Design Considerations for Advanced Control of the Modern Recovery Boiler

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ABSTRACT

Kraft black liquor recovery boilers provide three critical functions in the pulp and paper mill operation: (1) recovery of pulping chemicals, (2) disposal of waste from the pulping process, (3) production of steam for electrical power generation and process use. These functions are critical to the economics of the Kraft pulping process. Because of the highly integrated and interactive nature of Kraft pulping and recovery operations, minor variations in parts of the process can be propagated in and amplified throughout the mill. Consequently, favorable economics can be quickly changed to unfavorable economics by ineffective process control.

The relationship of black liquor flow, temperature, percent solids and viscosity must be considered for achieving the appropriate droplet size for effective liquor spraying and bed formation. It is important to provide a black liquor solids rate control and proper fuel/air ratio and air flow distribution on a consumed air basis trimmed from a combination of oxygen (O_2) and carbon monoxide (CO). This will optimize the products of combustion and still achieve optimum smelt reduction.

This paper illustrates some of the unique features of controlling the recovery boiler with microprocessor based distributed control systems. Control systems are configured to compensate for variations in black liquor solids and air flow properties, simplify operator control of the recovery boiler, and improve its operational safety.

KEYWORDS

Recovery Boiler, Control System, Combustion Control, Instrumentation, Optimization, Safety, Microprocessor Control, Statistical Process Control, Sootblowing.

RECOVERY BOILER OPERATION

The Kraft pulping process involves the cooking of wood chips to make pulp in either continuous or batch digesters using caustic white liquor and steam. After the cooking cycle is completed, the cooked pulp and resulting weak black liquor are discharged to a blow tank. From there it is fed at a continuous rate to the brown stock washer. Weak black liquor is washed and separated from the cellulose fiber in the brown stock washing operation. The collected weak black liquor (12 18% solids) is concentrated in a steam heated multi effect evaporator to 50 55% solids.

Pulp mills use either of two designs to further concentrate the black liquor prior to burning in a recovery boiler. One design uses a direct contact evaporator (DCE) as a part of the recovery unit. However, this generally produces odorous gas emission of total reduced sulfur compounds (TRS). To help reduce these emissions with existing DCE, mills oxidize the black liquor prior to the multi effect evaporator. The other design is a separate black liquor concentrator where the liquor does not come in contact with the hot flue gas. This is related to the low odor recovery boiler design with an enlarged flue gas heat trap such as an extended feedwater economizer. It is much more efficient to evaporate water in a separate concentrator than in a recovery boiler direct contact evaporator.

The concentrated heavy black liquor is then sent to the recovery boiler as fuel. Heavy black liquor (64 67% solids) is heated for viscosity and droplet size control and sprayed into the recovery boiler. Black liquor has to be concentrated to above 60% solids before it will burn without supplemental fuel. Black liquor enters the boiler using a spray suspension drying technique or wall drying technique depending on the recovery boiler manufacture.

Under normal operation, the heat involved in evaporating the remaining moisture from the liquor in the furnace is reported as being 8 10% of the furnace heat release. One of the reasons to go to higher percent solids is to reduce this liquor drying heat sink. The degree of drying of the liquor solids before reaching the bed has an effect on bed temperature and on the tendency towards affecting blackouts.

As the liquor droplets fall through the furnace, pyrolysis of the black liquor takes place producing sulfur gases and char. Pyrolysis is affected by heat rate, liquor composition and temperature.

Some of the liquor solids burn in the hot combustion gas suspension, but most of the solids burning takes place in a layer of char on the top of the smelt bed at the floor of the recovery furnace. Good black liquor combustion requires the proper blend of time, temperature and turbulence.

In the past, Combustion Engineering Recovery Boilers with suspension liquor drying used two air levels which were referred to as the primary and secondary air zones. Primary air enters the furnace through ports on all four sides near the smelt bed to support combustion of the liquor solids. Primary air is 55-65% of the total air required for combustion of the liquor solids. This creates a chemically reducing atmosphere for converting sodium sulfate in the black liquor to sodium sulfide. Secondary air is added tangentially in the upper regions of the furnace to provide turbulent mixing and completion of burning. The new designs of large CE recovery boilers includes three air levels.

Babcock and Wilcox Recovery Boilers with liquor wall drying uses three air levels referred to as primary, secondary, and tertiary air zones. Primary air enters the furnace thru ports on all four sides near the smelt bed to support combustion of the liquor solids. Primary air is 45 55% of the air required for total combustion of the liquor solids creating a chemically reducing atmosphere. Secondary air (20 35%) is used to trim the top of the char bed and provide more precise control of the drying and pyrolysis of the black liquor. Tertiary air (15 30%) is added to the upper regions of the furnace to provide turbulent mixing and completion of burning.

In recent years, all of the recovery boiler manufactures (B&W, CE, and the Scandinavian suppliers) have gone to three air levels on the newer larger recovery boilers. The new large recovery boilers are being designed with dedicated individual forced draft fans for each level. Air flow from each fan can be controlled by either fan speed or fan inlet vane adjustment to achieve the required air pressure for penetration at each level. It is becoming more important to balance the air and black liquor so they are distributed symmetrically.

New Recovery boilers are also being designed for higher solids firing. This usually is associated with stationary firing. Recovery boiler and evaporator manufacturers are promoting evaporation and firing black liquor at up to 80% solids. It is claimed that high black liquor solids firing will result in the following:

- Improved production
- Greater efficiency
- Higher steam production
- Higher availability
- Reduced emissions with less sootblowing

However, high black liquor solids firing also presents new challenges to the operator and the recovery boiler control system. The load range is more limited and loss of liquor solids could lead to furnace black outs.

BUILDING TODAY'S RECOVERY BOILER CONTROL SYSTEM

In the 1970's, recovery boiler computer control was thought of strictly on a main-frame digital computer basis. In today's world of instrumentation, the microprocessor has taken on more of the activities previously reserved for larger electronic process computers. The power of modern microprocessors has permitted powerful functions to be available in distributed microprocessor control system (DCS) which were unthought of a few years back.

Recovery boiler control automation has been successfully implemented in microprocessor based distributed control. Microprocessor based control instrumentation with time shared displays on a CRT based operator console considerably reduces panel space as well as improving operational capabilities. New recovery boiler installations are utilizing DCS systems. Process control manufacturing companies that possess many years of experience in product and system design, recovery boiler process knowledge and application expertise have used microprocessor technology to overcome recovery boiler control problems that at one time almost impossible to solve.

Many older recovery boilers are faced with changing operational requirements. Existing recovery boilers implemented with either pneumatic or electronic instrumentation are considering retrofiting with DCS such as NETWORK 90 *, illustrated on Figure 1. This figure illustrates how the entire recovery cycle can be implemented on the DCS data highway.

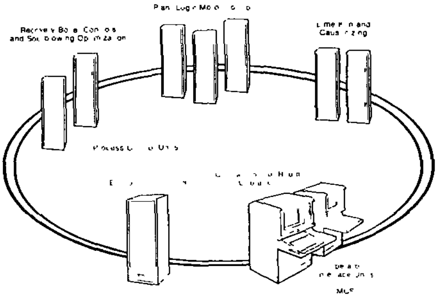

FIGURE 1 NETWORK 90 System Architecture

*NETWORK 90 is a Registered Trademark of the Babcock & Wilcox Company.

When converting to microprocessor control, one should avoid a complete duplicate of the existing instrumentation on a single element loop to loop basis. Microprocessor systems have great control potentials, and thus users can now be creative in his recovery boiler control design. The control system designer has a large quantity of measurements available as a data base, and these measurements can be effectively used to create a noninteractive control system design. There can be increased integration between the motor control digital logic and regulatory controls. New group startups and shut downs can also be integrated into the microprocessor control system.

Safety is still of highest importance on recovery boilers. Control design features must take into account the safety limitations and physical limitations of the recovery boiler and its auxiliary equipment. Distributed control system technology facilitates building in a higher degree of safety features than possible with pneumatic and electronic analog control.

The recovery boiler operates best at steady state conditions. However, with the skillful use of ramping, velocity limiters, timers, and adaptive tuning within the microprocessor configuration library, the recovery boiler can be designed to take programmed ramp loads in a well balanced manner. A DCS control system allows the step by-step implementation of higher level control and optimization strategies which previously could not have been considered. This paper provides several examples of high level recovery boiler control strategies.

OPERATOR INTERFACE

Presentation of data to the recovery boiler operator has always been a concern to instrumentation vendors and the mill operating department. The displays must be designed so that they will be acceptable to the operator and provide meaningful information that can be quickly understood.

The early generation DCS consoles offered panel board mimic displays in group/page formats. The display elements typically included.

- Controller faceplates
- Motor start/stop faceplates
- Trend displays

These units displayed a limited number of control points on one page.

In recent years, CRT based operator consoles have advanced tremendously, offering the following features.

- High resolution dynamic graphics
- Flexible display architecture
- Alarm management features
- Information processing and archival
- Report generation
- Touch screen, soft keys, pointing devices, etc.
- Display zooming, windowing, etc.
- Database managers

The challenge is to use this capability properly to provide a Man/Machine interface which is efficient and user friendly during all facets of operation.

CRT VIDEO GRAPHICS

The functions implemented from the CRT video display include the basic operational capability performed by conventional panelboard instrumentation such as Manual/Automatic setpoint operation, alarm acknowledgement, process variable indication in engineering units and trend graphics.

CRT video graphics enlarge the "Operator's Window" into the recovery boiler operation by re emphasizing operator process understanding. Such items as recovery boiler control overviews, sootblowing, rotor control, auxiliary burner management and other special group graphic displays provide the operator with a better understanding and identification of what the process is doing and what he is controlling.

Custom CRT graphics can display live process data in a number of formats. The operator can take control action directly from the custom graphic display. The following formats are available for dynamic elements·

- Numeric readout with alarm status
- Logic status readout with alarm status
- Selection of symbol shape and/or color based on process data
- Dynamic bars which represent the value of a real tag by their height
- Pipe systems with color depending upon Boolean State or real range

In all, microprocessor CRT graphic displays have evolved in a short time to become a powerful, flexible tool to promote operator usability and process control efficiency.

Typical dynamic graphic displays for CRT video console operation of the recovery boiler are shown on Figures 2 and 3. The main overview graphic for the recovery boiler is shown on Figure 2. A detailed control graphic display of the black liquor firing is on Figure 3. It provides the operator with specific information and

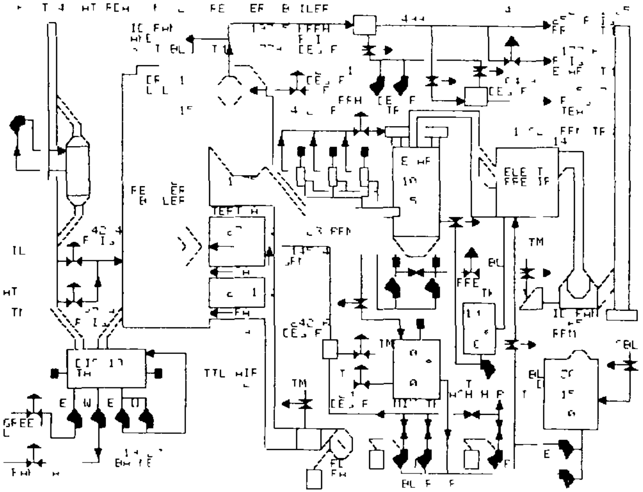

FIGURE 2 Typical Overview Graphic Display for a Recovery Boiler

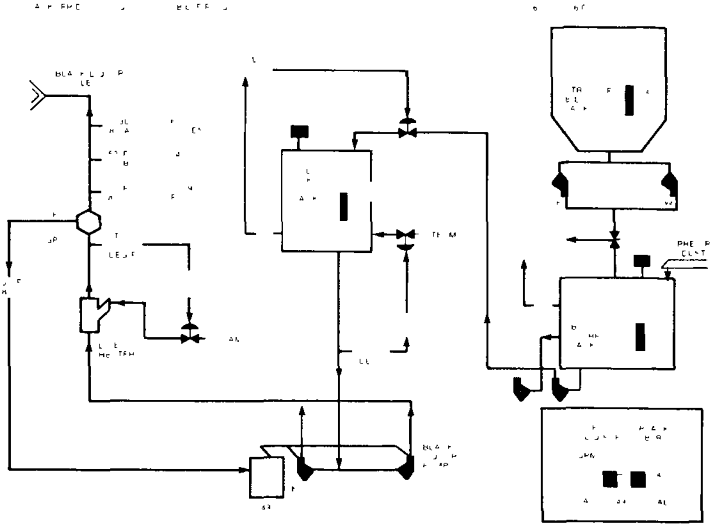

FIGURE 3 Typical Detail Graphic Display for a Recovery Boiler

control capabilities for start up, normal operating conditions and responding to abnormal situations.

CONVENTIONAL CONTROL STRATEGY

The first recovery boiler control strategy consisted of operators setting the black liquor flow and manually adjusting the air flow to keep a bright orange color in the primary zone. To avoid "blackouts", the operator had a tendency of carrying excess primary air flow. This resulted in heavy fume dust carryover to the superheaters and boiler tube banks with increasing fouling which required more frequent sootblowing. It also resulted in lower smelt reduction. The flue gas temperature was high because of high excess air which reduces the amount of steam generation. Newer control strategies attempt to limit excess primary air for the reason stated above. The best guide for controlling excess air is with the use of an oxygen controller.

The conventional control strategy for a recovery boiler with three air levels involves single element pressure, temperature, level and flow controllers. Some mills have added control for the ratio of primary and/or secondary air flow(s) to black liquor feedrate. The conventional control strategy can provide stable steam generation and chemical recovery only if the black liquor solids content, composition and rate as well as combustion air temperature, pressure and humidity remain stable for extended periods of time. Because of the highly interactive nature of the various elements in the pulping and recovery process, this stability is an extremely rare circumstance.

ADVANCED FUEL/AIR RATIO CONTROL STRATEGY FOR BLACK LIQUOR RECOVERY BOILERS

With conventional control, the operator must make many trim adjustments regarding the combustion control of the black liquor firing such as:

- Set the proper liquor heater temperature.
- Adjust the load by changing the black liquor flow set point.
- Set the fuel/ air ratio.
- Set the air distribution by adjusting the dampers on each level.
- Adjust velocity dampers in the secondary and tertiary air ports to modify air flow penetration.
- Investigate the probable cause for fouled liquor nozzles
- Check the primary air ports and rod if necessary.

An automatic primary air port rodding system helps to assure that primary air ports are not fouled, thus removing another variable in recovery boiler operation.

Advanced fuel/air ratio control strategies assist the operator in obtaining stable recovery boiler operation. Many of the conventional adjustments the operator manually sets can now be automatically trimmed from analyzers tied into the microprocessor control system. This is particularly true of refractometers, oxygen and combustibles analyzers. Other feedback guidelines comes from SO_2 and TRS analyzers.

Video smelt bed imaging systems also provide extremely useful feedback guidelines for operator analysis of the burning conditions.

Thermal mapping of the recovery boiler gas temperature above the tertiary level and at the superheater inlet level using acoustic temperature detection devices (Pyrosonic 2000 *) also provides useful information for the operator to balance the air and combustion gases so they are distributed symmetrically.

The following is a list of advanced control strategies associated with Network 90 microprocessor advanced control system for recovery boilers. Advanced control easily integrates into existing recovery boiler base regulatory controls:

- Black liquor droplet size control.
- Stabilize and control the black liquor solids feedrate.
- Total air control based on the black liquor solids feedrate.
- Ratio trim of total air to black liquor solids to minimize excess oxygen.
- Ratio control of primary air to black liquor solids to stabilize the recovery bed with trim from CO.
- Secondary air/primary air ratio control.
- Computation of combustion performance index (LBS Steam/LB Liquor Solids).
- Automatic compensation of total and primary air for auxiliary fuel firing.
- Automatic bed blackout prediction.

The general philosophy of the recovery boiler advanced control strategy for black liquor firing is illustrated in Figure 4. Heavy black liquor must be conditioned to achieve proper droplet size by heating in a direct or indirect line heater and adjust the flow to achieve the desired black liquor

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*Pyrosonic 2000 is a Registered Trademark of the Babcock & Wilcox Company.

solids production rate target. Two regulatory loops of line heater temperature and black liquor flow control are supervised by the advanced loop of droplet size control, black liquor solids rate firing control and Liquor Combustion Performance Index (LCPI).

DROPLET SIZE CONTROL

Black liquor must be conditioned to achieve proper droplet size control and spray pattern. Proper droplet size provides effective liquor spraying, bed formation and minimizes particulate carry over.

Droplet size is based upon a relationship between liquor flow, pressure, temperature, solids control, viscosity, liquor composition and organic/inorganic ratio and spray nozzle characteristics. The appropriate combination of these characteristics are used in an advanced control strategy to provide a cascade temperature set point for the direct or indirect black liquor line heaters.

The key to stabilizing the furnace and char bed for the best chemical smelt reduction is to control the bed height. Black liquor temperature must be controlled very accurately. Increasing this black liquor temperature set point results in more moisture flashing as the black liquor falls to the bed increasing the rate of burning. Lowering the black liquor temperature set point increases the residual moisture. This cools the char bed and slows the rate of burning.

BLACK LIQUOR SOLIDS RATE FIRING CONTROLS

It is particularly important to maintain a constant heat release for stable recovery boiler steam generation and a constant chemical recovery rate for stable green liquor production. Black Liquor can change in Btu content, chemical content, organic/inorganic ratio, percent solids and viscosity. Proper black liquor solids content control starts with the multiple effect evaporators where the exiting black liquor solids content should be held as uniform and as high as possible.

The advanced strategy utilizes an on line refractometer sensor for measuring black liquor solids concentration. A stable massrate of black liquor solids to the recovery boiler is calculated and established. Black liquor to the recovery boiler is controlled automatically from liquor solids target control.

LIQUOR COMBUSTION PERFORMANCE INDEX (LCPI)

An advanced black liquor controller continuously calculates a liquor combustion performance index (LCPI, pounds of steam per pound of black liquor solids). The calculator takes boiler steam flow and divides it by the liquor solids firing rate. Any steam generated by auxiliary firing is subtracted from the total steam flow before the LCPI is calculated. The LCPI can be logged to document the performance of the recovery boiler as a steam generator and quantify improvements over previous recovery boiler control strategies.

The LCPI can also be trended as a continuous indicator of recovery boiler performance. An abrupt decrease in the LCPI can be used as an early warning of impending bed blackout. The advanced controls monitor the LCPI for an abrupt, significant decrease in the LCPI and automatically takes control action to reduce the potential of an actual bed blackout. The control action generally utilized for avoiding bed blackout is to provide a positive bias to increase the temperature setpoint for the black liquor line heater temperature controller and to prevent the oxygen controller from reducing the TA/BLS ratio.

TOTAL AIR FLOW/BLACK LIQUOR RATIO

Variation in black liquor quality is the main disturbance to be handled in the TA/BLS ratio control. Since the BTU content of the black liquor cannot easily be measured on line, uniform control of the black liquor dry solids flow rate is used to stabilize the combustion process.

The required air flows are a function of the solids content of the black liquor, as well as the black liquor firing rate. Further, the composition of the black liquor solids varies with the species of wood digested. These composition variations have a significant effect on the stoichiometric air requirements for each pound of black liquor solids (dry basis) fired, and are the major disturbances which must be compensated for a stabilize operation of the recovery boiler.

It is important to provide a proper total air to black liquor solids ratio (TA/BLS) and air flow distribution on a consumed air basis, trimmed from a combination of oxygen (O_2) and carbon monoxide (CO). This will optimize the products of combustion and still achieve optimum smelt reduction. TA/BLS ratio optimization is achieved by reducing the excess air levels to as low as possible within the constraints of the process and boiler. This reduces the loss of sensible heat from the exiting flue gases which is the major component of energy losses associated with a combustion process. To insure adequate turbulence, the excess oxygen target is programmed as a function of firing rate to allow higher oxygen concentrations at lower firing rates.

If the flue gas CO concentration is quite high, the TA/BLS ratio is biased slightly until the CO concentration is within range for the CO controller adjustment of the primary air to black liquor solids ratio

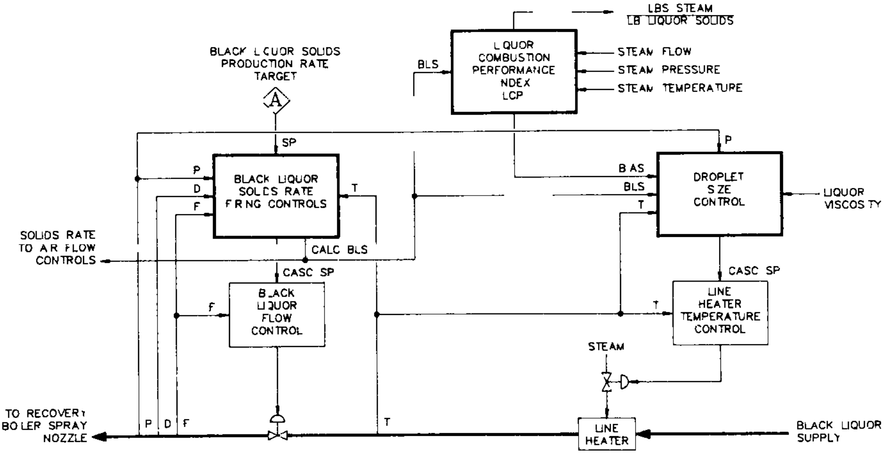

FIGURE 4 – ADVANCED CONTROL STRATEGY FOR RECOVERY BOILER BLACK LIQUOR FIRING

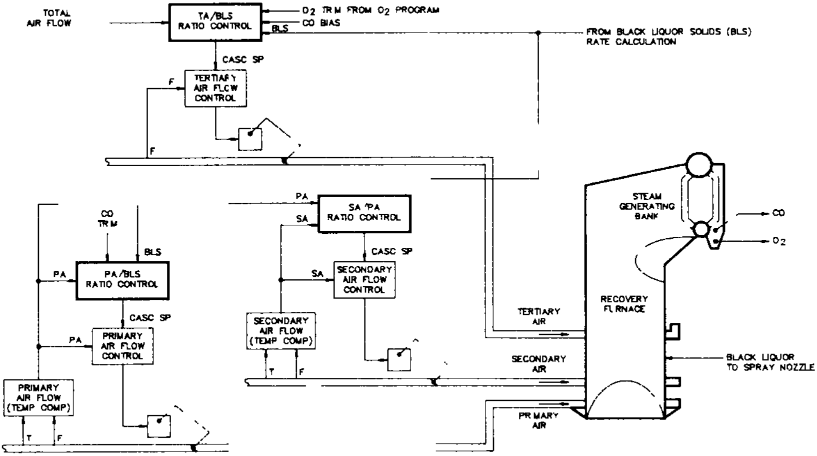

FIGURE 5 ADVANCED CONTROL STRATEGY FOR RECOVERY BOILER AIR DISTRIBUTION

(PA/BLS). The total air volumetric flow is compensated for temperature variations in the calculation of the total air mass rate.

AIR FLOW DISTRIBUTION

Effective chemical recovery and effective steam production depends on proper control of the three levels of air flows. If too much secondary and/or tertiary air is used for a specific black liquor firing rate, the excess air acts as a heat sink and carries heat out the recovery boiler stack, rather than produce steam. If too much primary air is used for the black liquor firing rate, the sulfide reduction reaction in the smelt bed will be inhibited and recovery of the pulping chemicals will not be maximized.

The proper distribution of total air among the three air levels is required to control the various zones and achieve the proper excess air. The air flow split between Primary, Secondary and Tertiary is based on a predetermined program.

The general philosophy of the recovery boiler advanced control strategy for black liquor air flow distribution is illustrated in Figure 5. Primary air enters at low velocity from all four sides of the recovery boiler. The air stream trims the periphery of the bed and contributes to the reducing atmosphere reaction and heat release. This increases the temperature above the bed without increasing oxygen level. Higher char bed temperature results from an increase in primary air and increases the smelt flow. Primary air adjustments changes the rate of char bed consumption upsetting the furnace balance.

Primary air flow controller is supervised by the primary air to black liquor solids (PA/BLS) ratio control. The PA/BLS ratio is controlled to compensate (feedforward) for recovery boiler load variations. This ratio is automatically adjusted (within limits) to maintain a set concentration of CO in the recovery furnace flue gas. The measured primary air volumetric flow is compensated for temperature during calculation of the primary air mass rate.

The secondary air flow controller supervised by the secondary air to primary air (SA/PA) ratio control. Secondary air reacts with gases emitted by the bed and pyrolyzes the liquor after drying. It increases the temperature above the bed without increasing oxygen level. Secondary air provides high reduction efficiency and excellent control of bed height.

The tertiary air flow controller is supervised by the TA/BLS ratio control. This is the balance of the total air demand used to set the tertiary air flow set point. Tertiary air is admitted above the liquor nozzle. It is designed to provide maximum turbulence for completion of combustion burning and reduces odorous emissions. It is necessary or large units where air streams must penetrate a wide furnace cross section. This furnace volume above the liquor nozzles is the oxidation zone for completion of burning. The oxidation zone requires air flow to create turbulence as a function of air velocity (wind box pressure).

COMPENSATION FOR AUXILIARY FIRING

Advanced controls continuously monitor the auxiliary firing fuel flow and provide a feedforward adjustment of both the TA/BLS ratio and the PA/BLS ratio to compensate for changes. This adjustment is based on the stoichiometric combustion air requirements for the auxiliary fuel. The flue gas oxygen and carbon monoxide trim controllers provide any additional adjustment necessary in these ratios to stabilize chemical recovery and minimize heat losses.

SOOTBLOWING OPTIMIZATION

In most overloaded existing recovery boilers, boiler cleaning is accomplished by continuously cycling through the sootblower sequence. Sootblowers are activated, one at a time, in a specific sequence until the entire boiler is clean. Once the sequence was completed. it was immediately restarted This strategy maximized recovery boiler heat transfer, but the steam consumption by the sootblowers can amount to 10 15 percent of recovery boiler steam capacity.

Sootblower optimization provides closed loop control of sootblower cycling and duration to optimally manage sootblower steam consumption and recovery boiler efficiency. It reduces sootblower steam consumption without increasing water wash frequency. The operator is provided an alarm when a recovery boiler water wash is required.

A multifunction controller with BASIC capability is used as the primary element for sootblowing optimization, fouling rate model, relative frequency of blowing, the sootblower group scheduler and the sequence generator.

The system maximizes boiler operating efficiency by cleaning the proper heat trap at the proper time. Flue gas exit temperature, delta pressure drops across sections of the boiler and boiler load conditions are key inputs for the system. Sootblower sequencing using NETWORK 90 is furnished to consolidate all recovery boiler operations into a single system, eliminating reliance on a separate or existing solid state panel.

RECOVERY BOILER OPERATOR TRAINING SIMULATOR

A black liquor recovery boiler NETWORK 90 microprocessor-based simulator is available for operator training and maintenance training. The simulator has an operators CRT interface console and can interface with similar microprocessor controllers used in the control of the actual process. The CRT operator console can be configured with similar tags, trends, stations, control displays and graphic displays to that of the actual recovery boiler process.

The similarity of this training simulator to the actual recovery unit helps the operator easily identify the new microprocessor control with the process.

The sinulator is preferably delivered to the job site several months before the main process startup. This enables the operator to train and become familiar with the control of the recovery boiler from the CRT microprocessor console.

STATISTICAL PROCESS CONTROL FUNCTION

Increased resource costs and global competition have fostered the spread of the computerized Statistical Quality Control (SQC) procedures from discrete manufacturing operations to continuous processing operations. Advances in microprocessor technology have substantially increased the capability of digital process control systems to the point that SQC techniques can now be used on-line in support of current operations.

The distributed NETWORK 90 microprocessor-based controllers provide cost effective implementation of on-line Statistical Process Control (SPC) for critical process parameters. Control Charts of key process variables are generated automatically and on-line with today's systems. These displays can elevate the operator's awareness of his actions and result in improved process variability.

Statistical Process Control is based on the fundamental principles that there is a normal level of random variation in every process measurement, and that this normal variation, can be quantified historically. Once the normal variation is quantified, any significant change in the observed level of variation can be detected and investigated. When a cause for abnormal variation is identified, operations managers can work to eliminate the cause or minimize its effects, if the abnormal variation is bad. On the other hand, if the abnormal variation is good, operations managers can work to perpetuate its cause or maximize its effect.

The primary goal of SPC is to manage process operations to the most economically favorable level of variation.

In the case of the black liquor recovery boiler, examples of application of the SPC function are as follows:

1. Percent black liquor solids of the heavy black liquor prior to firing.
2. Liquor combustion performance index (LCPI) in units of pounds steam per pound liquor solids.
3. Percent oxygen of the combustion flue gases.
4. Baume of the green liquor product from the dissolving tank.

ECONOMIC BENEFITS OF ADVANCED CONTROLS

The following savings are based on a 800 ton per day black liquor recovery boiler with 350 operating days/year and a cost for oil-generated steam of $3.00/MLB. Actual savings will vary from mill to mill, depending on the power boiler fuel cost, and other factors affecting recovery boiler ability to fire at reduced excess air. Sootblowing optimization savings are affected by insertion/retraction speed, sootblower group arrangements, relative frequency of blowing, and other factors wich impact the operation of sootblowing equipment.

A total annual savings of $143,000 can be realized by reducing the average excess air from 28% to 10% (excess oxygen reduced from 4.5% to 2%) using programmed oxygen trim control. The net steam production increase from this excess air reduction represents steam that need not be produced by power boilers fired with fossil fuel.

Additional economic gains can be realized in other areas of the recovery boiler, such as improved chemical reduction, reduced SO_2 and TRS emissions, reduced dust carry-over to the boiler tube banks, and less auxiliary oil firing for stability at reduced black liquor firing rates. Further, increased green liquor sulfide concentration will reduce the load on the causticizing department and reduce soda loss in the lime mud and brown stock washers.

Sootblowing optimization has demonstrated significant economic benefits. A 30% reduction in sootblowing steam consumption has been achieved for a 800 ton per day recovery boiler which was using 10% of its steam capacity for sootblowing. This reduction was accomplished without any detectable increase in the required water wash frequency. This results in a savings of $285,000/year, since the sootblowing steam represents a swing load, satisfied by fossil fuel power boilers.

CONCLUSIONS

The application of recovery boiler advanced fuel/air control has resulted in the following benefits:

- Stabilized recovery boiler operation.
- Improved combustion efficiency.

- Increased and stabilized reduction efficiency.
- Less auxiliary oil firing for bed stability at reduced black liquor firing.
- Minimized sulfur loss in stack emissions.
- Minimized operator intervention during process upsets.
- Enhanced recovery boiler operational safety.

Recovery boiler personnel have gained confidence in microprocessor based CRT display systems which has caused a considerable reduction of dedicated panel board display devices. The increased use of these microprocessor based systems will continue both for retrofit and new recovery boilers. There have been and will be many technology improvements to the recovery boiler in the pulp and paper industry. Todays microprocessor control systems can be designed to take advantage of tomorrow's technology.

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