A Microwave-heated Waste Drying System Can Provide a Ten-fold Reduction in Liquid Waste Processing Time

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A Microwave-heated Waste Drying System Can Provide a Ten-fold Reduction in Liquid Waste Processing Time

a report by

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Microwave-In-Drum-Drying (MIDD)

A New Volume Reduction Process for Radioactive and Toxic Liquid Waste

Liquid radioactive waste arises during the regular operation, downtime or shutdown processes of a nuclear power plant (NNP) and other nuclear facilities. In NNPs these liquids are, as standard, enriched using a circulation evaporator to a dry substance content of up to 20wt%. These concentrates must undergo an additional drying/concentration processes prior to be accepted for final disposal.

The concentrates must be dried in a separate drying plant and placed in a receptacle (e.g. a 200-litre drum) for the final disposal. Common techniques include using a rotary film evaporator; other techniques include evaporation at reduced pressure by external heating. The concentrates must be enriched up to a dry substance content of approximately 80wt% to get a solid salt block for final disposal. The hardening of the hot waste product to a solid salt block occurs during the cooling process. The residual (20wt%) water is bound in the crystal during the cooling step.

For several reasons it is more economic and safer to apply the drying procedure directly inside the final disposal container. The most common procedure is to heat up the wall of the drum from outside with strip heater. However, heating the outside of the drum leads to a temperature gradient between the drum wall and the drum centre. The highest temperature is achieved at the wall of the drum, leading the solidification process to start there and resulting in the formation of a salt layer there. This causes a reduced heat conductivity from the outside to the inside (liquid solution) and coresponding the thermal resistance increases. As a result, the solution in the centre of the drum generally does not completely crystallise, leading to longer process time and the need of considerable higher outside temperatures. The outside temperatures, however, are limited by the temperature resistance of the materials and process conditions. A actual time to dry a drum with the outside heating method is about 85 days.

A New Solution

As a result of a long-term development programme conducted in conjunction with the German nuclear industry, Linn High Therm has patented a procedure using microwaves to reduce the liquid content in radioactive liquid wastes. This process, microwave in drum drying (MIDD), is an evaporation-driven crystallisation process.

In co-operation with the German nuclear industry, Linn built a pilot MIDD plant. Several test runs with defined wastewaters (non-radioactive simulated solutions) have been performed successfully, which results are presented later.

The most important advantages of the MIDD process compared with the outside heating process include the following:

- Microwaves generate the heat directly in the solution over the complete volume of liquid layer.
- Minimal temperature gradients and homogeneous crystallisation.
- Process times that are 10 times shorter than the more common electrical heating methods (see *Figure 1*).

The MIDD Process

The MIDD process is semi-continuous and starts with feeding an initial amount of liquid waste into the final package (e.g. drum) while the drum is being preheated by induction heating. Then microwave heating is engaged and more liquid waste is continuously fed by a dosing pump. During evaporation the drum and the microwave applicator are kept under a slight vacuum. The exhaust steam is suctioned off by a fan. An aerosol separator removes entrained dust particles and liquid drops. The feed steam is condensed in a water-cooled heat exchanger, and the condensate is collected in a separate vessel. At the end of the process the dosing pump is stopped, and the microwave heat evaporates the rest of the liquid inside the container. After cooldown of the

Figure 1: Comparision of Process Times for the MIDD System and Electrical Drumheating Systems

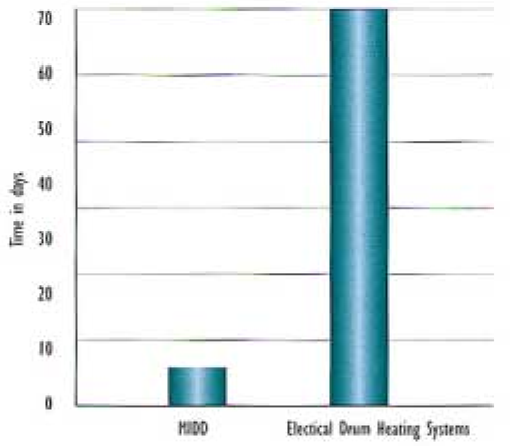


Figure 2: The MIDD Process

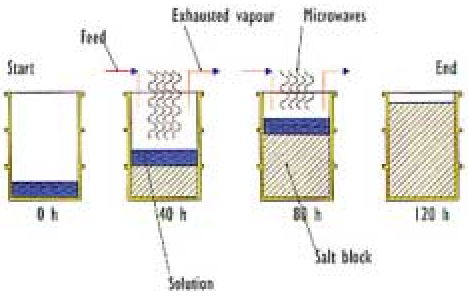
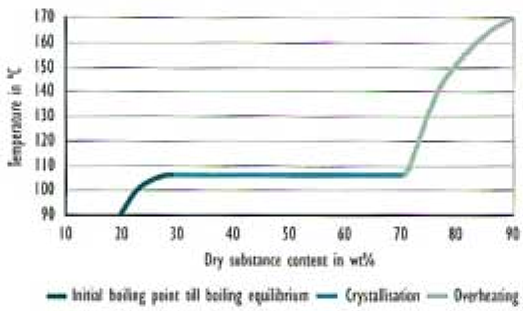


Figure 3: Temperature Diagram



drum and material the container is replaced by an empty one, and the cycle can begin again.

Generally, the condensate is discarded, and the solid waste in the container is ready for direct disposal. During the process a closed circuit cooler ensures a constant low temperature of the cold side of the heat exchanger, which guarantees that the exhaust steam is condensed completely. To control the MIDD plant, a PLC system (Simatic S7) is used. All in-and outgoing mass-flows are measured, so that the mass balance of the evaporation process is ensured. In addition, the pressure, the temperature and the liquid level inside the container are measured continuously. Together with the other control parameters, the sickness of the liquid layer above the dry salt layer inside the container is determined, which is necessary for a controlled crystallisation. All data are logged in a seperate unit. The data can either be shown at a 12-inch touch-screen at the control panel or printed from a connected external personal computer and printer. The MIDD process is visualised at the touch-screen control panel.

Technical Detail

The microwave in drum drying is a semi continuous crystallization process (see *Figure 2*). Before the start of the microwave heating a certain amount of solution has to be pumped into the recipient drum.

Then the solution is heated by microwave treatment. The microwave power has to be controlled with respect to the increasing boiling point of the liquid during the evaporation process because of rising salt content. At a dry substance content of about 30wt% the solution is oversaturated, and the boiling point, as well as the concentration, stays constant. At this point, the content of the solid phase is steadily growing. The thermal balance is reached at approximately 100°C and a reduced pressure of around 900 millibars absolute pressure. After the liquid waste feed has been stoped, the homogeneous liquid surface over the solid product disappears. This causes the product surface to be heated too fast, because of the low thermal conductivity and capacity. The boiling curve is shown in *Figure 3*.

The 70wt% dry substance content is calculated from the mass balance. The remaining weight percentage of water is being bound as crystal water. The residual moisture content is 0.2wt%. A pyrometer, installed to prevent overheating of the solution, detects the temperature of the product surface.

The controlled and determining process parameters are the microwave power and the feed flow. The grade of the drying strongly depends on the exact process control. The liquid waste contains salts that form crystal complexes with water at low temperatures. A 17wt% solution containing aqueous sodium sulphate solution and other additives can be used as a reference solution. Sodium sulphate crystallizes in the Glauber's salt ($Na_2SO_4 \cdot 10H_2O$) modification at low temperatures of approximately 32°C. To achieve a better drying, the solution should not be cooled below this temperature during the process. The evaporation-driven crystallisation goes on continuously, until the drum is completely filled with dry waste product. ■

A version of this article containing additional figures can be found in the Reference Section on the website supporting this briefing (www.touchnuclear.com).