Kevin T. Higgins, *Senior Editor*

The upside of cavitation

Product heating and mixing are being transformed with technology that makes cavitation a positive force.

Tony Mathis, technical manager-process, SPX Flow Technology

As a general rule, cavitation is an event that makes food engineers cringe, an anomaly associated with product degradation and hammering in pipes and pumps. But the formation and collapse of small bubbles is essential in marine propulsion, and a number of design engineers are mastering the explosive power of air bubbles and turning them into a positive force in mixing, heat transfer and other food manufacturing processes (see "Supersonic processing," *Food Engineering*, August 2005).

Over a decade ago, Hydro Dynamics, a Rome, GA, engineering firm, developed and patented the controlled cavitation technology. The initial focus was on rapid steam generation but quickly changed to scale free heating and mixing fluids or a mixing of a fluid and a gas. Chemical processes, paper-and-pulp applications and a few sanitary applications were pursued by Hydro Dynamics, but engineers at SPX Flow Technology saw an untapped potential for controlled cavitation in food and beverage production. They invited their Hydro Dynamics counterparts to exhibit their Shockwave Power Reactor at a food industry trade show in 2005. That led to some successful food applications and eventually a licensing agreement between SPX and Hydro Dynamics. At last year's PROCESS EXPO show in Chicago, SPX introduced an APV Cavitator customized for food applications.

More than a year's worth of research and development efforts made at the SPX innovation center in Silkeborg, Denmark, preceded last fall's launch. The core technology was coupled with SPX's line of APV brand centrifugal pumps. In August of last year, Tony Mathis, technical manager-process with SPX, became involved to facilitate the launch of the Cavitator. A graduate of the University of Louisville with a BS in chemistry and MS in industrial engineering from the university's Speed Engineering School, Mathis has specialized in heat transfer applications for 30 years, primarily in food and beverage. Much of his professional experience has been with scraped-surface heat exchangers. He has served as a product manager, senior project engineer and senior applications engineer. Over the years, Tony has had the opportunity to work with several SPX brands including Votator, Waukesha Cherry-Burrell, Gerstenberg-Schroeder and APV.

FE: How does the system differ from conventional heating and mixing systems?

Mathis: The overall concept is quite innovative. A specially machined stainless steel rotor, precisely positioned within a close clearance chamber spins at a high rate of speed. Orifices which are located along the periphery of the rotor, act as miniature pumps. The rotor and the cylindrical wall of the chamber form the cavitation zone. Small bubbles form and when the bubbles implode, a shock wave is created, causing intense mixing and rapid heat transfer because of the high rpm of the rotor. Basically, there's a mixing side and a heating side to the technology.

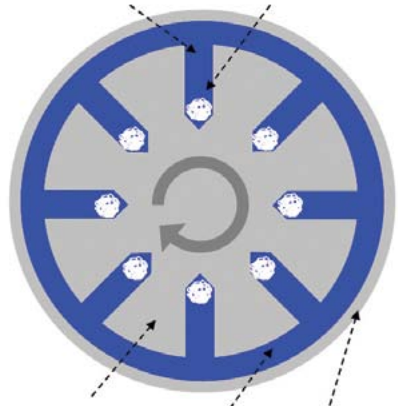
FE: Does the size of the bubbles dictate the degree of agitation and heat transfer?

Mathis: Bubble size is not important, but as rotor speed increases, the number of bubbles also rises, and that dictates process intensity. The important point is that all of the energy transfer and mixing occurs within the zone without any heat transfer surfaces, so there is virtually no potential for fouling or burn-on.

The rotational speed of the rotor is the control point along with flow rate and residence time. The number and size of the holes also dictates performance, and they vary depending on the size of the unit. The focus of the work in our innovation center was on making the process predictable and scalable for food and beverage applications.

FE: How was the technology initially applied?

Mathis: The inventors' original intent was to make steam and hot water. Later Hydro Dynamics' engi-



A rendering of the cavitator's cross section depicts the rotor and housing (grey areas), the liquid being processed (blue) and the cavitation bubbles (white) that are formed and then collapse to produce shock waves to emulsify and transfer heat to the liquid. Source: SPX Flow Technology.

neers devised a more effective method of oxidizing more sulfur in black liquor, which is a byproduct of cooking wood chips in the paper and pulp process. Black liquor can fuel boilers, but sodium sulfide concentrations can be 40 grams per liter or higher. The conventional approach to reducing pollutants is to oxidize sodium sulfide molecules in the black liquor and render them inert by introducing air bubbles and agitation. The problem is that the size of the bubbles limits the bubble surface area that is in contact with the black liquor, thereby reducing the probability that an oxygen molecule will come in contact with a sodium sulfide molecule and oxidize it. The bubbles also tend to concentrate in pockets, resulting in uneven distribution.

To reduce the time and energy needed to oxidize the black liquor, Hydro Dynamics designed a method of entraining air in the cavitation device, where a fast-spinning rotor could create microscopic cavitation bubbles in a cavitation zone. The collapse of these bubbles creates violent and continuous cavitation within the zone. Because much smaller bubbles can be formed, there is a higher likelihood that oxidation will occur because the aggregate surface area of the air bubbles is much greater.

Hydro Dynamics also recognized the technology had applications in biofuels, petroleum processing, environmental applications such as dissolved air flotation, and food processes such as homogenization and mixing, and the chemical industry.

FE: Has the technology already been applied to food?

Mathis: The technology generated quite a lot of interest when we invited Hydro Dynamics to exhibit with us at a trade show seven years ago. That led to some work in liquid egg pasteurization. Those applications were the most common installations done before we struck the partnership with Hydro Dynamics. We have received very enthusiastic feedback from egg processors. There's less product degradation during heat transfer, resulting in fluffier omelets and other quality improvements.

FE: What changes did your engineers introduce?

Mathis: The biggest one was the use of a close-coupled assembly based on our centrifugal pump technology. The shaft on which the rotor revolves is just an extension of the motor shaft, which results in a more compact design. All the seals and other power end components come from our existing manufacturing capabilities and are 3A certified. We expect to have 3A certification for the entire system very soon.

At a minimum, Hydro Dynamics's components were stainless steel, and their chemical work often required higher quality alloys, such as Hastteloy™. If an application required it, we could substitute some of those alloys for stainless steel.

FE: Are there any advantages with this technology over a scraped-surface heat exchanger?

Mathis: The rotating blades of a scraped-surface heat exchanger provide great heat transfer without fouling, but it does have limitations with heat sensitive fluids, such as with milk. The shaft body becomes hot by conduction, and you cannot mechanically clean it during operation to prevent burn-on. Also, the blades and the scraped surface need to be honed and refurbished from time to time. With the Cavitator, a single mechanical seal is the only component requiring maintenance, and the shock waves act as a self-cleaning mechanism.

It really depends on the specific application to determine which technology is the most economical to use. A scraped-surface heat exchanger heats using steam, which is very economical but normally less efficient. The electric motor coupled with the Cavitator is constantly in the 90% to 92% efficiency range, but can be a more expensive energy source. So as you can see, it depends on the specific material you are trying to process.

FE: What throughputs are possible with the Cavitator?

Mathis: The smallest unit was displayed in the SPX booth at last year's PROCESS EXPO in Chicago. It had a 50 HP motor and a 12-inch diameter rotor. It processes at a rate of 5 to 15 gallons a minute, depending on the product and the effect desired. A more typical unit has a rotor with a 14- or 16-inch diameter and would have a nominal rating of up to 90 gallons a minute. As the size increases, there's a spike in the amount of energy required. Some units require a 150 HP motor.

FE: What types of food would most benefit from mechanically induced cavitation?

Mathis: We see a lot of potential in dairy, where you have many heat-sensitive materials, and applications like mayonnaise, where traditional process technology may have some limitations. A colloid mill is usually required to complete mayonnaise's emulsion and create a stable product with sheen. The Cavitator can be more effective at producing a range of styles because its intense mixing abilities via shock waves can be adjusted simply by changing speed rather than by mechanically adjusting a clearance. It's a different type of shearing action than with impeller blades or close clearance shear devices.

Adding color or flavor uniformly to a highly viscous material is a very difficult thing to do, but the Cavitator can do it. It also hydrates powders into a liquid very well. In one application, a company was mixing a thickening agent into a fluid, and often there were big "fish eyes" of unhydrated materials that forced line shutdowns. Utilizing the Cavitator, a perfect blend without any fish eyes was achieved in one pass, and the throughput of 120 gallons a minute was much faster. ❖