Role of instrumentation in efficient operation of paper plants part-I-for small paper mills

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ABSTRACT

Automation is the technique of making a process or system automatic through the proper application and manipulation of equipment and machinery, which is primarily accomplished through instruments that measure and control the various operations. In India, in the papermaking, still the instruments are playing only a minor role in many paper mills. some of them only have Indicating type of instruments directly connected to process or mounted on posts or on walls adjacent to the process equipments, such as digestors, washers, storage chests, refiners and paper machines etc.

The use of instruments increases operating efficiencies, reduces production costs, and improves product quality and this has been the prime motive for mill management's decision to use more and more instrumentation in their mills. In order to achieve these objectives, proper instruments must be used to determine the state of these conditions during the operation of the process.

An effort has been made in this paper to discuss the various variables as present in small paper mills and their messurements to achieve the desired quality of paper through open or closed loop controls.

1. INTRODUCTION

The progress of measurement is the progress of science. Likewise the advancement of industrial progress must be preceded by advancement in the art and science of measurement, for the whole foundation of industrial processing and manufacturing lies in the measurement of materials entering the manufacture. measurement of product, and, not the least, estimation of cost. One important phase of measurement is the utility of measuring instruments designed for guiding the progress of various steps in manufacturing and processing. Automation is the technique of making a process or system automatic through the proper application and manipulation of equipment and machinery, which is primarily accomplished through instruments that measure and control the various operations. In India, still the Instruments are playing only a minor role in small paper industries, and some of them only have indicating type of instruments to measure the various process variables, with hardly any controls.

As a result of the comparatively recent rapid emergence of technology of process systems and automatic control in paper industry, the contrast with today's installation is startling. Sophisticated control systems, utilizing more advanced pneumatic and electronic long-distance transmission techniques of measurement and control signals, centralized in modern efficient control centres which are pushing instrumentation budgets very high, are becoming quite common in the new and progressive mills in India too. The interest in "on-line" digital process control computers is also increasing day by day and some of the Indian firms are now in a position to supply the complete computer aided design of process systems, the complete data capture and processing system for attendance and production recording, distributed control system for fuel conservation and improved plant productivity by automatic closed-loop control of industrial processes, and data acquisition systems for direct reliable recording and analysis of data in plant processes, product testing and research laboratories.

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Increasing operating efficiencies, reducing production costs and improvement of product quality have been the prime motives behind any mill managements' decision to use more and more instrumentation. These objectives are achieved by maintaining balanced conditions within the pulp and paper making processes in accordance with the predetermined established values.

Now-a-days more or less all production plants are facing stringent operating constraints, precipitated by rising energy and labour costs, limited raw material availability, pollution regulations and personnel attitudes. Pulp and Paper Industry is not an exception, rather it comes almost at the top of the list in these respects. Thus for efficient operation of the Indian Paper Mills the role of instrumentation should be much more dynamic than many other chemical industries. In India, while the electronic instrumentation and control techniques have been extensively applied to other chemical industries such as petroleum refineries, petro-chemical and Fertilizers etc., and the investment for which is 8-10 percentage on an average, the same for pulp and paper industry is comparatively small (2–3%) and that too for a large paper mill. The table—I indicates the extent of investment for instrumentation for different chemical industries in Indian conditions.

TABLE—I

	Name of the Industries	% of investment
(a)	Automatic boilers	12—15
(b)	Fertilizers	8—10
(c)	Petroleum refineries & Petro-chemical	8—10
(d)	Heavy chemical	5—6
(e)	Sugar	4—5
	Steel	3—4
	Pulp & Paper	2—3

Selection of instruments :

The selection of a particular instrument is based on the following criteria :

(i) Base cost for the instruments
(ii) Cost for the accessories
(iii) Installation cost
(iv) Cost due to Maintenance and repair.

Besides the above mentioned cost contributing factors some-other factors such as performance, reliability, together with other features specific to a given system and installation such as hazards etc. will obviously be intimately connected.

One of the most important factors for instrument is its high maintenance cost, although it varies from instruments to instruments. An analytical study made in a few major chemical industries reveals that instrument personnel account for about 15-20% of the total maintenance strength including electrical, mechanical, Civil and instrumentation. Care should also be taken to ensure that the instruments work properly. The instrument should be such that it should be safe, can operate without care for long periods even in very obnoxious environment, easier to maintain, faster in response with good degree of accuracy. Moreover the instrument should be reliable with low failure rates and above all it should be relatively economical in application.

2. INSTRUMENTATION IN A SMALL PAPER INDUSTRY :

Fig. 1 is a representative flow sheet of a small paper mill using waste paper as a raw material. Fig. 2 is representative one if a spherical digester is used with agricultural residues like Jute, rice and wheat straw etc.

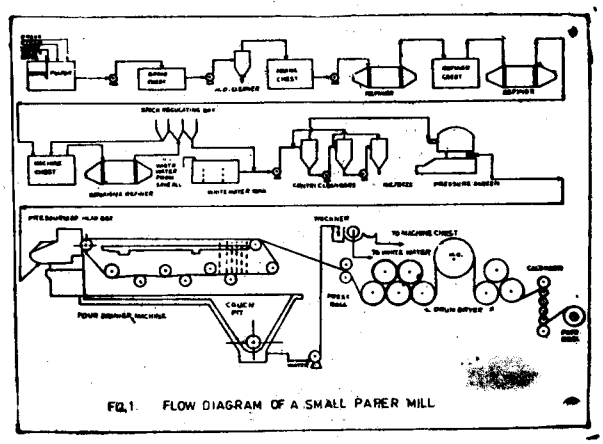

FIG.1. FLOW DIAGRAM OF A SMALL PAPER MILL

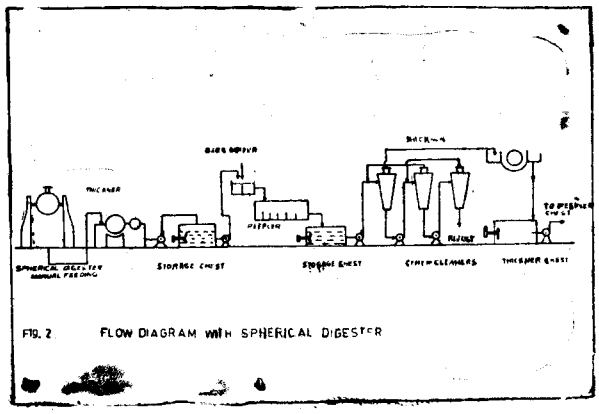

FIG. 2 FLOW DIAGRAM WITH SPHERICAL DIGESTER

TABLE—2

SMALL PAPER MILL SECTION WISE PROCESS VARIABLES :

A. Hydrapulper
   1. Save all water flow
   2. Fresh water flow
   3. Steam flow
   4. Temperature

B. Spherical Digester
   1. Steam flow
   2. Temperature
   3. Pressure
   4. Water flow

C. Potcher Washer
   1. Stock flow in washer
   2. Wash water flow
   3. Washing drum speed
   4. Filtrate level

D. Thickner Washer
   1. Stock flow in washer
   2. Wash water flow
   3. Filtrate level
   4. Stock exit consistency

E. Centricleaners and Screens
   1. Washed stock storage level
   2. Consistency and impurity level
   3. Stock flow
   4. Dilution

F. Stock Preparation and Blending
   1. Level
   2. Consistency
   3. Ratio Control of furnish
   4. Refiners-pressure, current, power required.
   5. Stock flow rate

G. Paper Machine (Four Drinier)
   1. Wet end
      a) Consistency
      b) Head box level
      c) Head box temperature
      d) Suction box vacuum
      e) Couch vacuum
      f) Suction box seal box level
      g) Couch pit level
      h) Pneumatic loading (press rolls)
      i) Shower water pressures
      j) White water tank level
      k) Save all level
      l) back water pH and consistency
   2. Dry end
      a) Header pressure
      b) Differential pressure between sections
      c) Felt dryer temperatures
      d) Steam flow
      e) Machine speed
      f) Pneumatic loading for calender stack and reel
      g) Sheet Tension
      h) Sheet moisture
      i) Basis weight
      j) Hood ventillation.

As the main process variables from Table—2 can be devided in the main heads as given in Table—3, the details shall now be discussed for these major process variates only.

TABLE—3 MAIN PROCESS VARIABLES

Temperature	Machine Speeds
Pressure and vacuum	Moisture
level	Basis weight
consistency	Analytical Measurements
Flow rate	

2·1 TEMPERATURE

All temperature measurements in the pulp and paper industry are of two types

a) Non-electric type, which includes the bimetallic, mercury-in-glass, and mechanical or filled thermal systems,

b) the electrical type, which depend on the voltage or resistance changes caused by either a thorno-couple, resistance element, or thornister element.

Bimetallic thermometers and liquid-in-glass thermometers are normally used as indicating type of instruments while the gas or vapour filled system, thermo couples, resistance thermometers and thermistors can be used for recording and controlling sensing elements. Electric type of measuring instruments are commonly used when the temperature sensing elements is over 30 meters away from the recording or controlling instrument. Neither the speed of response nor the sensitivity of the electrical system decreases with distance. Also the cost of connecting cable is much less than that of capillary tubing of liquid or vapour filled thermometers.

In small paper mills mostly liquid or vapour filled thermometers, or thermocouples are used as temperature sensing devices. Temperature controllers are installed in dryer section with control of steam flow rates by pneumatically or electrically operated regulating valves.

2·2 PRESSURE AND VACUUM MEASUREMENT

All pressure measuring systems consist of two basic parts. A primary device is in direct or indirect contact with the pressure medium and interacts with changes in pressure. The secondary device translates the interaction into appropriate pressure values for use in indicating, recording or controlling.

Pressure systems or instruments can be divided into two major categories : (1) those that employ mechanical means to detect and communicate pressure information from the process and secondary device and (2) those that rely on electrical phenomenon or relationship to carry out this function.

Mechanical pressure measurement systems include monometers, bellows, diaphragm and Bourdan metallic devices, while those which work on electrical phenomenon include strain gages, resistance, magnetic, capacitance, plezoelectric, oscillometric, photoelectric, thermo-electric, and ionization-conductance measuring devices for pressure measurement.

In paper mills Bourdan gages are most frequently used as indicating type of pressure measuring device at higher pressures but at low pressures diaphragms, bellows and strain gages are mostly used.

2·3 LEVEL MEASUREMENT

Level is an important variable in the pulp and paper industry, not only for proper process operation but for cost accounting and inventory purposes too. Level measuring devices vary in complexity from simple visual gages to local or remote reading instruments, depending on whether indication, recording or automatic control is required.

Level measurement in open tanks is carried out by many methods such as visual, pressure or hydrostatic head, direct contact or float etc. Air purge method or diaphragm box methods are quite frequently applied in pulp and paper industry which come under hydrostatic head category, as they can be easily employed when liquids are corrosive or have suspended solids. These are least expensive and most dependable, and can be used for remote recording and control of liquid level. Point level indicator/controller is very effective from 5°C to 150°C and from vacuum to 250 peig.

Level measurement in closed tanks, such as digestors, paper machine head boxes and condensate receiver tanks, more commonly requires measurement of differential pressure by using float position displacement, nuclear radioactive devices, sonic devices etc. Differential pressure cell (DP cell) transmitters are quite often used in paper industry, which can also be used to transmit the signal at control centres.

2.4 CONSISTENCY MEASUREMENT

Consistency measurements are considered among the most important and most difficult measurements to obtain. Process efficiency and the ease of equipment operation depend largely on the value and uniformity of consistency of the pulp and stock supply. Consistencies less than 1 percent are usually considered low, those greater than 6 percent are considered high and thus most consistency measurement devices operate in ranges between these values.

Continuous measurement of consistency is quite complicated due to the fact that stock is a two-phase suspension of water and fibers which is non-newtonian and exhibits no well-defined hydraulic properties. Water, on the other hand is a Newtonian liquid with well defined hydraulic properties. However, experience has shown that an empirical relationship can be established between certain stock characteristics and consistency. All consistency detecting equipment available today is designed to sense a change in one of these characteristics and relate that measurement to consistency. Under these conditions, and depending on the design of measuring device, this inferred value called consistency is affected by such known variables as velocity of stock flow, type of fibers, freeness, wetness, temperature, pressure, treatment, and broke addition. Accordingly, this inferential measurement exhibits no long term repeatable relationship between measurement and consistency and the short-term relationship is neither linear nor the same for different furnishes. Therefore, continuous consistency devices must be designed to selectively measure a characteristic that is closely related to fiber content and not greatly influenced by other variables over acceptable limited spans. These limitations have not prevented the widespread use of this general approach to consistency measurement. The ability of this approach to sense variations in consistency satisfies the requirements of the pulp and paper industry, and accurate measurement of absolute consistency is not, that important presently.

All the measurement devices that have commonly been used for continuous consistency measurement differ somewhat in the measurement methods. Viscosity and the dynamic forces of a stock slurry are very closely related and both of

these properties used as measured sensors, are primarily responsive to consistency related apparent viscosity properties. Others are primarily responsive to consistency related forces such as fiber friction, impact against the sensor, and velocity independent fiber network shear resistance. Elements are designed to isolate or compensate for the effect of velocity on the forces. Some are driven, moving sensors and others are stationary. The more common driven sensors have historically been in the form of paddles, modified propellors, cylinders, spheres, cones, discs and screws. Common stationary element forms are pinned shaft, rod and flat blades. In India, in many paper mills cone or paddle type of consistency regulators are in use which can work between 1·3 to 6 percent and 0·75 to 8 percent consistency ranges respectively. There is a necessity to periodically standardise these instruments for the varying working conditions.

2.5 FLOW RATE

Information obtained from flow measurements is used to control conditions of the process that are dependent on this variable. Such information also provides greater guidance and is of value in estimating quantities of materials used and processed for inventory control and accounting.

All flow measurement systems are composed of primary and secondary devices. The primary device, a sensing element, is in contact with the flowing medium and by interacting with it provides a measure of this flow. Such an interaction could be the differential pressure sensed by the changes in velocity of a material flowing in conduct or by changes in head with corresponding velocity changes. The secondary device is the device that translates the interaction between flowing material and primary device in values of volume, mass, or other rates of flow so that they can be used for indicating, recording, and/or control purposes

Table—4 gives common flow rate measuring systems and their primary and secondary devices.

With the present advancements in flow measuring devices a wide range of electromagnetic flowmeters with proper transducers are available for accurate, reliable and ease of operation. These electro-magnetic flow meters are useful for measuring flow of suspensions as there is no pressure drop in the flow and non-contact of parts.

2.6 MACHINE SPEEDS

Rotational speed measurements on motors, pumps, ventilating fans, line shafts, paper machines etc. are vital for efficient operation of paper process equipments. Speed measurement systems can be either mechanical or electrical. Mechanical type can best be illustrated by conventional tachometer which gives revolutions per minute of the machine in contact, on an indicating type of dial. Electrical speed measurement systems consist of a primary measuring element or transducer which converts rotational speed into an electric signal output to an indicator or recorder. The primary measuring element produces either an analog signal which can be used for analog indication, or pulses which can be digitally counted in terms of revolutions in a unit time as related to speed. Electric speed measurement devices are thus usefully employed for remote sensing and control of machine speeds.

2.7 MOISTURE MEASUREMENT

Moisture measurements are carried out in the paper industry where moisture content of the material must be kept constant or within tolerable operating limits. Moisture is generally expressed as measurement of liquid absorbed or adsorbed as a percentage of the total weight of the material. Solid materials on which moisture measurements are made in the pulp and paper industry are:

TABLE—4 FLOW RATE MEASURING SYSTEMS

Type	Primary Devices
Head	Centuri
	Orifice plate
	Flow nozzle
	Pitot tube
	Elbow taps
Area	Rotameter
	Cylinder and piston
Head Area	Weirs
	Flumes
Velocity	Propeller
	Turbine
	Electromagnetic
	Sonic
Wet	**Secondary devices**
	Liquid Manometers
	U-tube
	Well or reservoir inclined
	Mercury float
	Liquid seal
	Inverted bell
	Ring balance
Dry	Bellows Force balance

granular material such as coal, clay, starch; chips of wood cuttings, rags and grasses; and the most common of them all the sheet and web.

For continuous measurement of chips moisture microwave absorption and nuclear radiation techniques are used in varied forms.

One of the most difficult and persistent problems is the production of a uniform paper sheet containing the right amount of moisture. According to its degree of moistness, paper can display a number of peculiar physical and mechanical characteristics. Improper sheet moisture manifests itself on the paper machine by—

1. Variations in finish, bulk and density
2. Blackening of the paper sheet
3. Cockles, puckers and grainy surfaces
4. Excessive breaks on the machine resulting in loss of production time
5. Non-uniform strength properties such as burst, tear and fold.

The first essential step toward control of moisture content is its measurement. However, paper web moisture is one of the most difficult process variable to measure. This is because practically all means of continuous moisture measurement are indirect or inferential; and are affected to a greater or lesser extent by other process variables, such as temperature, composition, basis weight, and pH. None of the possible methods of measurement is universally applicable to all materials and no material is free of the extraneous effects of other variables. Therefore, the method to use is usually the one that provides the most reproducible results with the materials of interest and at the same time is least affected by other variables known to exist in the process.

Some of the related properties on which a number of the more significant moisture measurement techniques have been developed in the paper industry are classified in Table—5.

TABLE—5

PRINCIPLES FOR MOISTURE MEASUREMENT

A. Electrical
   1. Conductivity
   2. Resistance
   3. Capacitance
B. Mechanical
   1. Sheet tension
C. Humidity
   1. Hygroscopic
   2. Electrostatic
D. Temperature
   1. Temperature difference
E. Energy absorption
   1. Micro wave
   2. Infrared
F. Pilot dryer
   1. Cascaded control
   2. Direct control

Of the many possible methods of continuously measuring the moisture content of the paper, those based on the principles of the electrical properties of paper have been most extensively used. The electrical conductivity or resistance method of moisture content is based on the fact that with most types of paper a relationship exists between the moisture content of the material and its electrical conductivity or resistance, which is highly reproducible at a given moisture content.

2.8 BASIS WEIGHT

Basis weight is defined as weight in grams per square meter of any paper, and thus changes with thickness of the sheet or board. Radiotsotope instrumentation using beta-ray for basis weight estimation has now become a generally accepted method for reliable and reproducible results for continuous measurements.

Beta rays are high-speed electrons emitted by, certain radioactive isotopes such as strontium 90 cesium 137, thallium 204, and krypton 85. When a beam of beta rays is directed at a sheet of paper some electrons pass through it and emerge on the other side with sufficient energy to ionize air or gas. Some electrons lose energy in the sheet and become captured and some are sharply deflected from their path and ionize air or gas they contact on the same side of the sheet. The relative number of electrons transmitted through the sheet is an inverse function of its mass (weight per unit area) or basis weight. The number of electrons reflected or back scattered depends directly on the same factor. Therefore, as the paper increases in basis weight, the number of beta rays emerging from the opposite side of the sheet decreases while the number reflected from the sheet increases. Basis weight measuring systems take advantage of both of these phenomena and are divided into two broad classes-the transmission type and the reflection or backscatter type.

In India continuous measurement of basis weight is not used in any small mill and even in most of the big mills too, however, this may be used in future in high production capacity mills.

2.9 ANALYTICAL MEASUREMENTS

The purpose of analytical measurement is to provide information on the composition of the contents of the process stream-information that can be used to maintain conditions necessary to meet predetermined requirements.

Analytical measurements used to determine composition are either of a chemical or physical nature. Although there are many types of chemical analytical measurements, those most common to the pulp and paper industry are conductivity, hydrogen-ion-concentration (pH), ion selective potential, oxidation-reduction potential (ORP) and capacitance. Of the many analytical measurements of a physical nature, those that have been used in the pulp and paper mills are turbidity and humidity.

Conductivity measurements are made to detect electrolytic contaminants around water and waste treatment areas and in such normally low conductive liquids as condensate of digestor, liquor heaters and black liquor evaporator condensate. Information of pH in brown stock washer helps to operate it at optimum conditions. Continuous measurement of conductivity is carried out using conductivity cells.

The symbal pH represents the acidity or alkalinity of a solution. In the pulp and paper-making processes, pH measurements are made at a number of places such as bleaching section, paper machine's wet end and water treatment plants etc. The present method of pH estimation for continuous recording and control depends on the potential created by a set of special electrodes in the solution, which can even be used in colorued or turbid solutions.

3. ROLE OF INSTITUTE OF PAPER TECHNOLOGY IN THE FIELD INSTRUMENTATION :

The above analysis clearly indicates that for production of paper of right quality, certain degree of Instrumentation and control is essential. This has to be done within the broad frame work of available monetary resources and the return such an investment provides. It has to be kept in mind that the return may not necessarily reflect in terms of increase in percentage production but will be in the form of gains through improved quality, reduced down time and increased reliability which shall in turn increase the percentage of profits. Further a manpower competent to plan such instrumentation system and subsequently to operate and maintain them is necessary. In this sphere, the Institute of Paper Technology has been doing its bit by training first rate professionals to man the Indian Pulp and Paper Industry.

There are two courses at Institute of Paper Technology where Instrumentation and proceses control are taught and exposure is provided—

(a) The degree and university diploma courses in pulp and paper where roughly 4 precnet weightage on these subjects is given with emphasis on practicals in relevant areas. These are besides electrical and electronics courses. These students are capable of providing some cover to Instrumentation in day to day operation.

(b) The Two year post B.Sc. University Diploma Course on Process Instrumentation, trainee personnel with sufficient background to design, plan, operate and maintain complete instrumentation system for process industries including pulp and paper. These persons with two years' teaching and training in various areas of plant should provide the much needed direction to Indian Pulp and Paper Industry which has to go a long way in proper and modern instrumentation. It is felt that there should be atleast one instrument engineer in every paper mill for units upto 10,000 tonnes per annum capacity, and larger mills must employ one instrument engineer for every 10,000 tonnes annual capacity. These changes in manpower strategies will help in improving the industries performance as explained earlier.

4.0 CONCLUSIONS

The percentage of investment in instrumentation in almost all the Indian Paper Industries is at a much lower level, than desired. An analysis of process variables; selection of proper instruments considering cost, life and ease of operation; proper maintenance of existing instruments from corrosion and other static or dynamic errors which may effect their performance; is a need of the time. Institute of Paper Technology, Saharanpur shall try to do its might in helping the industry in all the above fields and shall always look forward for the same.