ISSN: 0379-5462
IPPTA: Quarterly Journal of Indian Pulp and Paper Technical Association
Vol. 37, E1, 2025, p. 72-75

# AI Enhanced Ozone Production for More Efficient Bleached Pulp Production

**Alexis METAIS**
*Pulp & Paper Key Account Manager*
*Xylem, France*

**Abstract:**

*Ozone production is a fully automated technology capable of adapting automatically to the bleach plant's needs. Ozone generation and ozone bleaching already involve several online measurements to provide reliable and cost-competitive operation. But AI now offers new perspectives. The article introduces the basics of ozone generation, state-of-the-art ozone generation technology, and discusses how automation and AI make ozone bleaching more efficient. In particular, it addresses the cases of adjusting ozone production to pulp parameters measured online and improved preventive maintenance thanks to AI.*

**Keywords:** *AI, ozone, bleaching, chemical, brightness*

**Introduction**

AI (Artificial Intelligence) already allows for the optimization and redesign of equipment and processes, as well as the simplification of operations. It can help every aspect of pulp and paper mills, including pulp bleaching and chemicals supply. This article addresses how AI participates in the first step of modern pulp bleaching: the Z-stage. It introduces the basics of ozone generation and how AI supported development of the latest generation of ozone plants, describes modern automation of the ozone plant, and how AI makes and will make ozone bleaching more efficient.

**I Ozone Plant Design**

For pulp bleaching, ozone demand is 2-6 kg/adt at a concentration of 12-13% by weight. Ozone production requires:

- Oxygen because ozone is made of three oxygen atoms

- Electricity to create the oxygen plasma where some oxygen molecules $O_2$ break into oxygen atoms (O) further combining with oxygen molecules to form ozone $O_3$ (Figure 1)

- Cooling water to remove heat

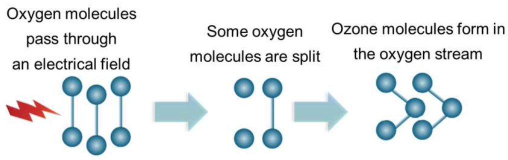


*Figure 1: Ozone Generation Principle*

Ozone formation takes place between two electrodes isolated from each other by a dielectric made of glass (or ceramic for older technologies) and by a small gap. A high voltage, middle frequency, unilaterally grounded alternating current is applied to the electrodes. Oxygen flows through the gap, resulting in ozone generation in the electrical field.

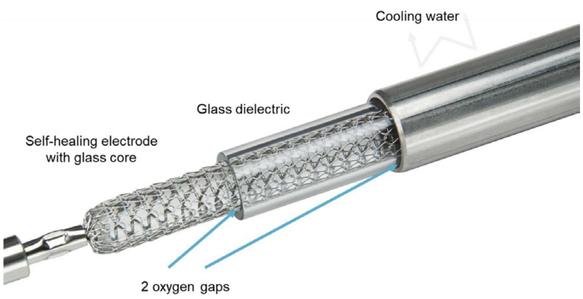


*Figure 2: Electrode Design*

Wedeco ozone generators consist in a shell & tube heat exchanger vessel filled with thousands of electrodes. Electrodes are fed into the generator vessel as per Figure 3, connected to the high voltage, and the generator is closed. Electrodes are not consumables and are therefore guaranteed for 10 years. Ozone generators do not need to be opened, even for standard maintenance. This limits the risk of any moisture intake (the presence of water should be avoided at the ozone generation location.

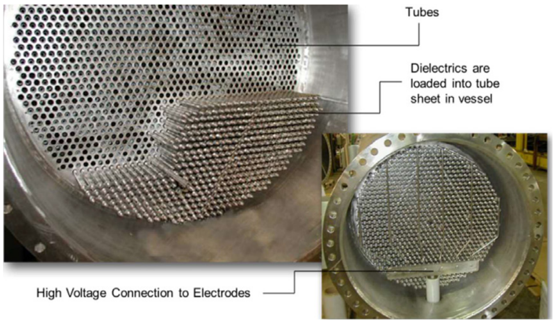


*Figure 3: Generator Assembly*

The ozone generator comes along one or two power supply units as per Figure 4. Power supply units house the power electronics and controls, which allows to generate the high voltage electrical field between the electrodes.


*Figure 4: Power Supply Unit and Ozone Generator*

Ozone technology is then mainly a question of fluids (gas and water) and electricity management. Xylem released at the end of 2024 its new ozone generation technology. It offers 5% lower electricity consumption to pulp producers than the earlier generation, already the market leader. This new development is partly the result of the use of AI-enhanced tools: AI was used to improve design of the cooling water flow after using CFD (Computational fluid dynamics) tools.

**II Ozone & Bleach Plants Operation**

A PLC (Programmable Logic Controller) controls the power supplies and the entire ozone generation process. It ensures safe operation, provides clear information, and communicates with the pulp mill DCS (Distributed Control System) without the need of any operator. Ozone production is a fully automated technology capable of adapting automatically to the bleach plant's needs. Looking at the generator's inlet, the oxygen line (Figure 5) is equipped with a set of valves and:

- a pressure switch (01.0.20) to monitor the oxygen inlet pressure

- a temperature transmitter (01.0.25)

- a dew point monitor (01.0.30)

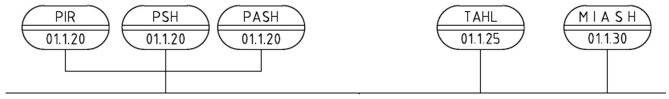


*Figure 5: Monitoring Elements on the Oxygen Line*

Overall, and not detailing every line, the PLC checks the following functions:

- gas flow parameters
- ozone concentration
- produced ozone mass
- ozone generation unit parameters (control of transformer operation, frequency converter, temperature)

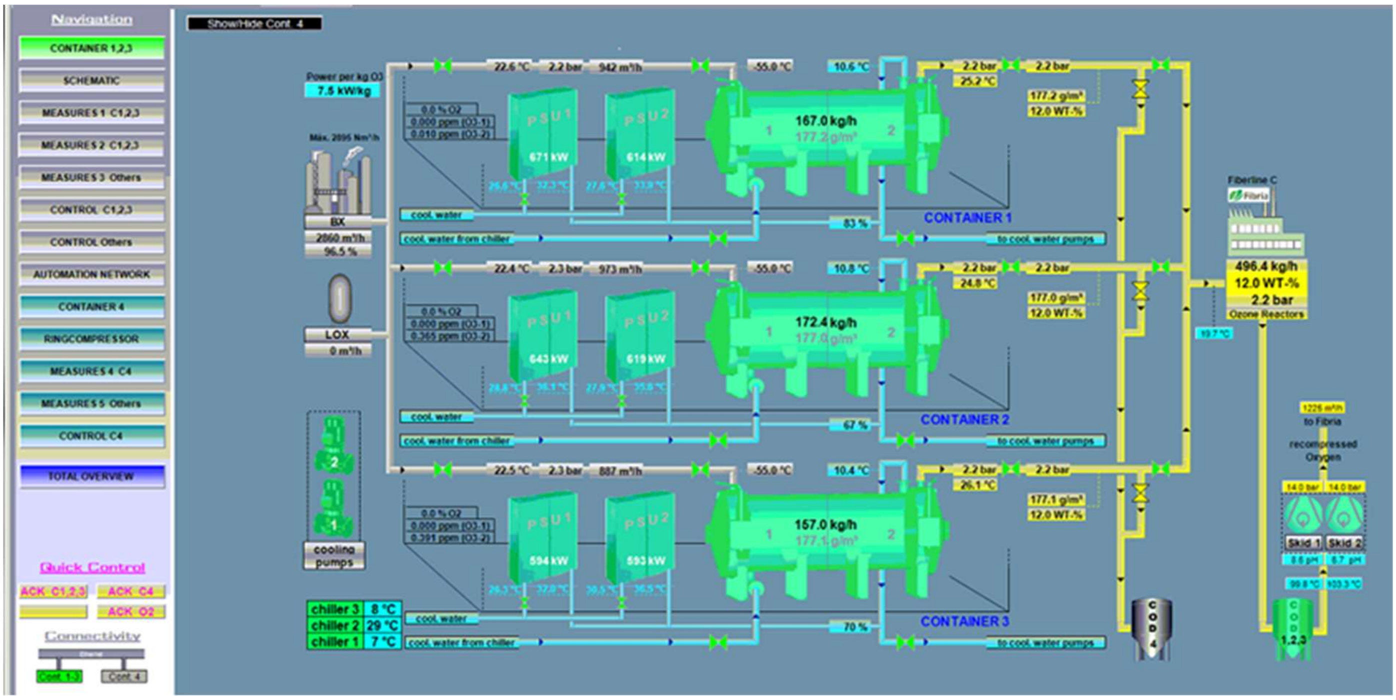


*Figure 6: Example of a PLC Interface (Real Case)*

- ambient air measurements
- oxygen pressure
- cooling water flow
- cooling water temperature
- power consumption
- main frequency and voltage

Figure 6 shows an example of ozone plant PLC with 3 generators.

The system sends alarms and automatically shuts down if reaching certain levels of specific parameters (in case of too low or too high pressure, too high moisture content in oxygen, etc.). For example, if ozone concentration reaches 0.1 ppm in the ambient air, an alarm starts with a horn and a flashlight. If ozone concentration keeps increasing and reaches 0.3 ppm, the system automatically shuts down. Switching off the system instantaneously stops ozone production: indeed, no ozone is formed without supplying electricity to the electrodes. From this viewpoint, ozone generation is safer than production of many chemicals involving unstoppable chemical reactions.

For the same reason that ozone production depends on the power input, it is extremely easy and fast to adjust ozone production to the bleach plant's needs. Ozone production reaches new setpoints in seconds without wasting any time or resource.

In practice, the mill DCS automatically adjusts ozone generation to a selected bleaching parameter setpoint measured online (Kappa number, viscosity, or brightness), residual ozone concentration in the off-gas, or with a special supervisory program optimizing chemical costs and final bleached pulp quality. The latter solution, used at least in one European pulp mill, can use AI, especially with machine learning and data analysis. The agility of ozone production is particularly important for dissolving pulp production where ozone accurately adjusts pulp viscosity to the targeted grade specifications.

However, in many cases the ozone plant simply operates at full load, without any adjustment, as ozone is the most cost-effective bleaching chemical on site. Bleaching is then managed by adjusting chlorine dioxide and hydrogen peroxide doses.

**III Maintenance**

Xylem started last year Ozone Vitals, an upgraded SCADA (Supervision Control and Data Acquisition) providing our service teams with pro-active advice for the maintenance of the ozone plants. It is in operation in one European pulp mill. It is available remotely, on computers and mobile phones, to allow for the fastest reaction. The example below (Figure 7 and Figure 8) shows an alert for high dewpoint (moisture must be avoided in the generator vessel) and specific electricity demand.

Ozone Vitals utilizes sets of data points related to the ozone system's health status. These are monitored and embedded into algorithms to drive alerts and highlight any anomalies. However, this still needs human interaction and assessment to conclude severity and decide on actions. This is carried out by Xylem-operated control centers. In the future, Ozone Vitals will include Machine Learning based-anomaly detection.

But Xylem has already started implementing InSkill.ai maintenance tools for simpler products than large ozone systems. It is designed to encapsulate the knowledge of an aging workforce for the future, assist technicians in repairing or replacing products, and more. For example, in case of failure, the copilot will guide local operators on the phone (Figure 9) without the need to contact a Xylem expert. It is a question of a short time before this is implemented in Ozone Vitals.

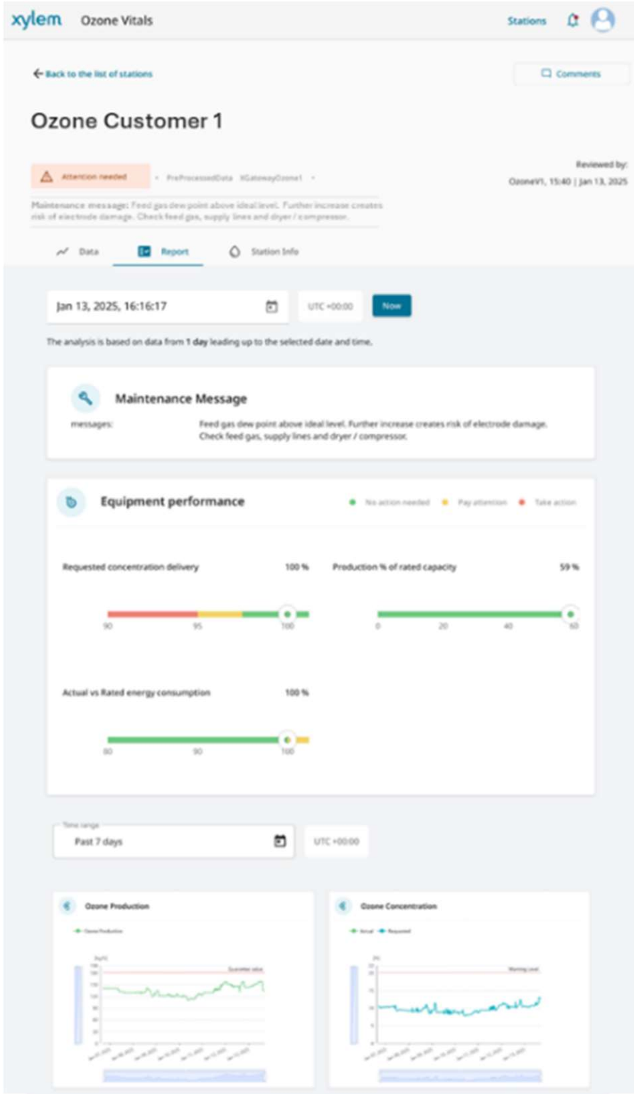


*Figure 7: Ozone Vitals Interface (Real Case)*

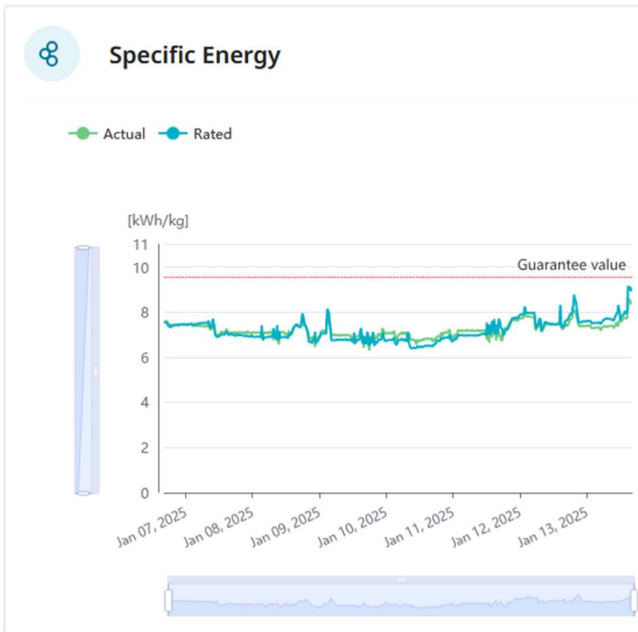


*Figure 8: Specific Energy Demand (Real Case)*

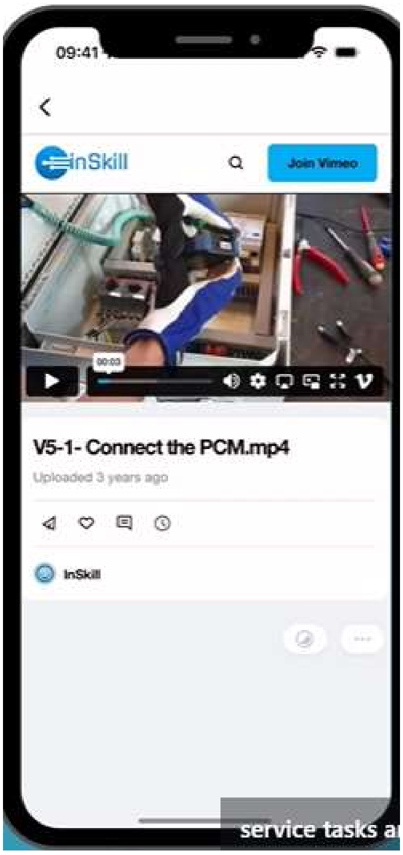


*Figure 9: Example of a Maintenance Copilot on Mobile Phone*

## IV Better Understanding Chemistry

Lignin structures including conjugated double bonds such as carbonyl groups (C=O), ethylenic groups (C=C), and aromatic rings are the main chromophores removed in the bleach plant. Bleaching chemistry is better understood nowadays, at least from

**Table 1. Bleaching Chemicals and their Reactivity Towards Lignin Structures [1]**

| Olefinic and aromatic groups | Free phenolic group and double bonds | Carbonyl groups including quinones |
|---|---|---|
| $Cl_2$ | $ClO_2$ | ClOH |
| $O_3$ | $O_2$ | $H_2O_2$ |

the general viewpoint. For example, Table 1 shows with which chemical structures the main bleaching chemicals react.

Reaction kinetics are also known for the main typical lignin structures. For example, it is now well established that ozone reacts 1,000 times faster on C=C and phenolics than on cellulose [2].

But is it possible to better know by-products of pulp bleaching without trying to measure hundreds or thousands of molecules in pulp, condensates, and off-gas? Is it possible to define the most appropriate bleaching chemicals mix for each specific pulp?

Frankly, it is still impossible at this stage. But AI-enhanced chemical reactions simulators will help in the coming years to better understand pulp bleaching chemistry. There is still development work ahead on this topic: AI is a tool that needs to be trained.

## Conclusions

Improvements in technology, operations, maintenance, and overall process understanding are speeding up thanks to development and implementation of Artificial Intelligence. AI has been successfully implemented to improve ozone production technology and enhances the cost of the bleaching chemicals mix for the desired pulp quality by adjusting on real time the dosing of bleaching chemicals. In the future, AI will also help to improve maintenance efficiency and better understand pulp bleaching chemistry. We are only at the beginning of a new revolution that will make the pulp and paper industry even more profitable and sustainable.

## References:

1. *Lachenal, D. Muguet, M. "Degradation of Residual Lignin in Kraft Pulp with Ozone Application to Bleaching", Proceedings of the International Symposium of Wood and Pulping Conference, pp 107-112, Melbourne, Australia, April 28, 1991*
2. *Lachenal, D. "Ozone has the Potential of Becoming a Universal Bleaching Agent", Proceedings of the EFPG Days 2005, Grenoble, France.*