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THE RWE POWER WTA PROCESS (FLUIDIZED BED DRYING) AS A KEY FOR HIGHER EFFICIENCY

1. Introduction

Lignite is a significant source of solid fuel in Europe and other parts of the world. However, lignite is encumbered by a high moisture content, ranging as high as 65% for very recent and shallow lignites. Other than ash, which behaves energetically largely as an inert dilutant of the coal and ballast during combustion, much like nitrogen in combustion air, moisture, through evaporation, actually absorbs some of the energy contained in the coal, thereby reducing the energy available for conversion to electricity. As is well known, this energy lost to evaporation cannot be recovered during conventional combustion processes, since the vapour content of the flue gas is too low for condensation under ambient conditions. Since this loss is related to the amount of moisture per unit amount of dry coal matter, the loss rises non-linearly with increasing moisture content. While at 25% moisture (typical subbituminous coals), the energy loss is about 3%, rising to about 7 at 40% moisture, it increases to 12 at 50% moisture, and to 20% for lignites with 60%.

Translated into emission of CO₂ per produced kilowatt-hour, the specific CO₂ emission of lignite with 60% moisture is 25% higher than for a completely dry equivalent lignite, all other things being equal.

Given the necessity to reduce CO₂ — emissions during power generation, and given the importance of lignite as a domestic energy resource Germany, RWE as one of Europe's large electricity generators and the world's biggest lignite miner, had a strong incentive to find ways of drying the lignite prior to combustion in an energy efficient way.

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2. Steam Drying

Steam drying, another drying method, has been relegated to a niche existence in coal drying until today. In 1979, Potter et al. took up the principle of steam drying and, in laboratory tests, proved that lignite can also be dried in a stationary fluidized bed using slightly superheated steam [1].

What makes steam drying particularly interesting for lignite drying are two aspects. One is the necessity to remove a large amount of water from the raw lignite, of the order of half a ton of water for every ton of raw lignite. The other is the fact that lignite behaves hygroscopically, that is, the moisture content in the lignite will equilibrate with the surrounding atmosphere and, for a given lignite, is only function of the pressure of water vapour and the temperature. When drying lignite in pure steam at constant pressure, say atmospheric pressure, the equilibrium moisture is only a function of temperature. The curve describing this relationship is known as the desorption isobar. This is of particular interest from a process control perspective, since the moisture of the dried lignite does not depend on the drying time, provided that the lignite is dried long enough to have equilibrated with the steam atmosphere. Furthermore, the lignite cannot be “overdried”, because the moisture content no longer changes, once equilibrium is reached, regardless how long it is kept in the dryer.

The desorption isobar depends on the lignite. Figure 1 shows this dependence for Rhenish and Australian lignite at a system pressure of approx. 1.1 bar. An equilibrium moisture content of app. 12% wt is reached in Rhenish lignite at a temperature of app. 110°C and in Australian lignite at 107°C [2].

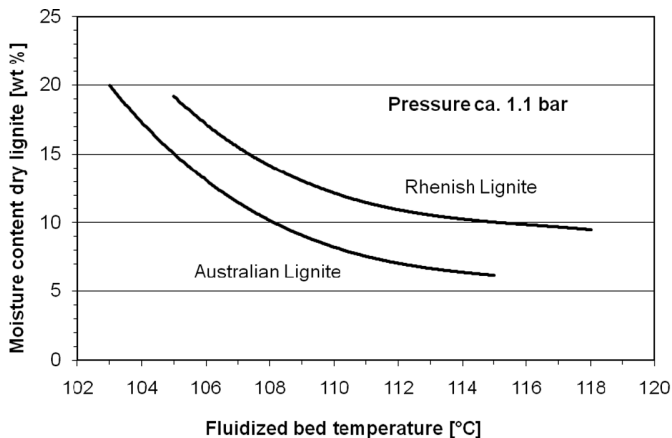


Fig. 1. Desorption isobars of Rhenish and Australian lignite

Steam drying has thus a number of fundamental advantages for the drying of lignite materials:

- Drying is carried out in an inert atmosphere, ensuring a high degree of inherent safety for the potentially explosive dry lignite.
- At constant pressure, the moisture content of the dry lignite is only a function of temperature.
- Drying is carried out at comparatively low temperatures.
- Virtually 100% of the drying vapour consists of steam, so that it condenses isothermally. It is thus an attractive source of waste heat that can be used energetically in a sensible manner.
- The condensation of the vapour avoids large-volume steam emissions and dust emissions.
- At the same time the condensate formed is a utilizable source of water that can contribute to meeting the water requirements of an industrial plant.

In view of these advantages of steam drying, RWE had been researching the steam drying process since about 1990 [2] and by now holds 22 patents related to the process.

3. Process principles of WTA drying technology

The WTA drier operates in a stationary fluidized bed with low expansion at slight overpressure (Fig. 2).

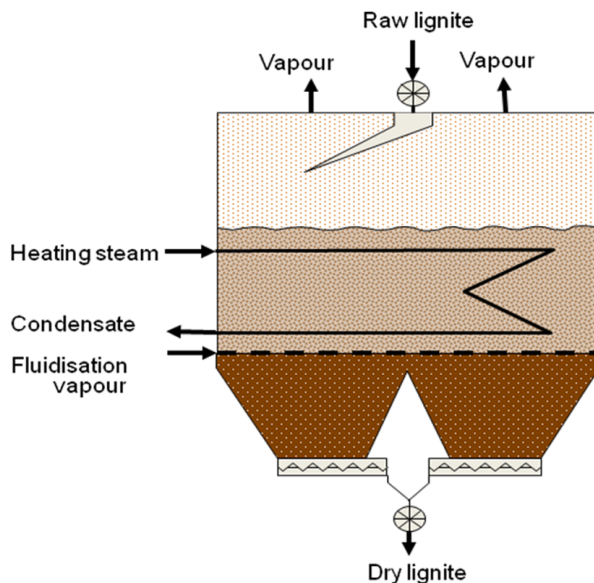


Fig. 2. WTA dryer structure

Energy is supplied almost exclusively via heat exchangers installed in the fluidized bed and only to a small extent via the fluidizing medium. Therefore the fluidizing flow and the energy requirements of the dryer can be controlled independently of each other. The heat transfer between the heat exchangers and the fluidized bed is so good that high heat flow can be achieved even with small temperature differences. As a consequence, driers with high evaporative capacity can be built as compact units. Since milled raw lignite is practically impossible to fluidize in bulk due to its cohesive properties, the fluidized bed is designed as a mixed bed of dry lignite as carrier medium and freshly added milled raw lignite.

4. Function of the WTA dryer

As shown schematically in Figure 2, the raw lignite is introduced by a star feeder into the dryer which is under slight overpressure. A system developed specially for WTA technology and installed in the upper part of the drier distributes the added lignite evenly across the fluidized-bed surface. The middle part of the drier houses the actual fluidized bed with the built-in tubular heat exchangers. Either low-pressure steam or (depending on the process variant) recompressed vapour is used for heating; the pressure is approx. 3–4 bar in either case. A special system geared to the conditions of the lignite drying process is used for fluidizing the fluidized bed, which has a total height of about 3.5 m. A fixed-bed forms below the fluidising system and the dry lignite is removed from it and out of the dryer via suitable systems. The water evaporated from the lignite (vapour) is withdrawn from the freeboard via the dryer top. Due to the compact design possible with WTA-technology, the dryer of the Niederaußem WTA plant has a total height of less than 10 m.

5. Overall Process

Figure 3 shows the overall process of the fine grain WTA variant with upstream raw lignite milling and integrated mechanical vapour compression to utilize the heat of evaporation within the drying process. After dust removal in the electrostatic precipitator, the vapour is recompressed to app. 3–4 bar in a compressor, so that the vapour can be used for heating the heat exchanger installed in the drier. The sensible heat of the vapour condensate is used to preheat the raw lignite to approx. $65\div 70^{\circ}\text{C}$, making an important contribution to meeting the energy needs of the drier. Some of the cleaned vapour is recirculated and used to fluidize the fluidized bed. The dry lignite is cooled and — if necessary — reground to a particle size of $0\div 1$ mm by a mill integrated in the process, so that it can be used directly for firing in the power plant.

Figure 4 shows the overall process of the fine grain WTA variant with upstream raw lignite milling and downstream vapour condensation for preheating boiler feedwater from

the water-steam cycle of the power plant. For process control reasons, some portion of the vapour needs to be vented to atmosphere in this variant.

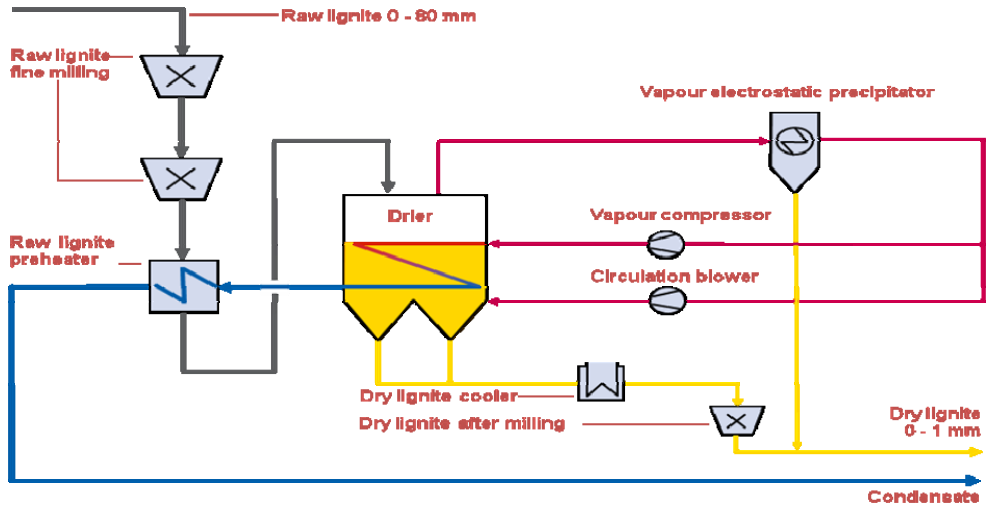


Fig. 3. WTA variant with integrated vapour compression and coal preheating

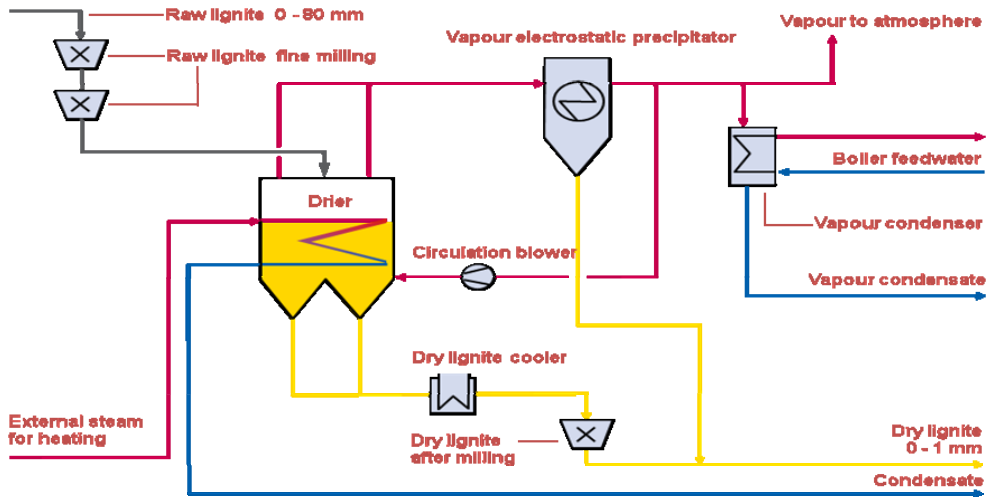


Fig. 4. WTA variant including vapour condensation

Figure 5 shows a low-cost variant without vapour utilization as used, for instance, to improve the calorific value of low-rank coals [4].

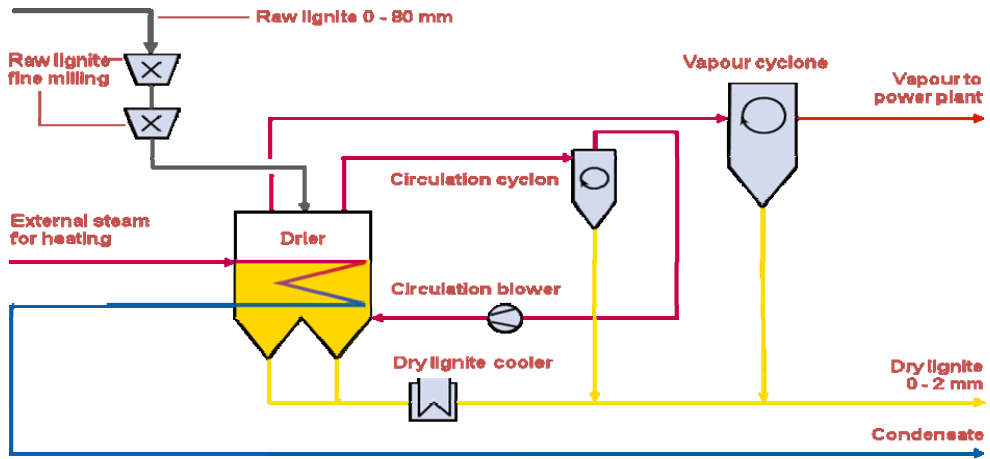


Fig. 5. WTA as low-cost variant

6. Development History of WTA-Technology

The first steam-fluidised bed dryer developed by RWE, the WTA-1 demonstration plant at Frechen near Cologne, Germany, was a demonstration plant with a throughput of 53 t/hr of raw lignite with a grain size of 0÷6 mm and an evaporative capacity of 25 t/hr. During the 20,000 — hour test operation from 1993 to 1999, the WTA-1 demonstration plant and the vapour compression system for drier heating, which was employed for the first time worldwide in lignite applications, proved to work extremely well and reliably [3]. Further theoretical work and an evaluation of the test operation of the WTA-1 plant revealed that there was further technical and economic process optimization potential. Several lines of development were considered and it was shown that a reduction of the grain size held most potential for further improvement [2, 3].

In 1999, RWE built a test plant for the fine-grained WTA process, called the WTA-2 plant, directly next to the WTA-1 plant in Frechen. This new plant had a design capacity which was increased in several optimization steps from originally 16,4 t/hr raw lignite throughput and 8 t/hr evaporation capacity to a raw coal throughput of 28.7 t/hr and a water evaporation capacity of 13.1 t/h. with a total of 8,200 hours of operation by 2011.

Based on the extensive experience from the operation of the WTA-2 plant with a range of lignites from the Rhenish Lignite District, RWE decided in 2005 to build the commercial-size WTA-Prototype plant at Niederaußem which would be integrated into the water-steam cycle of the BoA. The design capacity was 210 t/hr of raw lignite throughput, 110 t/hr dry lignite output and the evaporation capacity was 100 t/hr. This represented a scale-up step of a factor of more than 8. The plant was designed as a production plant with industrial-type process control system and safety features. Just like the WTA-1 and WTA-2 plants, it was completely designed and procured by RWE Power. It was erected between 2006 and 2008,

first raw lignite was dried in December 2008 and since February 2009, the plant is in test operation and the shake down phase. An unexpected number of plant-related problems in the conventional (not WTA-specific) section led to a considerable delay in commissioning. Meanwhile these problems have been solved and as of January 2011, the plant operates smoothly under automatic control for periods of more than 500 hours, consistently and continually producing dry lignite to specification. During the operation it was noticed that the drying process would be affected by changes of the raw lignite composition, as delivered from the BoA. The control system could automatically compensate these, thereby maintaining the dry lignite product within specifications. However, it also emerged that the lignite mixture supplied to the BoA now is very different than the standard lignite mixture at design time of the WTA unit. As was confirmed by tests at the WTA-2 plant in Frechen in November 2010, the current lignite mixture behaves significantly more cohesive and contains more wood. It has a noticeably lower heat transfer coefficient than the originally specified lignite, or, for that matter, any other lignite ever tested at the WTA-2 plant, including lignites from Poland and Australia. This underlines the necessity for drying tests at Frechen prior to the design of a WTA plant. Further work at Niederaußem will concentrate on improving the throughput.

7. Summary

WTA technology is an important element in RWE Power's efforts to further increase efficiency in electricity generation. A number of variants have been developed for the technology that allow pre-drying to be integrated optimally into power plant processes and into lignite gasification processes. For the latter, WTA technology is a significant contributor to improving the energetic efficiency of the process. The construction and operation of the WTA plants in the various development stages demonstrate that industrial-scale maturity has been reached.

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