

Process control in an integrated pulp & paper mill

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ABSTRACT

The article deals with various types of process control checks that are necessary in a Pulp & Paper Mill from the stage the raw material is received in the yard till paper is packed and despatched. It is a survey in brief meant for all those who are engaged in Plant Operational Work. Students of Pulp & Paper Science will be benefitted to have such a survey in hand.

For a smooth and trouble-free production and to maintain an Uniform quality of products, it is necessary to have process-control discipline at all stages of manufacturing operations. Productivity and Process-Control go hand-in-hand for the successful performance of a manufacturing concern. In an integrated pulp and paper mill, the discipline of process-control starts right from the time of raw material arrives in the storage yard, to the final despatch of paper. Such a control system consists of two disciplines, viz.

1. External Technical Control, and
2. In-Plant Process Control.

External Technical Control

Under this discipline, all such activities are included which are vital for successful manufacturing operations, both qualitatively and quantitatively. This discipline consists of the following areas :

- a) Laboratory studies and testing of different raw materials, Chemicals, dyes, etc, for selecting the materials of optimum quality for use in the process.
- b. Adequate training facilities of mill personnel.
- c. Market research for effective sales system.
- d. Statistical methods of analysing process data for framing and optimising the process-control norms, and

- e. Work-audit analysis facilities for day-to-day check up of the overall process control system performance.

In- Plant Process Controls

In-Plant process-control discipline call for move of common sense and understanding of the basic principles of science and engineering. This covers the entire gambit from the receipt and storage of raw material to stage of packing and despatch of the finished goods. In this discipline all such activities are included which are vital for control of quality and production. Operators and supervisors working in the plant, need a thorough understanding and awareness of such control methods. Control laboratory forms an essential part of this discipline. It is necessary to have a complete diffusion of understanding and information between the process operators and process-control personnel. Both have to move hand-in-hand for a successful production schedule. Although they belong to two independent areas, yet their close cooperation is a dire necessity. Operators and Technicians, operating different processes have to keep in mind following important points.

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1. Operator must understand well the fundamentals of working of equipments and process, which he is to attend,
2. He should be alert to detect any change in the working of the equipment, or quality of product other than when he observes in normal working, and report it to his immediate supervisor for his attention,
3. Any equipment, in use, should be run at its rated capacity. If such is not the case the operator and the responsible technician or the engineer should make all efforts to achieve it. On no account it should be left for the next man to come and attend.
4. Machines require constant maintenance and attention and correct handling. We should not fight with them to make them obey our whims. They are friends and not slaves, of course costly friends, who need careful and correct handling failing which they turn into foes.
5. Last but not the least, one must remember that the facts of science never change or distort. If any such thing seems to happen in process-operation, it only means maloperation at some stage or the other. We should not try to justify it with our "over intelligence".

In an integrated pulp & paper mill, with its captive power plant, following stages of operation constitute the entire discipline of In-Plant Process Control.

Raw Material Storage Yard :

This is an open-air plant, where raw material arriving from forest or farm is to be safely and correctly stored. When the material arrives in the yard, it should be checked visually for any rotten or damaged part. Bamboo and wood should be checked for borer effected or rotten material. Suitability of wood species need checking, if the material received is from the approved list of species or non-pulpable. In bamboo, its quality for green or semi-dry or rotten and old bamboo should be noted. Rotten and old bamboo should be stacked separately. Green and Semidry bamboo should be stored separately so that spraying waste water of pulp mill over it, be possible. Pulp Millwaste

water, particularly effluent from Bleach Plant contains some free chlorine and some alkalinity. When such water is sprayed over semidry bamboo stacks it helps in two ways; firstly the water drenched bamboo gets easily chipped with little dust nuisance, secondly the free chlorine helps in checking against white-ant effects. In case of bagasse, old and over-dry bagasse and fresh bagasse should be stored separately. In any case, samples from arriving stocks should be drawn for determining moisture. In case of material of doubtful quality, sampling for laboratory cooking trials is also necessary. In case of bagasse, besides moisture, pith and fibre content test should also be carried out. In case of straw, the content of roots and tops bearing grain portion, need to be determined as they do not yield any useful pulp and give rise to specks and shives.

Storage yard should have adequate drainage system so that the water sprayed over bamboo stacks and rain water may not get accumulated at the bottom of the stacks which will otherwise spoil the material.

Regular checking of stacks against white-ant, attack, etc. should be carried out and any defective or damaged stack should be consumed first.

Chipper/Chopper House :

To maintain uniform quality of chips, it is necessary to have routine check of chip size and moisture. For this purpose samples of chips, both before and after screening be periodically drawn for chip classification and moisture tests. Any deviation in the content of oversize chips or dust, should be determined and accordingly the efficiency of chipper performance be checked. Regrinding of knives or any mechanical adjustment of chipper should be made accordingly. Moisture determination in chips helps to have an idea of possible dilution of cooking liquor in the digesters, Since high dilution of cooking liquor adversely effects cooking reaction, it is necessary to have only optimum wetting of chips. Accordingly the water sprays should be controlled. At least one test for bulk density of chips with composite sample of 24 hours be carried out to have an idea of digester loading of the raw material.

Digester House :

Digester House is the most critical plant of a paper mill. The quality of pulp, ultimately resulting in the

quality of paper, is controlled only in the digester house. Therefore rigid control of process operations and a constant vigilance is required to control and optimise cooking conditions, in the digesters. Continuous or batch digesters should be provided with pressure and temperature gauges and also with pressure/temperature recorders. They need regular checking and any faulty instrument should be replaced or rectified in time.

Facilities for sampling of pulp and cooking liquor from running digester should be provided so that periodical sampling for pulp and cooking liquor can be made. The pulp samples should be checked for Kappa no. to find out the rate and quality of pulping. The Black Liquor samples should be checked for °TW, temperature and residual active alkali, which will also tell the rate of cooking and liquor consumption during pulping operation. Before the White Liquor is charged to the digester, its total analysis for NaOH, Na₂S, Na₂CO₃ and percentage of sulphidity by determining TAA and TA should be done to ascertain the optimum quality of cooking liquor and to find out the volume of White Liquor to be added to the digester.

As regards the determination of Kappa no. in place of Permanganate number, it is always preferable to test the former as the Permanganate number testing gives erroneous results particularly when the pulp is cooked on harder side. By finding out the temperature, time and pressure, H-Factor can also be determined and controlled to have uniform quality of cooks.

Pulp quality is also reflected by the behaviour of pulp over knotter screens or Johnson screens. In case of a hard cooked pulp the knots will not be clean. They may be hairy, with too much rejection at the knot-catcher, resulting in the jamming and overflow of pulp from these screens. In a neat cook, the knots are always clean. Hairy knots also indicates the possibility of shivy pulp during bleaching. K. C. screens should be kept clean and free from jamming.

Brown Stock Washers & Fine Screening :

Purpose of washing is to recover as much chemicals as possible from the pulp, and at the same time make the latter purer in its form, so that the subsequent process operations of screening and bleaching may be

trouble free. Poor washing means higher loss of chemicals as "Carry-over" with the pulp and troubles in screening and bleaching due to excessive foaming. The black liquor separated on first washer is sent to the Recovery Plant for recovery of alkali from it for reuse in cooking. To keep an account of the liquor sent to Soda Recovery the °TW (Twaddel), temperature (°C), free titrable alkali, total solids ratio of Organic : Inorganic, SiO₂ and total Na-salts are determined in a 24-hour composite sample. To control the smooth functioning of the washers, the twaddel, temperature and residual alkali of random samples of black liquor, collected from 1st washer and the last washer are checked from time to time. Any fluctuation in these values from the optimum desired values indicate malfunctioning of the washers. Pulp stock consistency in washer vats, and vacuum in respective washers are also checked from time to time. Any fluctuation in consistency or in the vacuum may upset the washer performance. On the last washer, the temperature of the wash water and consistency of pulp cake coming out are periodically checked to keep the washing conditions at optimum level. A 24-hour composite sample of washed pulp is collected and total Na-salts going with it are determined by ash method. This value gives the carry over of Na-salts with pulp as Sodium Sulphate.

Levels in all the seal tanks of respective washers should be checked from time to time. Too much difference in levels in different seal tanks cause serious fluctuations in the flow of dilution liquor.

In fine screening system consisting of centrisorters and centri cleaners, pulp consistency entering the equipment plays an important part. Pressure of the inlet stock is equally important. Any fluctuation in consistency and stock pressure seriously effects the efficiency of the screens. Therefore regular checks of consistency and stock pressure entering the screens and fibre content in the rejects from each screen or each effects should be checked for T. S., Ash & fibre content. In case of multi-stage centricleaners stock pressure and rejects quality from each effects should be checked. To find out the fibre content in rejects. The same may be taken in small quantity in a glass jar with high dilution with water. On stirring the contents with a glass rod, the fibre content can be qualitatively assessed.

Bleaching :

Bleaching consists essentially of three chemical reactions, e.g.

- a) Dissolving of lignin by reaction with chlorine gas into chloro-lignins, commonly called the chlorination stage.
- b) Washing out of chloro. lignins by dissolving them in caustic alkali commonly called Extraction stage.
- c) Removal of residual lignins and colouring matter by controlled action of Hypochlorite bleach liquor and/or chlorine dioxide or in combination, called as Hypo stage/or Dioxide stage.

Now-a-days some mills are also using oxygen in extraction stage to remove more of lignins with lower pollution in waste water.

In small mills, working on straw and bagasse, only with hypo stage of bleaching, in one or two stages, is carried out. In medium sized mills working with straw/bagasse/hessian etc. chlorination and extraction stages are also carried out, preceding hypo treatment. In large sized mills, C-E-H or C-E-H-H or C-E-O-H/H or C-E/O-D-H-D and the like varying combinations of treatment stages are operated. Some times use of SO_2 or H_2O is also made in the last stage to improve brightness and pulp properties.

In chlorination stage pulp at consistency around 2.5% is mixed with chlorine gas and then taken in an upward flow tower with a retention time of about one hour. The pH of pulp during chlorination should be around 2-2.5 and temperature at room temperature. This pulp is washed over a vacuum rotary filter with hot water of temperature around 60-65°C, subsequently mixed with a dilute solution of caustic soda and taken in a downflow tower at a consistency around 10-12%. Additional L.P. steam is given to the pulp before entering the tower to raise the pulp temperature around 70-75°C to enable quick action of alkali in extracting chlorolignins. Alkali treated pulp is subsequently washed over vacuum rotary filters and it is mixed with hypo bleach liquor or any other bleaching chemical and transferred to respective reaction towers, where at an optimum consistency, pH

and temperature, the bleaching action goes on. Finally the bright pulp is washed with warm fresh water for supply to Stock Preparation.

During the above mentioned operations, the pulp consistency, pH, temperature and bleaching chemical concentration play very critical role in bleaching. At every stage these values have to be checked and any deviation from normal level is corrected in time.

In chlorination stage the pressure of chlorine gas, the gas flow-meter reading, the pulp consistency, pH of pulp stock and stock temperature, both in the reaction tower and over the wash filter are regularly determined. In extraction stage, pH of the treated stock and Kappa number of the washed extracted pulp is occasionally determined to assess the extent of extraction. In latter stages with Hypo or ClO_2 , the residual chlorine in treated pulp, P.C. number of pulp, pH, consistency temperature, and chemical concentration checking is essential. Finally the brightness and residual chlorine in bleached washed pulp is checked and also the Cu. No., ash, P.C. number and viscosity. Viscosity check tells the strength of pulp and consequently the strength of paper. P.C. No. (or Post colour number) gives the tendency of brightness reversion of pulp, whereas the copper number indicates the extent of deterioration of pulp by oxidation of cellulose molecule, which also reflects the shade reversion tendency of the pulp. Residual chlorine in squeezed liquor from bleached washed pulp indicates the extent of unused bleach liquor going with the pulp and consumption of bleaching chemical during bleaching reaction.

Stock Preparation and Beater House :

Bleached and/or unbleached screened pulps are received from Pulp Mill in the Stock Preparation Plant or the Beater House. Pulps from other sources, like the Rag Pulp, Waste Paper Pulp, Paper broke pulp etc. are also received from respective plants for preparing different pulp blends for furnish on respective paper machines or for different paper qualities. Here different pulps are blended together as per requirement of a particular furnish for different varieties of papers. Besides the blending of different pulps, dyes, sizing chemicals, loading material, retention aids and any other chemicals are also mixed with the

final batch. This blended and mixed pulp is subsequently passed through a set of refiners for achieving certain hydration and freeness of pulp.

During refining, consistency of stock, pH, refiner load, are three important factors that effect the refining quality. A periodical check of consistency regulators, temperature, pH of stock is made and a record of refiner load is also maintained. Dilution water is controlled to maintain uniform consistency. Temperature of stock exceeding 40°C adversely effects hydration of fibre. Therefore, care has to be taken to adjust refiner load in way that excessive heating of stock does not take place.

While adding alum to stock, pH has to be controlled and regularly checked to avoid excessive addition of alum.

Finally the Head Box pulp stock should be checked for its consistency, SR, temperature and pH. A random check of fibre classification of the Head Box stock is also desirable. It is also desirable to prepare random thin sheets from the Head Box stock to see for shives, if any, visual fibre-characteristics and matching of paper shade in case of coloured papers. Alum solution should be checked for its clarity. In case it is turbid it is likely to create specks in paper. Therefore some sulphuric acid need to be added to turbid alum solution to make it clear. The diluted rosin solution should also be checked for its uniform appearance free from solid particles. If there is any chance of solid particles or undissolved rosin coming in the solution, it should be carefully screened. Similarly the loading material (Talcum/China clay) slurry should also be screened and checked for any grit or big solid particles and °TW.

Wet-End and Press Part of the Paper Machines :

Processed pulp stock, after adequate refining and addition of chemicals and loading material, enters paper machine chest. From machine chest the stock flows to the paper machine through consistency controller to Flow Box, also some times called Head-box, From flow Box the stock passes on through a fan pump followed with a vertical screen and a set of centricleaners into the slice box of the paper machine. White water is added to the stock in flow channel after the flow box, to make finally the dilute pulp slurry to run over the

paper machine. In slice box a definite head of the pulp stock is maintained as it flow over the wire, where larger part of the water gets drained forming a web. The wet web containing nearly 70% water enters the press part, first a suction couch on to a Suction press, Plain Press and a smoothing press, by which time the water content gets reduced to about 60% and the moist paper web enters to dryer section for drying. From fan pump till suction couch, consistency and SR of stock in slice box, pH of tray water T.S. in tray water are cheked periodically. Stock head reading is also constantly noted. pH of tray water indicates the optimum alum addition during refining process. In the tray water, random samples are cheked for ash and fibre content to assess filler and fibre/fines losses.

In wet press section, random check of moisture in wet paper web samples coming out of the suction couch, suction press and plain press are collected to find out the optimum performance of these presses. In different basis weight papers, this data is collected and plotted on a graph to give guidance to the paper-maker for proper wet press section operation.

Determination of moisture in wet web, after respective press-part, indicates if the presses are working satisfactorily with uniform and adequate pressure at the nip. Any fluctuation in moisture indicates uneven pressure in the press. To find out uneven pressure in the press or its defective setting, a long sheet of paper with inlaid carbon paper is passed through the press, when the loose points in the press are reflected by faint or no impression marks of carbon paper on the paper sheet.

In the dryer section a periodical check of surface temperature of all dryers is made and a graph is drawn to find out the temperature profile of the dryer section. A Smooth temperature profile curve indicates satisfactory performance of the dryers. Any deviation in the profile reflects uneven heating of dryers, due to either faulty steam flow into the dryer or accumulation of condensate inside. Faulty pattern of heating adversely effects the dimentional stability of the paper.

A periodical check of caliper and gsm of paper before and after calender rolls is made to find out any possible defect in calanders, presses and slice. An uniform caliper will indicate uneven pressure in presses

or the calanders and uneven basis weight will indicate uneven adjustment of the slice

From every running roll of paper, on the paper machine, frequent samples are collected and tested for gsm variation. A full deckle paper sample is taken from every out going roll and it is tested for caliper, basis weight, burst factor, tear factor, double folds, tensile strength, ash, brightness, opacity, etc. Variations in caliper and gsm in cross direction are noted to correct the paper machine operation. Routine checking of different properties of paper helps in better operational control of the paper machine. At the paper reeler also, paper coming out of the paper machine should be checked for any calender creases and corrective measures should be taken to rectify this defect in paper. Finish in the paper is also an important property and it is controlled by calendering

Cutting & Reeling Section :

Even if paper coming out of the paper machine is of good quality, it may get damaged or spoiled during cutting or reeling operation. Due to faulty adjustment of the machine, winding creases, cross-cut, blunt-edges, torn paper pieces may be created. Therefore the quality of paper being cut or reeled should be periodically checked for any defect mentioned above. Corrective measures should be taken in time.

During finishing also the performance of the finishers should be checked, if they are not throwing away good paper due to negligence or carelessness.

Paper Godown & Despatch :

Paper reams and reels after packing are stored in the godown for despatch. The godown must be free from insects, white-ants and damp spots. During rainy season particularly such problems may arise. Therefore, periodic check up of the godown for such defects should be made and corrective measures should be taken in time. During loading of paper on trucks or in wagons, handling by labour should be constantly checked against any damage or possible damage of reams and reels during loading or in transit. Handling manually or by machine should be such that the covering of the reams or the reels do not get torn off or damaged.

Chemical Recovery System :

Chemical Recovery is the most vital part of pulp & paper making economics. To achieve the best economy in production cost, it is necessary to achieve highest chemical recovery. Recovery Plant consists essentially of three important sections of process-operations where vigorous and regular control tests are necessary.

a) Evaporators :

The black liquor separated from pulp in the pulp mill brown stock washers, is received in a tank and from here it is fed to a set of evaporators for concentration to thick liquor. In evaporators alkali losses take place as contamination of vapour condensate. Some times due to faulty operations, foaming, high liquor turbulence or leakages in evaporator tubes, carry-over losses occur. To assess the total alkali received from Pulp Mill, volume of the weak liquor received, its TW°, temperature, T.S., SiO₂, T.A. and T.A.A are determined regularly. The thick liquor coming out from the evaporators is also regularly tested for its TW°, temperature, Organic & Inorganic ratio, T.S., T.A, SiO₂ and R₂O₃ and for its calorific value. The vapour condensate from the evaporator is also periodically tested for pH, conductivity and TAA as gpl to find out any extra alkali losses at this stage. From the TAA values of thick liquor from the evaporators and of weak liquor fed to evaporators, the alkali losses during evaporation are calculated. Weak liquor is also tested by screening over a 100 mesh screen to find out fibre & fines present in the liquor which may choke the evaporator tubes. Volume of thick liquor is noted.

b) Recovery Furnace :

The thick liquor from the evaporators is further thickened in cascade evaporators to around 60°-65°TW from 45°-50° TW received from the evaporators. This thick liquor is then mixed with salt cake and the mixture is fired in the recovery furnace.

Salt cake is also tested for its Na₂SO₄, Na₂CO₃ and NaCl contents to find out its purity.

The thick liquor burns in the furnace and the smelt containing Na₂CO₃, NaOH, Na₂S, SiO₂, NaCl, etc. flows out which is dissolved in wash water to

make green liquor. Random samples of smelt are collected and tested for total Sodium Salts, NaOH, Na_2CO_3 , Na_2S , NaCl, SiO_2 , etc. The green liquor is also periodically tested for TAA and TA. Losses due to difference in TA input into the furnace and output into green liquor is accounted as stock losses. Smooth running of furnace or smelter is necessary for maximum recovery. To achieve it, the quality of salt cake, quality of injective liquor, pressure of injection liquor, optimum proportionating of primary and secondary air and temperature in oxidizing (burning) zone are carefully controlled. Regular check of pressure, temperature and flow rate of primary and secondary air, temperature and pressure of injection liquor, temperature of boiler bank zone are made. Temperature of flue gases before and after cascade evaporator, temperature of stack gases entering electro static precipitator are also regularly checked. Random check of the composition of stack gases for total solids carry-over, Na_2SO_4 , Na_2CO_3 and other particulate matter in the T.S., Temp., O_2 , CO_2 , CO, SO_2 and H_2S are determined. Abnormal values of O_2 in stack gases indicate disturbed conditions of burning in the furnace. More than normal suspended solids indicate trouble with precipitator or uncontrolled forced draft in the furnace. Solids collected in ESP, are checked for its TA content and quantity is assessed for recovery.

Cases of high SiO_2 in black liquor should be carefully investigated for any possible source for timely correction. SiO_2 besides forming hard scales in evaporator tubes, gives rise to beehive formation in the furnace, which are hard to remove, reducing the efficiency of the furnace.

c) Causticizing section :

In causticisation unit, green liquor is mixed with lime to generate caustic soda. Green liquor contains mainly sodium carbonate which in reaction with milk of lime gets converted into caustic soda. Green liquor and milk of lime are mixed together in hot condition. Lime is powdered and lumps are dissolved in wash liquor, where heat is generated. The hot milk of lime is first cleaned in a classifier where grit and unburnt and overburnt stones get separated. The hot milk of lime is then pumped into a tank called causticizer where green liquor is mixed with it. Reaction is carried out to its maximum efficiency. Lime

mud is separated and it is washed in stages in a series of mud washers. The clean overflow from causticizers, consisting of NaOH, Na_2S and some Na_2CO_3 is taken in a white liquor clarifier for further classification. The mud after final wash is taken over a vacuum rotary filter where it is thickened, further washed and then disposed off. Wash liquors from different mud washers is used in a counter-current way. To assess losses at various stages of operation and the total TA TAA finally recovered from white liquor clarifier as white liquor following routine control tests are carried out.

1. Green liquor measurement of volume, TA, TAA, Na_2S TW°, Temp. in °C.
2. Lime random & composite samples of lime from table feeder for CaO , SiO_2 , MgO and R_2O_3 .
3. Grit From classifier-for adhering alkali to assess alkali loss.
4. Causticizing tank Temp, TW°, TA, TAA, Na_2S , volume, % of causticizing efficiency.
5. White Liquor Clarifier final clear W.L., overflow, temp. in °C, TW°, TA, TAA, Na_2S , % sulphidity.
6. Mud Washers TA, TAA, T.S.
7. Lime Mud Filters Concentration of TA in filtrate, feed liquor and % NaOH, $\text{Ca}(\text{OH})_2$, SiO_2 moisture in lime mud.

Dregs collected from causticizing tank, to be thrown off, are also checked for alkali losses. Whatever fresh caustic soda is added to WL charges to make up its required concentration, is also tested for its purity.

Power & Boiler House :

For smooth & trouble free operation of Boiler House and power. turbines, it is necessary to control

- a) Quality of feed water to boilers
- b) Correct system of chemical dosing in feed water
- c) Quality of condenser cooling water of turbines.

- d) Temperature of boiler feed water in deareaters
- e) Turbine condensate characteristics
- f) Coal quality
- g) Quality of cinder or coal ash discharged from boilers, and
- h) Quality of blow down water from each boiler.

For treating and purifying boiler feed water, the water is treated through ion-exchangers to remove metallic ions of Ca, Mg, or is fully demineralised to make it free from all metallic and non-metallic ions including Cl^- , SO_4^{--} , CO_3^{--} etc. Demineralised water is free from all dissolved impurities and is like distilled water. For high pressure boilers only demineralised water is used, whereas for medium pressure boilers partly treated water, free from Ca, Mg ions is used. To keep all these processes in perfect safe limits constant testing of water and return-condensate is made. In a water softening plant, regular analysis of incoming raw water for permanent and temporary hardness, P & M values, pH, conductivity, SO_4^{--} , Cl^- and SiO_2 is done. Based on permanent and temporary hardness the dosing of lime and sodium aluminate in the lime-soda process, is controlled. After removing temporary hardness the treated clear water is filtered and passed through sodium ion exchanger or through demineralising units. At every stage the purity is tested by testing for P & M values, SiO_2 conductivity and pH. Boiler blow down water is tested for pH, P&M values, T.S.S., T.D.S., Temperature. Depending on these values the blow down is controlled at optimum level.

Chemicals are added to boiler feed water and to boiler drum under pressure, values of blow downs give the guidance to control the dosing of these chemicals.

In the Cinder or Coal Ash, random checking of the percentage of the unburnt coal gives an idea of the amount of coal being wasted due to either faulty operation of the boiler or bad quality of coal.

Condensate from Turbine is checked for its conductivity value, to find out if any contamination is taking place due to condenser tube leaking. Turbine cooling water should be tested for the polyphosphate content and any fall in value from the optimum is made up in time. Inlet and outlet temperature of the turbine cooling water also needs checking, which if high, indicates choking, of condenser tubes. Recovered

condensate from process plants is tested for its pH, temp and conductivity, and if necessary it is treated once again with softening chemicals and ion exchange resins to fully purify it.

Water Supply and Effluent Treatment Plants :

In paper making water forms a major part of the basic raw material requirement. The quality of water effects the quality of pulp and the quality of paper. Therefore the water to be supplied to process plants must be clean, free from suspended impurities, clear, colourless and within acceptable pH limits. If water is taken from surface streams or lakes, it may be turbid. Underground water may be having undissolved and dissolved SiO_2 and other impurities. Raw water from any source is first cleaned in clarifiers, where chemicals like alum, lime, acid are added to control unduly high content of carbonates etc. Treated water is subsequently filtered through sand beds. Tests for turbidity, pH percent and temporary hardness are made both for raw and Treated water.

Since more than 90% of the raw water used, goes out as effluent in a pulp & paper mill, it forms a major item for disposal. The combined mill effluent is contaminated with various types of organic and inorganic chemicals, which come from cooking, bleaching and paper making processes. As per pollution control Act, the objectionable chemicals and suspended matter like clay, fibre/fines have got to be removed before the effluent are discharged either to surface streams or on land. The paper mill effluent contain lot of organic matter, which gives rise to putrefaction resulting in depletion of dissolved oxygen, which is essential to aquatic life. Treatment of effluent by suitable methods, either a facultative oxidation pond or activated sludge method, etc. has to be carried out; to consume all organic matter by bacterial action and to restore dissolved oxygen to an optimum level. For this purpose pH, alkalinity, total dissolved solids (TDS), Suspended Solids (SS), volatile matter, Nitrates, COD and BOD values, SO_4^{--} , Cl^- , undesirable metallic ions, colour, have to be tested before and after treatment of the effluents. Nutrients are added in case of biological treatment. The purity and nutrients like Urea, Diamonium Phosphate, etc. are periodically checked.

Air Emissions :

In an integrated pulp & Paper mill, having boiler and power house and recovery boiler, emissions from

digester blowing boilers and recovery furnace take place, which are serious source of pollution both aesthetically and physically. From Digesters blowing foul smelling gases consisting mercaptans are emitted, which though not so much harmful physically, do create nuisance of smell. The coal fired boilers, suspended particulate material (SPM) and gases like SO_2 , H_2S are emitted through stacks. From Recovery Furnace stacks, gases like SO_2 , H_2S , mercaptans and S.P.M. consisting mainly of sodium sulphate are emitted. If an electro-static precipitator is installed, it arrests most of the SPM and thus the nuisance of white smoke coming out of the Recovery Furnace can be arrested.

To assess the concentration of various gases and SPM, in the atmosphere, periodical check is made by analysing stack gases and atmospheric air in the surrounding area.

Solid waste disposal :

In a pulp & paper mill, large quantity of solid waste is generated from various sources. The main items are lime mud from Soda Recovery Section and Cinder or Coal ash from Boiler House. For every tonne of paper made, nearly one tonne of lime mud is generated. Depending on the ash in coal, but mostly being around 40%, the cinder generation is also quite high running in several hundred MT per day. Besides these two, Chipper Dust from Chipping of bamboo & wood, saw dust from saw mill, rotten siliceous material from Raw Material Stack yard, trash rejected from Waste Paper Plant are also the solid wastes, which require suitable disposal.

Random samples of Coal Ash or Cinder are checked for percentage of unburnt coal to assess the amount of coal going waste due to bad quality of coal or defective burning.

The lime sludge from Soda Recovery Plant is also tested periodically for free alkali, unused $\text{Ca}(\text{OH})_2$,

SiO_2 , R_2O_3 and moisture. This analysis helps in controlling and improving the washing of lime mud on rotary washers and also in mud washers operation. Free alkali in mud indicates to dispose off the mud in isolated places, away from habitation, as the alkali in dust is harmful to human beings and also to vegetation.

Chipper House dust is tested for any recoverable fibre content and accordingly the operation of the chippers is controlled.

From waste paper and rag plants, the trash material like plastic and foam pieces, stringes, deep coloured unusable rags, metallic pins, etc. are removed both by manual sorting and mechanical separators. This trash is regularly inspected to find out any inefficiency of the sorting and separating process.

Organisational set up of process control crew :

In the preceding paragraphs, a detailed coverage of various process control system has been given. To enable routine and timely check of tests and inspection, it is necessary that the process control team is so organised that their checking reports are available in the shortest possible time. Any undue delay in such reports loses its utility and effectiveness in operational control of the plants. In some plants like the Paper Machine House, pulp mill and soda recovery, the testing and checking facilities should be available at the spot.

Besides the sectional laboratories it is also necessary to have a well equipped control laboratory, where well qualified chemists and engineers be available for special investigations and cross-checking work. It is also useful to employ statistical methods of analysing day-to-day plant reporter to pin point the areas of neglect or default. The purpose of Process Control System should be to improve and optimise the plant operations and reduce waste generation.