Pulse-jet Fabric Filters for Coal-fired Firetube Boilers

John Thompson, a division of ACTOM (Pty) Ltd, has been designing and constructing pulse-jet fabric filters for the power utility industry in South Africa for many years. They are also the largest supplier of package firetube boilers in sub-Saharan Africa with more than 3,000 boilers installed. This unique position has enabled the company to develop a pulse-jet fabric filter specifically suited to coal-fired firetube boilers. In other parts of the world, such as Europe, where firetube boilers are used and emission regulations are strict, gas and oil are the dominant fuels. As these do not produce significant emissions of particulate matter, the use of fabric filters on firetube boilers is therefore not widespread. Fabric filters, also known as bag-filters, are used to reduce the emission of particulate matter from the exhaust gas of various industrial processes. These processes include the manufacturing of pharmaceuticals, food and chemicals; and the combustion of biomass fuels and solid fuels such as coal, for steam and electricity generation.

Electrostatic precipitators (ESP) can be used in the same applications, but their efficiency depends to a great extent on process parameters. Variables such as particulate resistivity, temperature and gas velocity need to stay within narrow parameters for an ESP to be effective. On the other hand fabric filters can handle widely varying process parameters while easily maintaining very high collection efficiencies.

Fabric filter design
There are two major design types of fabric filters; high-ratio (pulse-jet) design and low-ratio design. The difference being whether the ash is collected on the inside of the bags (low ratio design), or on the outside of the bags (pulse-jet design). For the pulse-jet design, the soft and flexible bags are supported on the inside by a steel wire cage and the ash-laden gas is taken through a sieving textile media. The ash is collected on the outer surface of the media, and the deposited layer of ash becomes an integral part of the sieve. The pore size of the composite media/ash-layer sieve is very small, typically in the range of 10 to 30 microns. Due to the sieving effect, the collection efficiency is high. The separation efficiency is, among other things, a function of the porosity of the media, the ash properties and the cleaning technique. In general terms, the smaller the pores, the higher the collection efficiency. Irrespective of the type of filter, the deposited ash-layer must periodically be cleaned off the bags in order to control the pressure-drop over the filter.

Coal-fired firetube boilers
Users of coal-fired firetube boilers in South Africa have for a long time been required to control their emissions. These boilers are normally equipped with multi-cyclone collectors which have collection efficiencies of up to 85% and particulates emission of 250 mg/Nm3. However, due to increased awareness of global warming and health issues attributable to pollutants, there is pressure on users of these boilers to reduce their emissions. In fact, the Air Quality Act, 2004, in the environmental condition for solid fuel and biomass fuel combustion installations for steam and electricity generation, with design capacity equal to or greater than 50 MW (65 t/h steam), to 50 mg/Nm3 for new installations and 100 mg/Nm3 for existing ones. Legislation pending for design capacities from 10 to 50 MW (13 to 65 t/h) proposes 120 mg/Nm3 for new installations. Below 10 MW the emission limit remains 250 mg/Nm3.

Coal supply
Firetube boiler users rarely have a long term coal supply contract directly with a mine specifying acceptable and stable coal properties for the duration of the contract. This is due to the relatively low volumes they require compared to the likes of Eskom. They are therefore forced to buy coal with widely varying properties from coal stockists. The combustion of this coal produces ash with widely varying properties making the use of an ESP challenging. However, fabric filters are well suited to deal with varying process parameters such as varying ash properties.

Development challenges
Many challenges were faced during the development of this product. The process parameters that a fabric filter at the outlet of a package boiler has to deal with are very different from that of a utility boiler. Boiler loads can vary widely on an hourly or daily basis. This leads to widely varying flue-gas temperatures with possible acid attack at low temperatures and fabric damage at high temperatures. Peak flue-gas temperatures are much higher than those of utility boilers due to the lack of economisers, air-heaters and superheaters in firetube boiler installations.

Fly-ash from firetube coal-fired boilers contains varying amounts of unburnt carbon and aggressive chemicals depending on the highly variable coal used. The particle shape and size distribution of this fly-ash is hard to handle with a high percentage being smaller than 10 Micron. This is characteristically unlike utility boiler fly-ash where size distribution stays within a controlled range. Due to the short gas path beamed of the firetube boiler combustion zone and the chimney stack, spark carry-over in the flue-gas can potentially cause combustion of the fabric filter material. To prevent this, John Thompson developed a spark arrester incorporated in the inlet box of the unit.

Boilerplant installation
Solutions to all these challenges were found and the first fabric filter installed on a coal-fired firetube boiler was successfully installed and commissioned for one of John Thompson’s customers in the food industry located in an environmentally sensitive area in the Western Cape. The installation includes a 15 t/h John Thompson EUROPCAC coal-fired boiler complete with pulse-jet fabric filter, multi-cyclone collector (bypassed during normal operation), ID fan, gas ducting, chimney stack, pre-boiler plant and coal and ash handling equipment. Ash from the boiler and fly-ash from the fabric filter both discharge into the ash conveying system.

Operation
The filter bag material was selected for operation within a temperature range of 150 to 200°C. The fabric filter plant can be bypassed during start-up and shut down, and also at low loads if the flue-gas temperature drops below set-point, to prevent acid formation, corrosion of steel components and consequent damage to the filter bags. During gas ‘slow’ periods, the flue-gasses are ducted through the multi-cyclone collector to limit emission of particulate matter. For further protection against acidic conditions, the filter bags are coated with lime before every cold start-up procedure.

The fabric filter plant has been in operation for over two years with a collection efficiency in excess of 98% and emissions below 50 mg/Nm3. As replacement of filter bags is a major portion of the life cycle cost of fabric filter plant, John Thompson, in collaboration with the fabric suppliers, has been able to increase the fabric life from two years to an expected four years.

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