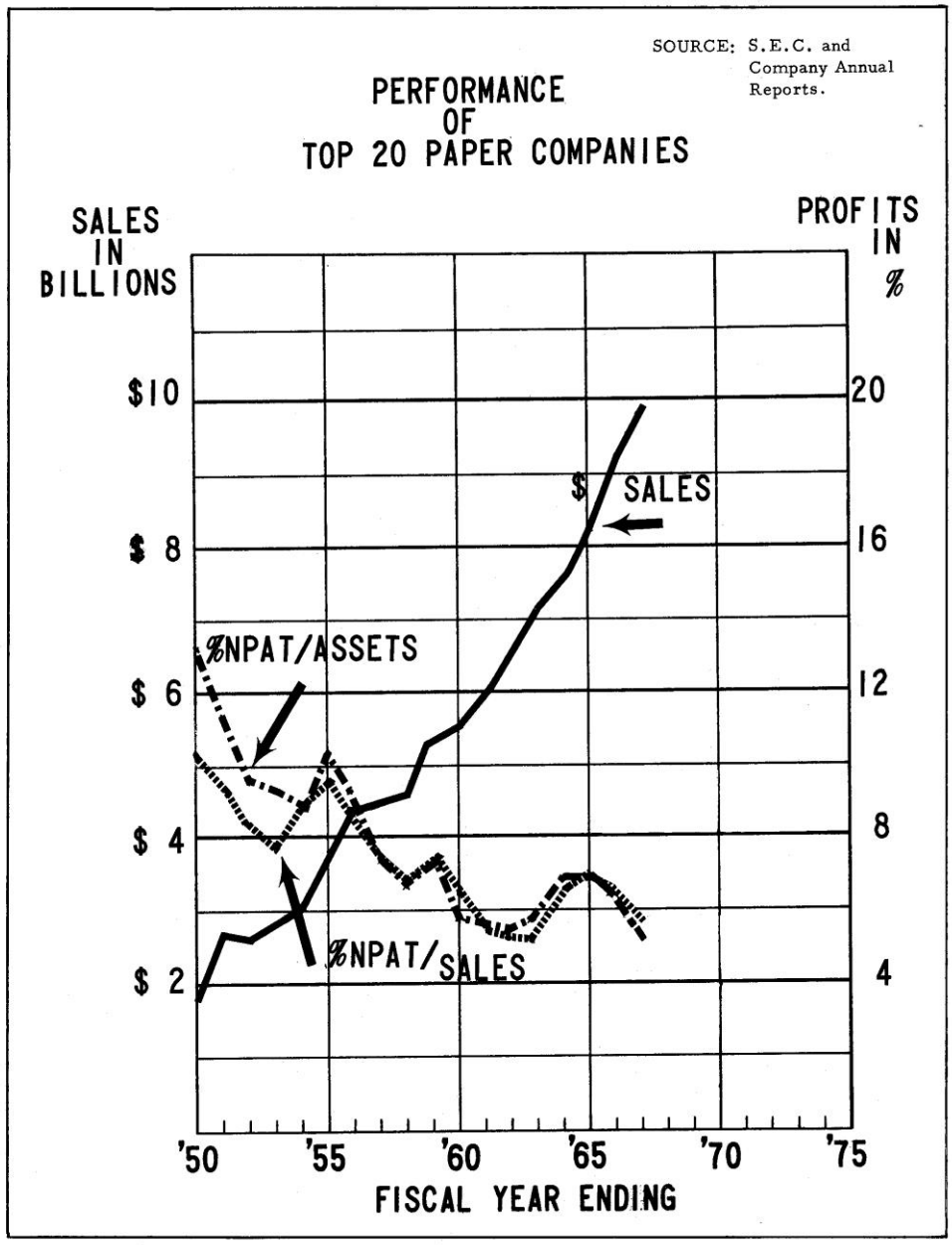
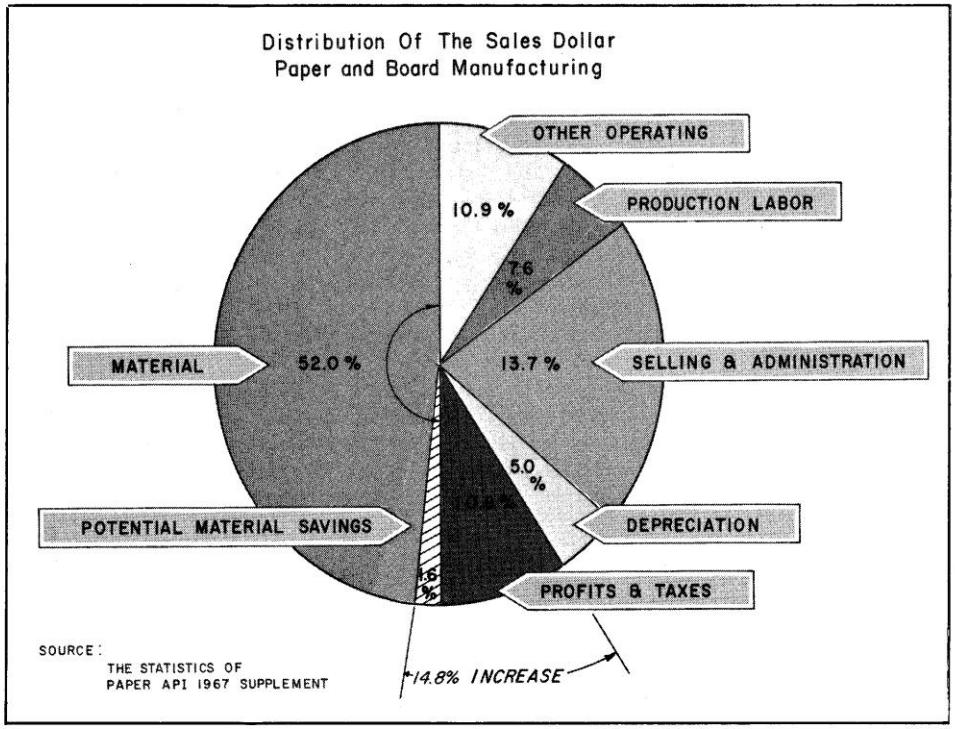


Figure 2

A 1.6% savings in material can amount to a 14.8% increase in profits before taxes.



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