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CheMin Probe: Material and Corrosion Monitoring for Optimisation of Plant Efficiency.

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Biomass and solid waste are relevant fuels in terms of numerous global attempts to protect environment, climate and resources. Therefore energy efficiency is an important issue for power plants fired with biomass, solid waste or fuels derived from solid waste. In many cases these fuels are characterised by several positive properties such as long term available, renewable, avoiding diffuse emissions (as given from landfilling) and supporting the usage of heat and/or electricity on a local scale by small power units. Therefore, power plants fired with biomass and/or solid waste are important to stabilize the electricity grid which is facing the growing demands due to the increasing contribution of volatile wind and solar power. This effect is even more important, if nuclear and coal fired power plants are of limited acceptance, like in Germany ("Energiewende"). To optimise the role of biomass and waste for a stable and continuous power production, energy efficiency of the plant should be as high as possible. The given limitations, i.e. the more conservative design with steam temperatures not above 400°C (for waste) or 480°C (for biomass), is mainly related to the problems with corrosion of water walls and superheaters, due to high temperature chlorine corrosion and/or salt melt corrosion. Optimisation of plant efficiency is therefore strongly related to an optimum usage of corrosion protective materials. To select a proper material and a proper application and design is a complex demand for plant manufacturers and operators due to several limitations:

- The market for materials to be used to protect from corrosion (and/or erosion) is wide and complex.
- There is no simple problem-solution relation available.
- The limitations of a specific material, like thresholds of material temperature or flue gas temperature towards an increased corrosion dynamic are not well known.
- The experience gained at one power plant with a given corrosion protection concept is not transferable to other plants (with other fuels and/or firing conditions).
- Tests with protective materials at a given plant are typically done by applications inside the boiler, which means access to the application only during outages (after a whole operational period). This limitation results in a flat learning curve.

The process of an individual corrosion protection design is necessary for every plant on the one hand, but also time consuming on the other hand and is therefore avoided in many cases. Instead, the above mentioned conservative design for steam temperatures is accepted by plant manufacturers (during plant design) and operators (during plant optimisation). In the light of an increasing diversity of power production and the need for stable power availability this status quo has to be overcome. CheMin developed a precise, fast and predictive measure to select the best corrosion protective material for a given power plant and a given fuel using a corrosion probe. These “CheMin-Probes” (patented) are based on the experience in corrosion and fouling derived from failure studies and expert witness work. The features of the CheMin-Probes are:

- The probe corresponds to the real boiler component in terms of size (boiler tube), material and optionally with corresponding corrosion protection (e.g. ceramics, weld overlay, spray coating).
- The temperature range on the probe surface is freely selectable and is kept on a constant level by a temperature control. This allows the temperature range to be observed simultaneously on the material surface.
- The probe can be applied at different flue gas temperatures (from secondary combustion chamber to flue gas cleaning).
- The probe can be used for a time period which is freely selectable (from hours to months) and can be inserted or removed at any time. This means special operating condition can be investigated specifically.
- The heat flux can be measured on the basis of the amount of cooling air and its outlet temperature.
- The application of different materials on the probes allows evaluation with regard to their resistance to corrosion.
- Following the operational application of the probe, laboratory tests have to be started with regard to the given issue, e.g. cause and mechanism of corrosion, dependence of corrosion or fouling on temperature, corrosion resistance of various materials, etc.

The goals for the application of CheMin-Probes are wide spread and depend on the interests of the different actors in the worldwide market of biomass and waste fired power plants. To give some examples:

Pool of experiences (plant manufacturer):

Already during plant design the major conditions for the power plant process have to be determined, without the chance for testing. Therefore, plant manufacturers have an interest to know at least roughly the limits of material temperature and flue gas temperature for a certain corrosion protective material for a given type of fuel. Such information can be achieved by systematic application of CheMin-Probes at existing power plants. Different options of protective material can be tested (several weeks each). With these applications, the different corrosion rates at different material temperatures can be evaluated and therefore the implementable material temperatures and its limit can be detected.

Higher energy efficiency for a given plant (operator):

Operators of power plants use CheMin-Probes to learn the threshold of material temperature for the given material in order to check the margins of the scope of steam parameters. For example, if the superheater (400°C steam temperature) is cladded with Alloy 625, the same material (and application) is used for the CheMin-Probe and the temperature window on the probe will be fixed from e.g. 380°C to 480°C. After some weeks inside the boiler (near to the superheater) the thresholds for higher corrosion rates can easily be detected on the probe surface. With these results the operator is able to increase the steam temperature to a certain value without risking strong corrosive attack. In general, the relation between higher steam temperature and its higher corrosion rate becomes transparent and the temperature range with a dynamic increase of corrosion rate can be avoided. With this information the relation of material costs for exchange of the superheater and the lifetime of the superheater (two, three, five, ten times of an operational period) and the higher revenue from electricity due to higher steam parameters can be balanced to an commercial optimum.

Best available corrosion protective material for a given plant/fuel:

Both, plant manufacturer and operator, have an interest to support innovation of new material and/or new application methods for corrosion protection of waterwalls and superheaters. In the past a lot of materials have been excluded from operational tests only due to not promising results derived from a laboratory test design. From this, the manufacturer of ceramic or metallic protective materials can use the CheMin-Probe to test on-site new materials and new designs at power plants. Tests can be performed e.g. under strong corrosive operational conditions or for a selected fuel or for a selected structural component etc. In any case, a wide range for material temperature is registered simultaneously with each probe. The time period for a CheMin-Probe inside the boiler is typically in the range of 500 to 1000 operational hours. Specific results (i.e. corrosion rates) are available after few days after removal of the probe. More detailed results (i.e. corrosion cause, corrosion mechanism), however, are available after two to three weeks after removal of the probe. This allows a precise and dynamic development of new material or new application methods.

CheMin-Probes can be applied as:

Corrosion Probes, Material Probes, Fouling Probes

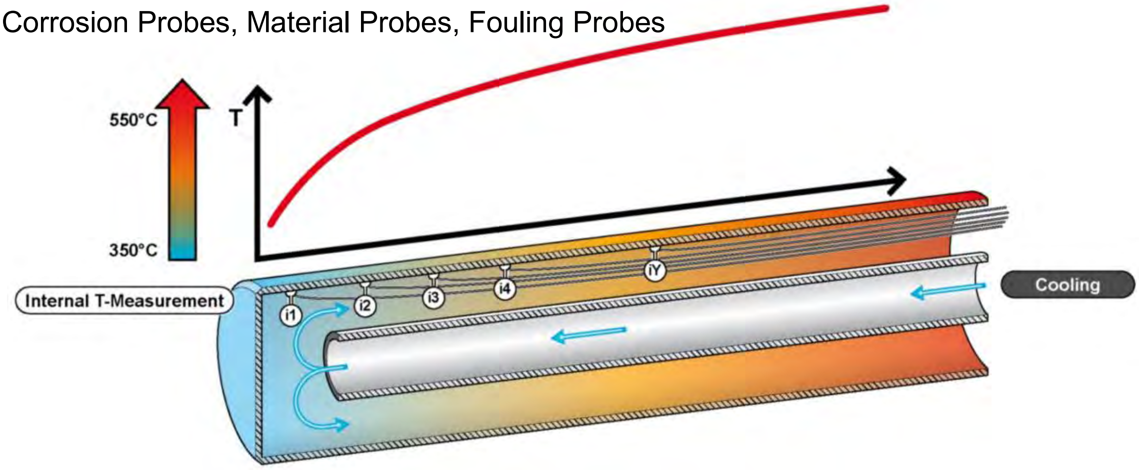

Figure 1: Probes with a temperature profile: How does it work?

Figure 2: Cause and mechanism of corrosion

Figure 3: Deliqueszence corrosion of hygroskopic salts (operation time 15 h, flue gas temperature 260°C

Figure 4: Material probe, application of inside thermocouples: before or after coating of the tube