Metso Outotec's 5th Generation of CFB Alumina Calciners – Optimized Process and Equipment Design

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Abstract

Metso Outotec and its predecessor companies introduced the Circulating Fluid Bed (CFB) calcination technology to the alumina industry in 1970, and since then it has gone through several development stages with more than 60 installations worldwide, resulting in the latest generation of state-of-the-art CFB calcination technology that Metso Outotec has provided to recently commissioned alumina refineries.

The continuous design evolution of our CFB technology finally culminated with the development of the Generation 5 Calciner. The clear intent has been to advance the integration of the calciner flowsheet and to reduce overall plant weight, for example, by the implementation of a highly efficient pre-separation stage prior to the electrostatic precipitator which has significantly reduced the required size of the ESP without compromising the low dust emission figures. Furthermore, the air-lift system can be replaced, and only a lean pneumatic transport system for the ESP dust is required. At the same time, latest key equipment design developments have been implemented to improve the plant performance: These design improvements include the optimization of critical process equipment, all contributing to both an energy efficient as well as reliably stable plant operation.

Metso Outotec's Generation 5 alumina calcination technology has been successfully applied at 3 alumina refineries for a total of 5 units with a maximum capacity of 3500 tpd of alumina production.

Keywords: Alumina calcination, Capital cost, Circulating fluidized bed, Specific energy consumption.

1. Introduction

Calcination as the final step of the Bayer process is both, responsible for a very high fraction of the fuel and energy consumption in every alumina refinery as well as decisive for several critical alumina product quality parameters. With the change from floury to sandy alumina production in the beginning of the second half to the twentieth century and the main drivers mentioned before in mind, Metso Outotec and its predecessor companies developed and continuously improved the stationary calciner based on the circulating fluidized bed technology. With more than 60 applications worldwide, Metso Outotec's CFB calcination as the final step of alumina production accounts for a significant share of global smelter grade alumina production capacity.

The development of the fluid bed calciner began in the 1950s and 1960s and led to introduction of the 1st generation CFB calciner to the market in the early 1970. This marked a giant step for the calcination technology, as significant improvements of fuel efficiency had been achieved in comparison to formerly used rotary kiln plants.

Ever since the first application, the CFB calcination process is constantly reviewed and improvements have been applied. The evolution of the technology is divided in several plant generations, each of these are characterized by new key process improvements. The development culminated in today's 5th generation of CFB alumina calciners.

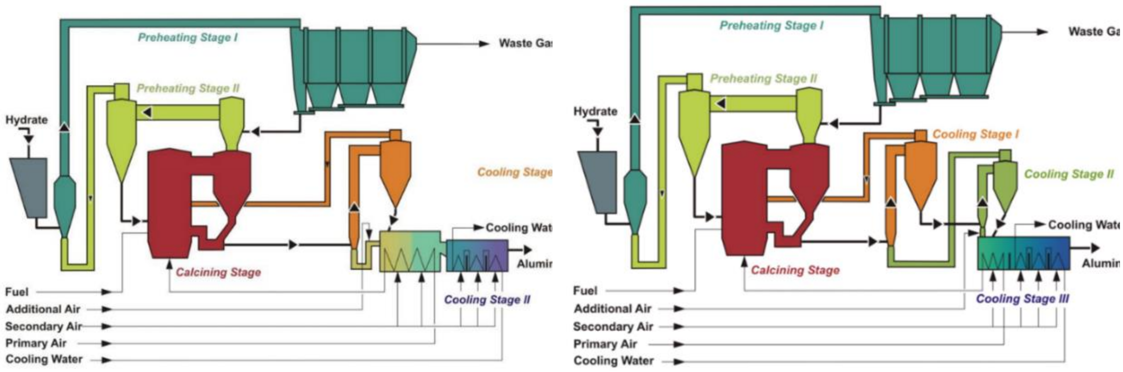

Figure 1. The CFB Alumina Calciner Flowsheet for Generation 2 (left) and 4 (right).

To exemplary reproduce the developments since the introduction of the technology, hereafter the key process design developments for generation 2 and 4 are described. Both flow sheets are displayed in Figure 1. Generation 2 marks the first evolution step developed in the late 1970s and applied throughout the 1980s at (among others) Nalco A & B, Worsley 1,2 & 3 and Alunorte A & B. The main features include 2 preheating stages, 1 cooling stage for secondary air preheating ad the fluid bed cooler for primary air preheating and product cooling. With further development in the 1990s and early 2000s, the 4th generation was launched with a second cooling stage with direct heat exchange and a joined fluid bed cooler design. This has been applied e.g. in Alunorte's plants D to G.

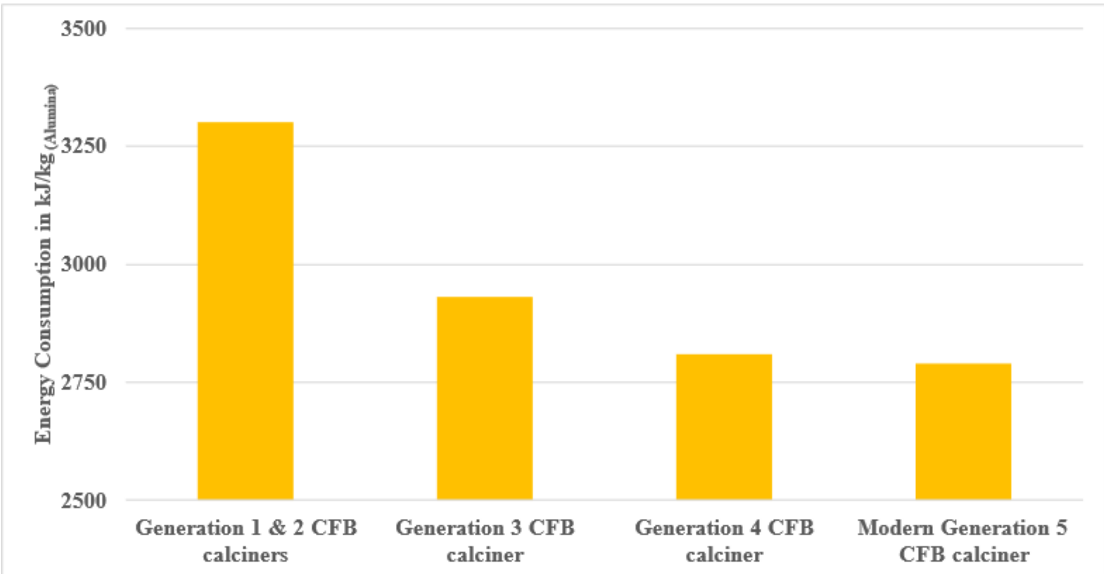

Figure 2. Fuel Energy Consumption for CFB calciners (adapted from [1]).

The constant improvement led to an outstanding development of the specific fuel consumption figures. Its decrease across the different plant generation is displayed in Figure 2 above.

This paper provides an overview on the latest generation of CFB calciners, which has recently been applied with 5 plants at 3 different alumina refineries.

2. Process Advancements for Generation 5 CFB Calciners

In addition to the main innovation drivers fuel efficiency and product quality mentioned above, the capital cost of the plant installation (or the specific cost per ton of produced alumina) is also a main criterion for the competitiveness and success of the offered process solution. Although the specific weight to capacity ratio has been decreasing throughout the development of the CFB calcination technology [2], this is a specifically important factor for the Generation 5 plant. A series of design changes and improvements, detailed in the sections below, successfully simplified the process, but also contributed to a more economical plant arrangement and total weight, benefitting also the sizing of critical equipment (e.g., the ESP).

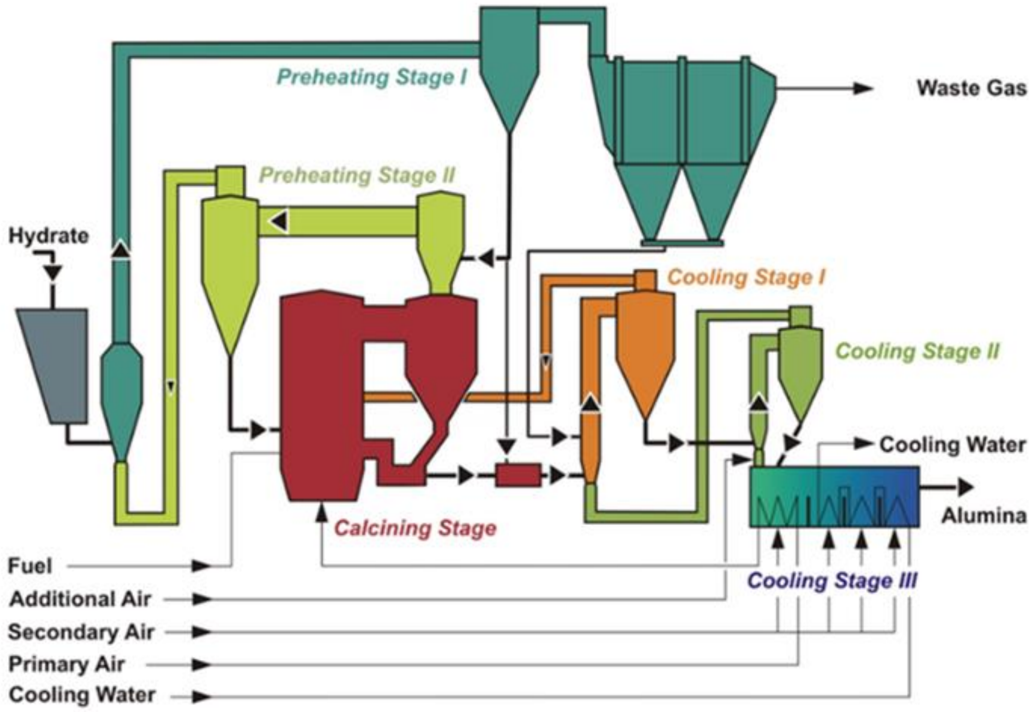

Figure 3. Generation 5 CFB alumina calciner flowsheet.

Metso Outotec's 5th generation of CFB alumina calciners is in principle based on the CFB process with two preheating stages and three cooling stages, incl. 2 direct heat transfer stages, consisting of a lift-duct – cyclone combination, and a fluid bed cooler with immersed heat transfer surfaces for primary air pre-heating and final product cooling with cooling water. See Figure 3 for an overview flow sheet.

Detailed information on key improvement and design concepts is given in the sections below:

2.1 Gas Solid Separation of Preheated Hydrate in Multiclones

In former plant generations, the dried hydrate material coming from the venturi preheater stage 1 was fully conveyed to the ESP and separated there from the off-gas (in a mechanical separation chamber followed by electric fields), requiring a relatively large ESP due to the high dust load. Furthermore, a transport system was required consisting of chutes, an air slide and an air lift system with a dedicated blower, provided high pressure air to transport the hydrate back to the high plant elevation of the second preheating stage (venturi and cyclone).

In the newly developed and applied concept for Generation 5 calciners, the main solid fraction is already separated from the off-gas by a battery of specifically designed cyclones (so-called multiclones) located on top of the plant in the duct from the venturi preheater stage 1 (where the wet hydrate feed enters the plant) to the ESP. The multiclones provide high efficiency separation of approximately 95 % of the contained solids, hence only a low load of fine dust is reporting to the ESP. The solids separated in the multiclones are collected in a hopper and directly feed via a seal pot to the adjacent venturi preheater stage 2. The close arrangement of multiclones, seal pot and preheating stage 2 saves significant amounts of space and material, as it makes the formerly used complex hydrate transport and lifting system redundant (compare the concepts of generation 4 & 5 in Figure 4). This potential benefit regarding a more compact and simplified plant arrangement was taken advantage of in the most recent calciner projects.

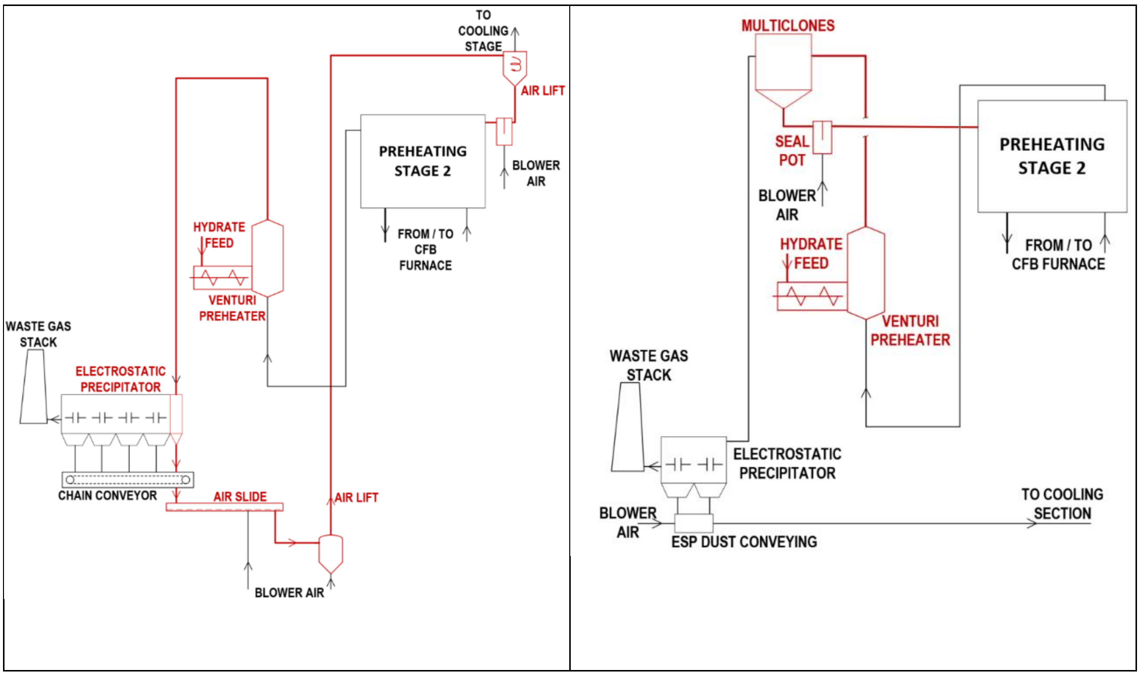

Figure 4. Preheating stage 1 - Comparison Generation 4 and 5.

2.2 Smaller ESP and Light Dust Transport System

The introduction of the aforementioned solid separation system significantly reduces the solid load in the off-gas to the ESP by approximately 95 %. This way, the requirements for electrostatic precipitation is reduced, hence reductions in ESP footprint, required collection area and also electricity consumption are possible, while still achieving modern dust emission regulation limits. In direct comparison to generation 4 plants, the specific ESP footprint is reduced by 25 % and more, depending on the specific dust emission limit. The size reduction will also materialize in a significant cost impact, as the ESP represents a specialized 3rd party equipment with a high cost fraction of the total plant.

The collected ESP dust is especially challenging for any conveying application because of high abrasiveness, due to a very small particle size and high alumina content. The conveying system applied in modern Metso Outotec calciners is equipped with a specially coated sealing device to handle the ESP dust. The dust is finally re-injected into the cooling section of the calciner.

2.3 Compact FBC with Optimum Air Flow Requirement and Heat Transfer

The modern fluid bed cooler offers efficient heat transfer and safe alumina cooling down to temperatures adequate for handling with conventional conveying systems, usually in the range of 60-80 °C. It consists of an air-cooled section, where primary air for the fluid bed furnace is preheated in heat exchanger tubes immersed in a fluid bed, and a subsequent water-cooled section where indirect heat-exchange with cooling water is cooling down the alumina. For the 5th generation of alumina calciners, the geometry of the fluid bed cooler has been optimized: The more compact design offers a smaller footprint and a lower demand for high pressure fluidization air, reducing the plant's specific consumption of electrical energy. Furthermore, the water tube bundle design has been standardized and can now be extracted from the side of the cooler, eliminating the requirement to open the cooler roof as in previous CFB calciner generations.

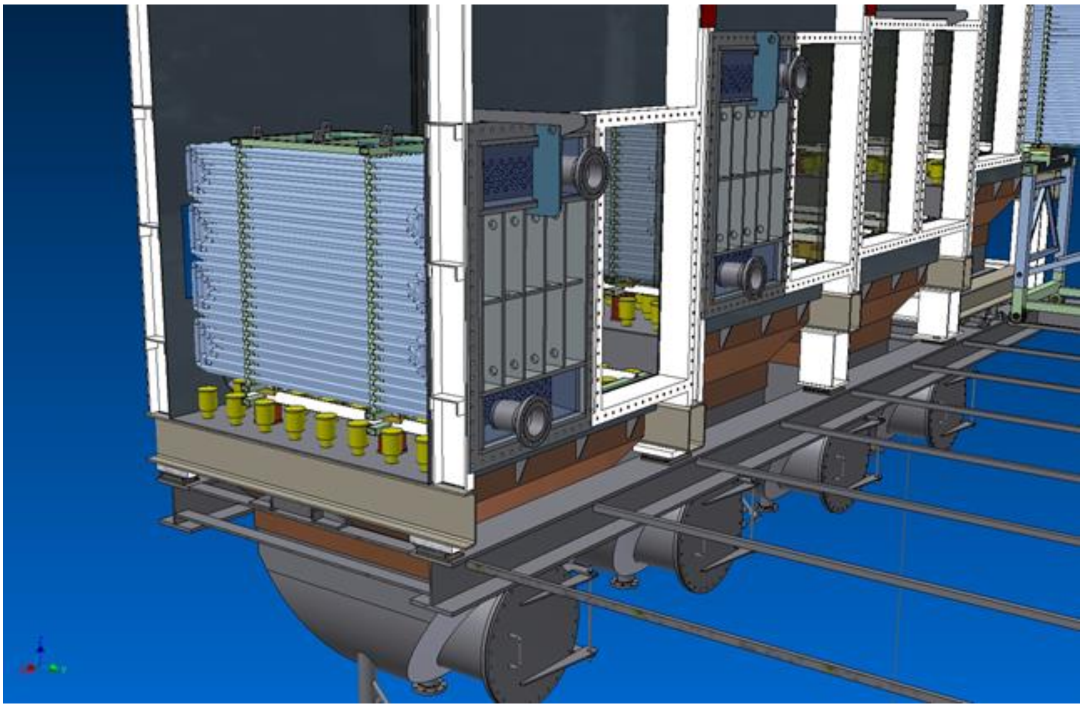

Figure 5. Fluid Bed Cooler 3D Model

2.4 Optimized Cyclone and Seal-Pot Design

Cyclones and Seal-Pots are among the most process critical plant components in the CFB calciner. Apart from the Multiclones (see respective section above), the typical generation 5 calciner flowsheet has 4 refractory lines cyclones for gas-solid separation as part of the CFB furnace, the pre-heating, and cooling stages. In modern generation 5 calciners, the cyclone design is revised with significant improvements with the help of state-of-the-art in-house computational models. These are used to evaluate and optimize the design of the inlet section, the cyclone barrel as well as the outlet vortex finder. This design methodology enables advanced separation efficiencies of up to 95 %, making a considerable contribution to fuel energy savings.

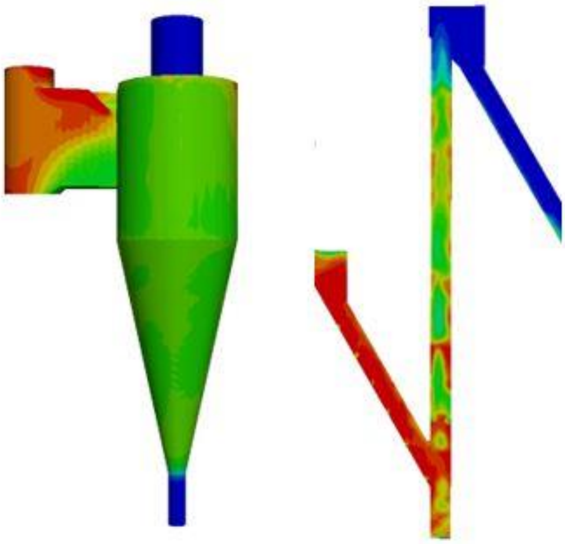

Figure 6. CFD simulation result examples for cyclones and seal pots

Seal-pots are used in fluid bed systems to transfer solids in between equipments with different operating pressure and provide sealing between those equipment. In a generation 5 calciner, there are 3 different critical seal pots, including the Multiclone-Seal-Pots, transferring solids from the Multiclone hopper to the venturi of the 2nd preheating stage; the secondary air Seal pot, transferring the solid product flow from the first to the second cooling stage for efficient secondary air preheating; and the Discharge Seal Pot, conveying the solids out of the cooler and sealing the high pressure in the fluid bed cooler against the ambient pressure at the discharge end. All these Seal-Pots are critical for the stability of the calciner operation. Based on Metso Outotec's experience with the operation of these equipment and with the help of computational models and simulation, optimum fluidization pattern and air-injection locations where identified. The modern Seal Pot design was then successfully implemented and proven to provide stable and reliable solid transport.

2.5 Hot Standby Mode – Continuously Running Preheat Burner

The generation 5 calciner is equipped with a preheat burner, that is designed to run continuously also during normal production operation of the plant. After successful preheating and ramp up of the calciner, the pre-heat burner will remain on low load.

In addition, the combustion air for the preheat burner is supplied by a dedicated preheat-burner fan. Hence the burner operation (Air-Fuel ratio, burner load) can be controlled independently from the main fuel combustion for alumina calcination. This offers the possibility to implement a so called Hot-Standby operation mode. Depending on the severity of the trip condition, the plant can be tripped into this new fail-safe mode. Here all equipment (incl. blowers, main fuel supply) will be tripped, but the preheat burner and the preheat burner fan will stay in operation. This operation mode allows for small, required maintenance works without high temperature drops in the furnace. The calciner can quickly be taken back into operation, as long reheating periods, up to 24 hours depending on the duration of the production break, are not required. The gain in flexibility will shorten production stops due to maintenance and limit the stress for the refractory as the temperature in the furnace can be kept stable.

2.6 Process control and Safety

All major operational procedures of the generation 5 calciner are highly automated and covered by automated sequences, including plant purge, preheat burner start, preheating, main fuel start, cool-down and hot-standby. During alumina production, advanced control methodologies can be applied to optimize air, fuel and hydrate flows to sustain most efficient calciner operation.

As per industry standard of the international electrotechnical commission (IEC) 61511 and safety requirements, all safety functions have been identified and assessed in a Hazop study, and together with the burner functionalities are implemented in a Safety instrumented System (SIS), running in parallel to the distributed control system (DCS) of the plant. The SIS is monitoring all critical parameters of the process and shuts down the process when the inlet parameters or the conditions inside the process are outside the safe operating range. This will bring the plant to a safe status and prevent dangerous situations.

3. Generation 5 CFB Calciner – Operation of Reference Installations

Metso Outotec's 5th generation alumina calciner has been applied with 5 installations at 3 different alumina refineries in a range of plant capacities from 500 to 3 500 tpd of alumina production. The most recent installations are 2 units at EGA's Al Taweelah alumina refinery located in the United Arab Emirates.

The two plants were successfully commissioned as part of the greenfield refinery in 2019 [3]. In 2020, the Metso Outotec calciners contributed to reaching the name plate capacity of the refinery of 2 million tons of alumina after only 14 months of operation [4]. In the following year 2021, EGA reported a continuous 3-month period of operation at or above the name plate capacity

Figure 7. Two generation 5 CFB alumina calcination units.

The successful experiences from our operating installed base of generation 5 calciners demonstrates the value of Metso Outotec's CFB calcination technology to our customers. The design improvements and the associated savings in capital expenditure combined with an outstanding performance and reliability create a measurable benefit and proves the generation 5 calciner to be a successful development step.

4. Outlook and Options for More Energy Efficient Alumina Calcination

Metso Outotec is continuously developing its CFB calcination technology by considering lessons learned from ongoing and completed plant projects and also valuable customer feedback from years of operation of our CFB calciners. Also, we keep identifying and implementing the latest developments in plant engineering and global technological trends.

In addition to the development of the fundamental calciner flowsheet and design, we offer further options to enhance the calciner performance: The application of digital tools such as advanced process controllers are an important pillar here. Independent of the plant generation, this can further boost operational stability, energy efficiency and product quality, as described by [6], based on experiences with at a CFB calciner in Brazil.

Furthermore, there is the possibility to further enhance the CFB calciner flowsheet by integrating Metso Outotec's Hydrate Drying technology, which uses heat in a range between 150-200 °C from the fluid bed cooler section to pre-dry the wet hydrate feed. This concept can further reduce the specific fuel energy consumption by up to 90 kJ/kg of alumina [7] and it is also possible to be integrated into a generation 5 CFB calciner.

In conclusion, the Metso Outotec CFB alumina calciner is under constant evolution to always offer the most competitive alumina calcination technology to our customers. The successful installation, commissioning and operation of the 5th generation of CFB calciners marks an important step and underlines this evolution.

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