AGRO FUELS & BOILER AVAILABILITY

The use of Agro fuels for steam generation is increasing day by day. Some agro fuels are waste products after we recover the useful grains / oil. Some agro fuels are biomass such as firewood which has no other use except for steam generation. Some times it could be a byproduct fuel such as plywood waste or saw dust. Many of the boiler users have had the bitter experience with firing agro fuels as it reduced boiler availability. In this paper, the fuel characteristics are discussed. The care to be taken for boiler design / operation is discussed. Measures to be taken to increase the boiler availability / efficiency are discussed.

Following Are The Partial List Of Agro Fuels Used In Boilers.

Fire wood, Saw dust, Coffee husk, Cashew shell, Palm bunch, Wood shavings, De oiled bran, Rice husk, Wheat straw, Cotton stalk, corn cobs, Coconut shell, Bagasse, Eucalyptus leaves, Groundnut shell, Cane trash, Bamboo dust, Julia flora and Coconut coir pith are some of the fuels

CHOICE OF COMBUSTION TECHNOLOGY

The choice of combustion technologies had been based on several factors, major of which is the seasonal availability of fuels. Other criteria had always been the steaming capacity of the boiler and the process application. Power production does not tolerate pressure swings due to inconsistent fuel quality. Some plants required constant steam pressure for the process.

Available combustion technologies – use of fuels		
Hand firing on fixed grate	-	Used for firewood, plywood waste
Hand firing on dumping grate	-	For fibrous fuel where air can diffuse easily even if the fuel is dumped. -Used for bagasse & saw dust firing.
Dumped firing on horse shoe furnace	-	only for bagasse firing since fuel is fibrous
Suspension firing on fixed grate	-	Bagasse, saw dust
Suspension firing on dumping grate	-	Bagasse, saw dust
Suspension firing on traveling grate	-	Rice husk, bagasse, sawdust, GN shell
Mass firing on a traveling grate	-	Odd sized fuels
Over-bed firing in Fluidized bed combustor- open bottom	-	Rice husk, GN shell, Coffee husk, wood chips
Under-bed firing in fluidized bed combustor	-	Rice husk, GN shell
Circulating fluidized bed combustor	-	Ideal for rice husk, sized fuels with ash fusion temperature above 900 deg C
Mass firing on inclined grate	-	All kind of odd sized fuels
Mass firing on pusher grate	-	All kind of odd sized fuels
Underfeed stoker firing	-	Used for rice husk , GN shell, saw dust

CHOICE OF BOILER CONFIGURATION

External Refractory furnace with shell Boiler	-	Not suitable for slagging fuels
Internal furnace shell boiler	-	Firewood , rice husk
Waterwall furnace chamber with shell boiler	-	Firewood, rice husk, GN shell
Waterwall furnace chamber with water tube boiler	-	Wood chips, rice husk, GN shell,
Waterwall furnace chamber with radiant	-	Non slagging / fouling fuels

Superheater		
Waterwall furnace chamber with convection superheater	-	Slagging fuels
Waterwall furnace with tail end superheater	-	Ideal for Slagging fuels

Following are the some properties of fuels that affect the efficiency & availability of the boiler.

- Moisture content
- Ash fusion temperature
- Alkali content
- Chlorine content
- Fuel size
- Flow property
- Decay property

MOISTURE CONTENT EFFECT ON BOILER EFFICIENCY & AVAILABILITY

- This brings down the boiler efficiency – more fuel has to be burnt to account for evaporation of fuel moisture which leaves the boiler as a waste.
- We can choose to dry the fuel in sun light. But long term storage brings down the calorific value of the fuel. Part of the volatile matter leaves the fuel over a period.
- We can choose to stock the fuel in a well ventilated covered storage yard.
- Room heating is an option. Steam coil heaters can be used to bring down and maintain consistent moisture. Many small boiler users do this trick by stacking the wood logs in the boiler room.
- The fuel moisture creates flow problems in bunker. This leads to difficulty in maintaining an interrupted fuel feed to furnace. Fuel feed interruptions increases the fuel consumption.
- Fuel moisture leads to fungus growth and leads to lump formation. Calls for manpower to dislodge the fuel.
- The fuel moisture adds to flue gas moisture which condenses inside air preheater tubes and acts as nuclei for ash build up. Subsequently the tubes choke up calling for use of tube scale cutters. In case of gas over tubes, the gas flow path may be blocked.
- The fuel moisture adding to flue moisture condenses in pollution control equipment such as bag house / Electrostatic precipitator. The steel casing corrodes away in ESP.
- The fuel moisture adding to flue gas moisture condenses in chimney & idle gas ducting sharing the chimney. This corrodes the chimney and leads to sudden collapse of chimney. RCC chimney is preferred for agro fuels. Self supported steel chimneys are to be avoided.
- When the flue gas moisture leads to choking of the APH tubes, the furnace draft is affected. The required combustion air can not be given. Thus blue smoke is seen in chimney.
- Reduction in draft also leads to soot formation in furnace / duct / chimney and leads to black particulate emission.
- Reduction in draft leads to reduction in FD fan air flow and leads to grate bar burning.
- Moisture leads to APH tube failure at leads to direct passage of air in to the ID system. The furnace starves for air. The boiler capacity comes down. Many boiler users wonder how this could have such a pronounced effect.
- Increased moisture content disturbs the furnace condition. Higher moisture content will need more drying time. This will cause shifting of combustion zone to Superheater leading to high Steam temperature. In case of slagging fuels, the deposits accumulate and block the flue path. Boiler has to be taken for cleaning.
- Decreased moisture than design also disturbs the furnace in case of slagging fuel. The deposits build up in refractory walls of the furnace.
- Moisture pick up is faster in case the biomass gets trenched in rain.
- When the biomass is stored in pyramidal form, the pick up is less as the water runs down easily.

DEPOSITS IN BOILER HEATING SURFACE

Deposit formation on heating surfaces is the biggest problem in biomass firing. Its effect is to lead to shut down of boiler due to draft problem (depending on boiler configuration) and the loss of steam generation. Damages may occur in some cases due to increased gas velocity when fouling takes place. Every fuel has a non-combustible mineral fraction which is converted to ash on combustion. Formations of deposits are due to fuel quality, boiler-design, boiler-operation and boiler-maintenance.

SLAGGING & FOULING

Deposits can be classified as slagging & fouling. Slagging occurs in the boiler sections that are directly exposed to flame. Slagging is a mechanism of stickiness of ash, ash melting & sintering. Fouling is due condensation of volatile compounds in fuel over tubes in convective path. Fouling deposit is porous and easily removable. Combustor design and furnace design have to be based on feedback on operating experiences. Inspection windows are to be strategically located for physical observation of deposition while the boiler is running. Based on actual deposition pattern & operating conditions, design of future boilers must be done.

SLAGGING IN FURNACE

Slagging is due to ash fusion. Stickiness begins with initial deformation temperature of ash. The ash fusion in furnace is controlled by disposition of waterwall tubes, furnace plan dimensions, furnace volume, fuel distribution inside furnace, fuel size, excess air, combustion technology and the way in which the air is thoroughly mixed with fuel while spreading the fuel inside the furnace.

- The fuel moisture also decides slagging to a large extent. Part of the furnace volume is used up for drying itself. The furnace outlet temperature shoots up and thus leading to slagging at superheater / boiler bank. Hence it is necessary to maintain fairly constant moisture content in fuel.
- Slagging occurs over convective tubes when the furnace exit temperatures are higher. Superheater tubes would be fouled with harder deposits which are not easily removed.
- When the ash melting temperatures are lower, parallel flow superheater is adopted. This ensures the superheater is not coated with ash.
- Un-cooled Superheater spacer clamps offer sites for ash. The design should avoid such details.
- Radiant superheater is susceptible for ash slagging, particularly when the furnace volume is inadequate. The furnace gas residence time of 2.5 second is adopted. In addition the waterwall heating surface should be adequate to cool the gas to a temperature decided by the slagging tendency.
- When the air flow through furnace gets reduced due to wrong operation of boiler / leakages in boiler roof / leakages in Airpreheater would lead to high combustion temperature and leads to ash slagging in furnace. There are many cases where the furnace behavior has been returned to original design condition only by attending the leakages.
- In general the ash fusion temperature of the biomass is low. The low ash fusion temperature is due to low melting alkali compounds with Potassium & Sodium radicals. This leads to sticky deposits on Superheater tubes and refractory furnace walls & uncooled metal spacers / alignment bands used in convection coils. The deposits are not easily removed. The best way to avoid is to place the convection heating surfaces after the flue gas is cooled below 650-700 deg C. However this is not being done by any manufacturer as the boiler cost goes up. A typical boiler configuration has at least three passes made out of waterwall, before the gas enters convection Superheater.
- The ash melting tendencies of ash is modifiable by using fire side additives. A separate feeding system is used to add the chemicals. This keeps the superheater cleaner as compared to a case without any fire side additive.

- Co-firing of agro fuels with coal or a combination of agro fuels is found to modify the characteristics of deposition of sticky fuels. For example it has been possible to use cotton stalk along with rice husk.
- Many boiler users have arrived at the optimum combination of fuels which would extend the periods between cleaning. Yet the best is possible if only boiler design is modified.
- Fly ash from coal fired units may help in modifying ash fouling pattern.

FOULING ON CONVECTIVE SURFACES

Fouling occurs due to condensation of volatile species. It is removed by a mechanism of rapping or blowing. If not done, the fouling keeps on building up until a maximum thickness is achieved. Fouling can be seen in the rear portion of Superheater tubes.

- Fouling is not seen in boiler bank tubes / Economiser tubes as the deposits get cooled to powdery nature and flue gas velocity is generally sufficient for a self cleaning action.
- Locating Superheater in low temperature region avoids the build of fouled deposits. Self cleaning action ensures the Superheater is free.
- High temperature superheater at furnace exit gets fouled first. Then the ash builds up over the fouled ash and offers still hotter surface. Dripping molten ash is seen in some Superheater.
- Soot blower positioning & sequencing are important for removing the fouling.
- Furnaces which have good temperature control will avoid the fouling of convective surfaces. AFBC & CFBC technologies have good furnace temperature control compared to others. Grate firing technologies do not have accurate control over furnace temperature. The only way to control furnace outlet temperature would be furnace dilution by cold secondary air.

FOULING ON AIRPREHEATER SURFACES

Fouling on air preheater surface occurs with a different phenomenon. As the flue gas moisture condenses, the ash gets cemented over the tube surface in cold sections of Airpreheater. When the gas flows over the tubes, the flue path may not be obstructed provided pitch is in excess of a minimum value. When the gas flows over the tube, the ash is able to plug the tubes easily. Many Airpreheater tubes are cleaned annually by high pressure water jets. Sometimes the ash will have to be drilled through. Excessive fuel moisture leads to quicker choking in Airpreheater. When the flue gas contains sulfur dioxide, tube gets eaten away faster. Otherwise the Oxygen and water condensation together leads to tube puncture by pitting corrosion.

- When the gas flow is over tubes, the choking of flue path can be prevented.
- By adopting air operated soot blower system / acoustic cleaning system, flue path choking can be prevented.
- Use of steam coil air preheater would delay the tube failures due to flue gas moisture condensation.
- Use of steam coil air preheater would also delay the ash plug formation inside the tubes.

CHLORINE CORROSION

- This is a very serious matter in case of Boilers with high temperature Superheater. All green leafy biomass would have what is known as Chlorophyll. The chlorine is found to corrode the Superheater sections. The Chorine converts the ferrous ions to ferrous chloride. There is no way combat this except we locate the Superheater coils with inlet gas at less than 650 deg C. sulfur injection is found to be a solution. Injection of sulfur to maintain S/Cl ratio at a value between 2 to 4 have been proved to reduce the corrosion effect. But the boiler tail end heating surface such as economizer & air preheater and flue gas cleaning equipments have to be designed for this.

- The main steam pressure should be limited to 460 deg C, if chlorine is found to be present in agro fuel. Cotton stalk, sugar cane thrash, bamboo trees are known for their chlorine content.
- It is necessary to analyze any new biomass to be fired. Once the damage is done it does not reverse unless the deposits are removed in dry form.
- Injection of fly ash from coal may modify the deposition of ash over superheater, but the same should have been commenced even before the Superheater is coated with potassium, sodium & chlorine containing biomass.
- In view of the above fact black recovery boilers are designed for Steam temperature of 485 deg C. Similarly Municipal waste fired boilers are designed for 450 deg C steam temperature with a pressure of 45 kg/cm2g. The boiler is not provided with Airpreheater.
- Chlorine is present in three forms, namely molecular chlorine, Hydrogen Chloride and alkali chloride. Corrosion by HCl is seen in reducing atmosphere in furnaces. Alkali chlorides have lower fusion temperature and thus after deposition in superheater, they dissolve the metal as chloride. It has been proved that FeCl2 again oxidizes and releases chlorine. Part of the chlorine releases goes back to metal to cause continuous corrosion.

SIZING OF FUELS FOR BETTER AVAILABILITY OF BOILERS

- Depending upon the combustion technology adopted the fuel needs to be sized. Handling the different fuels require different kind of equipments. For example tractor with grab buckets are used for picking and dropping the cotton stalk / wheat straw.
- Husk / GN shell / coffee husk / Saw dust / De-oiled bran is pushed in to hoppers by tractors equipped with pusher plate.
- Oversized fuels have been notorious for tripping the fuel feeders. Secondary sizing equipment would be necessary.
- When the fuel is made uniformly small the handling becomes simpler. Yet many manufacturers ignore this.
- Oversized fuels reduce the availability of the boiler due to disturbances in fuel feeding. Steam pressure and steam temperature fluctuation and loss of steam generation have been seen in Industry. Silos and drum feeders adopted for bagasse can be used for other fuels if the secondary size reduction is addressed with respect to biomass.
- Foreign material such as stone had been of great problem with rice husk / Groundnut shell. Screening is a must to remove oversized stones.
- Iron piece coming with fuel trip / damage the fuel feeding system. Long wires, nails have been notorious in causing damage to traveling grate components. Magnetic separator is to be installed in feeding conveyor.
- Fuels that need sizing must be done when it is green. This is important to save chipping power. Processing after drying would call for more power.

FLOW PROPERTY DISTURBING THE BOILER OPERATION

- Of all the biomass fuels, rice husk has the best flowability. Thus the boiler with this fuel is provided with bunker. It is a practice to blend some fuels like saw dust, Ground nut shell with rice husk.
- Other fuels can also be stored & fired in system such as silo & drum feeders. But uniformity in size is important.
- Smaller hoppers must be used at boiler end to minimize the troubles due to fuel flow problems.

DECAY PROPERTY CAUSING MORE FUEL CONSUMPTION

- Being organic fuel, presence of moisture can lead to decay of the biomass fuels. It is important to avoid dead storage. The fuels should be consumed as much as possible from bottom. We may

implement expiry date system to avoid unnecessary decaying of biomass. As the decay takes place the hydro carbons leave in the gaseous form. The useful calorific value is lost.

- Ventilated but covered storage is required during rainy season. Closed room drying is preferred to bring down the fuel moisture.

CARRYOVER OF WATER TO SUPERHEATER

- When the fuel feed can not be properly regulated the steam generation is reduced. As the steam drawal continues, it leads to water level fluctuation leading to carryover. It is not possible to maintain drum level with erratic fuel feed.
- Fuel silos system is required to avoid this.
- When the carryover is present, the high TDS water gets carried to Superheater. As the dissolved solids get deposited, the Superheater gets heated locally, leading to long term / short term overheating failure.

SHELL TUBE CHOKING

- Shell tube boiler is not a right choice for fuels which have low ash fusion temperature. The First pass tubes often get choked and cleaning is resorted to. This is a great disturbance for plants. Water tube configuration is the right choice.
- Again adequate radiant furnace area must be provided before a convection bank is arranged. The deposits over the tubes do not lead to boiler stoppage.
- Sonic soot blowers or steam operated soot blowers can be used when the gas flows over tubes. But when gas flows inside tubes only sonic systems are usable.

CONCLUSION

There is a need to review the boiler design for improved boiler availability. Boiler outages on account of ash slagging & fouling must be avoided. An update of boiler design in Europe needs to be understood.

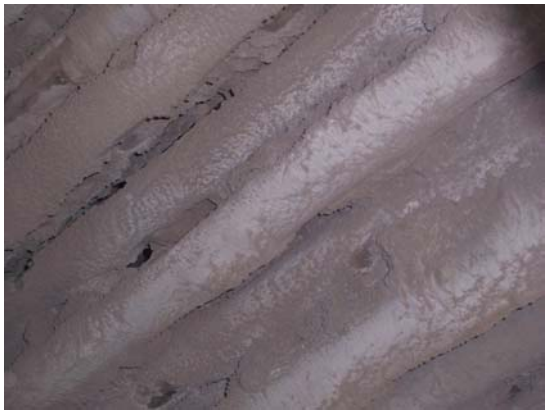

Photo 1: Ash deposition over tubes

Photo 2: Flue gas moisture condensation inside duct

Photo 3: Ash build up due to moisture condensation inside APH tubes

Photo 4: APH metal loss due to moisture condensation

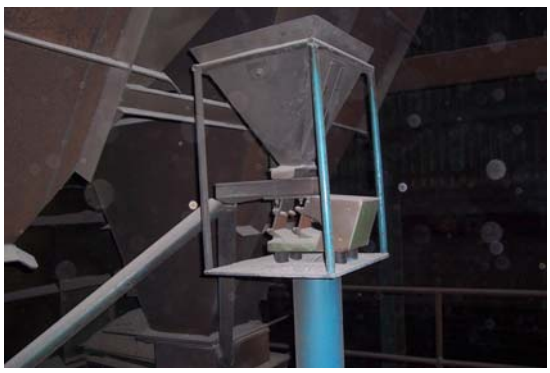

Photo 5: Fire side additive feed arrangement.

Photo 6: Ash build up over superheater due to inadequate furnace volume / water wall.

Photo 7: Ash deposition over tubes

Photo 8: Fouling & corrosion over superheater

Photo 9: Furnace ash slagging since the waterwall surface is in adequate.

Photo 10: frequent shell tube cleaning calls for disturbance in plant.

Photo 11: Ash builds up on convective Surface – inadequate furnace volume

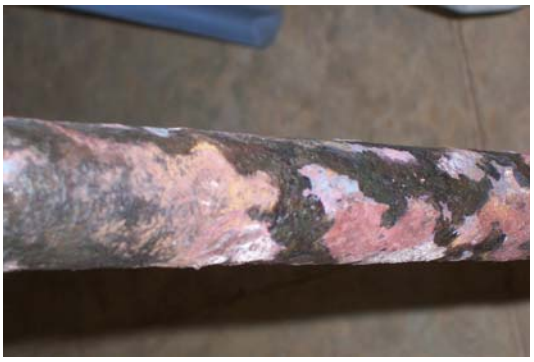

Photo 12: Superheater tube corrosion due to alkaline chloride corrosion.

Photo 13: oversized wood chips – cause interruption in fuel feeding

Photo 14: A clean furnace with bagasse as fuel.

Photo 15: Corn cobs cause fouling in furnace. Furnace must have water wall without refractory.

Photo 16: Ash molten in furnace due in adequate furnace size & waterwall surface.

Photo 17: Poor fluidization in furnace - mal-operation

Photo 18: Air ingress from roof in a boiler designed for paper mill.