The Dense Medium Separation of Carrots

Back in 1985 the largest cannery in Belgium, NV Talpe, had asked me to design a separator that would remove extraneous material from freshly harvested carrots. Over the years this cannery had just about given up all hope of isolating carrots from the endless variety of contaminates that might surround them. Two dynamic effect separators, followed by a sophisticated color-sorting apparatus, followed by a group of 20 women, all failed to deliver a clean carrot. It was clear to me that the carrot industry in Europe demanded a radically new technology that would not generate separation errors and would deliver a thoroughly consistent and predictable product.

This quest for a perfect separation was rendered even more complex in view of the tonnages so often demanded by this industry. Some carrot processing facilities were set up to handle 60 tons per hours in a single line, and they were not in a position to down-size or modify the tonnages they were accustomed to handle.

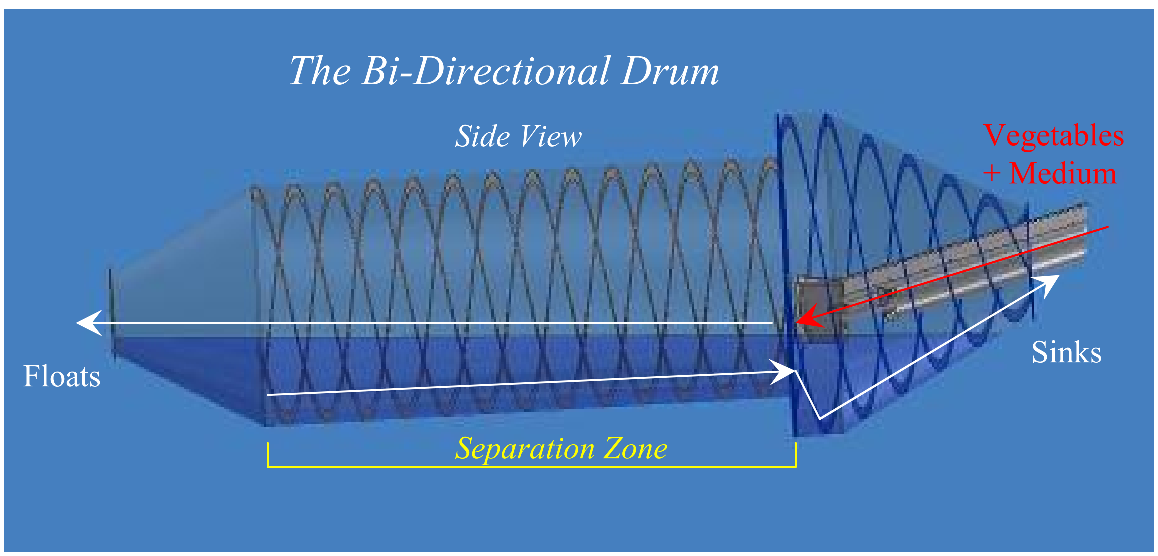
My background in mineral separation put at my disposal a broad field of techniques and gadgets to separate mineral from mineral or maceral from mineral, and there was only one process that stood out from all the rest: dense medium separation. Here we find the dynamic of a quiescent bath where the density of water is changed by means of fine particles in suspension. At first glance, nothing could be simpler: one fraction floats, while the other fraction sinks. But at high tonnages even the best dense medium separators generate errors, and where should one go to find the suspension materials needed to change the density of water in a carrot application?

Twenty years ago all dense medium separators on the market were mono-directional, with floats and sinks reporting on the same side of a relatively short horizontal drum. This concept was seriously flawed for at least four reasons. 1) At the critical moment of introducing solids into the drum, floats are easily buried with sinks and cannot find their way to the surface of the bath. 2) A typical dense medium bath is relatively deep, and this makes it difficult for the suspension particles to remain in suspension. If a medium is not stable, we find water at the top of the bath and a dense sludge at the bottom of the bath, and of course, in this stratified liquid, no separation takes place. 3) The mono-directional bath is quite short, and it happens quite often that before a particle can float or sink, it is already out of the bath. 4) In the conventional dense medium drum, the curtains needed to prevent floats from crossing over with sinks are located in the separation zone and, due to turbulent fluid movement in the vicinity of these curtains, floats are easily sucked under these curtains and report with sinks.

Instead of the usual mono-directional drum, I opted for something quite different: a bi-directional drum with floats moving in one direction and sinks moving in the opposite direction (see drawing on next page). No one in dense medium technology had ever attempted this, and this radical shift in design set the stage to address the four major flaws outlined in the previous paragraph. 1) At the critical moment of introducing solids into a bi-directional drum, the medium together with solids is injected over a broad three dimensional plane, making it almost impossible to bury floats with sinks. 2) Instead of a deep bath, I chose a shallow bath, and the gentle action of the sinks scrolls pulling underneath the bath provided just the right amount of movement to keep the suspension medium stable. 3) I extended the length of the separation zone, greatly increasing the residence time of a particle in the bath, and thereby making it impossible to find sinks in floats. 4) And finally I situated the curtain that prevents floats from crossing over with sinks completely outside the separation zone, making it impossible to find floats in sinks.

In the classical mono-directional design, sinks are continually lifted out of the bath by means of a series of lifters welded to the wall of the drum, and at each rotation of the drum, these sinks are removed from the bath while still in the separation zone. The action of these sinks evacuation lifters, passing underneath the two curtains running the full length of the separation zone, creates a great deal of turbulence, and this turbulence destroys the accuracy of separation. This severely limits the speed of rotation of the drum as well as the tonnage of sinks evacuated within a given period of time. Consequently a mono-directional drum cannot handle a large quantity of sinks.

In the bi-directional design however, sinks are lifted up and out of the bath only when they are completely outside of the separation zone. Scrolls welded to the bottom of the bi-directional drum gently move the sinks in one direction, while the floats flow out on the surface of the bath in the opposite direction. When the sinks exit the separation zone, they drop down underneath a curtain into an expanded cone and only at this point are they screwed up and out of the bath. Since there are no lifters and curtains within the separation zone, a bi-directional drum can be rotated at relatively high speeds without jeopardizing the accuracy of separation. Since there are no lifters and curtains within the separation zone, the entire surface of the bath is available for separation and remains fully visible to the operator at all times.



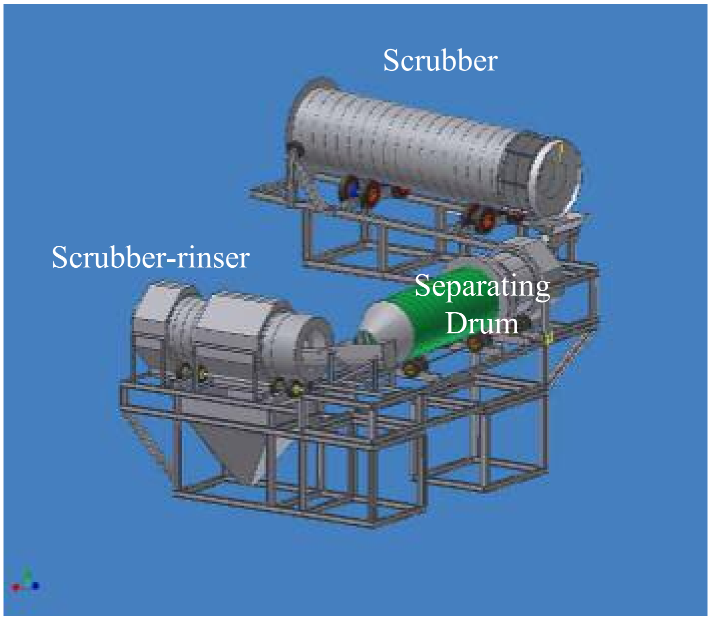
But even with this neat bi-directional design, I was still faced with the problem of where to find the fine particles needed to create a suspension medium. Carrots do not float on water, and without a change in the density of water, just about everything we put into a separating drum sinks. In mineral separation, the density of waster is changed by means of fine metallic powders (magnetite, ferrosilicon). Some of these metallic powders cost over $1,000 per ton, and who could justify using them alongside food products? One way around this problem involves the use of salt. Salt in solution is cheap, but how does one dispose of the brine generated by this process? What maintenance engineer would want to deal with the corrosive effects of salt throughout a carrot line?

No metallic powders and no salt, so where then on earth can one find inexpensive and safe suspension fines to float carrots? Soon it became apparent that we need look no further than to the carrots themselves. Just about all soils in which carrots are cultivated contain ultra-fine sand between 15 and 100 microns. This sand constitutes an excellent suspension medium, and it easily achieves separating densities 1.6 times the density of water. By means of two stages of classifying cyclones, this fine sand can be easily isolated and reclaimed from the scrub and rinse water of a carrot line.

With the logic of a bi-directional dense medium drum and with an abundance of sand freely available from the carrots themselves, the first bi-directional dense medium separator was commissioned during the summer of 1985. It was hard to believe the initial results. Not only were all the stones and metals removed from the carrots, but also this separator removed all near-gravity extraneous material such as corn stubble, fly ash and bits of plastic. Even young potatoes that had sprouted from a previous year's harvest separated out nicely and reported in their entirety with the stones (see picture above). But the biggest surprise of all was the precise separation of a good carrot from a partially dehydrated carrot.

Imagine a load of carrots temporarily dumped on a concrete slab waiting to be processed. Some of the carrots on the surface of the pile that see the sun may become soft and partially dehydrated. With a loss of moisture, there is an increase in density, and with an increase in density by only a few points to the third decimal place, this bi-directional dense medium drum has all that it needs to make a precise separation. No color sorting apparatus can remove partially dehydrated carrots, since an hour or two of sunshine does not change the color of a carrot.

Eventually sixteen bi-directional dense medium separators were sold in Belgium and France. The leading vegetable processor in Europe, Bonduelle, with a 30% market share, bought five separators. Their fifth separator, recently installed in August 2004 in Renescure, France, is the first vegetable separator designed by ESR LLC that does not employ vibratory screens (see picture on previous page). The food giant, Nestle, bought two 60 TPH potato separators which were installed at its dehydrating facility in Rosiere, France.



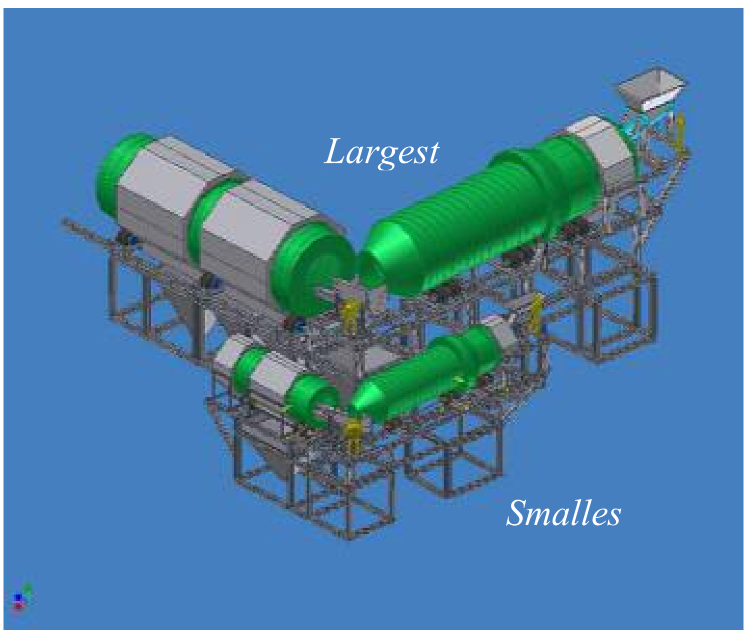
Oftentimes carrots in Europe are harvested during rainy weather, and as much as 50% of what is brought out of the field under such conditions consists of mud and clay balls. ESR LLC designed a scrubber barrel to liberate carrots from this muddy mess, while effecting minimal damage and breakage to the carrot.

After separation, the dewatering and rinsing of carrots poses a special problem. To dewater by means of vibratory dewatering screens is far from ideal. All vibrating screens are difficult to maintain, they have limited material transfer capacity, their panels easily blind up with trash, and they presuppose large volumes of rinse water emanating from spray nozzles that only impact the surface of a bed of carrots. Based on its experience in the rinsing of nonferrous metals, ESR LLC developed a unique dewatering, scrubbing and rinsing device called a scrubber-rinser.

A scrubber-rinser is a counter-flow vessel consisting of one or more stages of scrubbing and draining. In a scrubber-rinser solids are scrolled in one direction and rinse water is pumped from scrub section to scrub section in the opposite direction. Since in the scrub stage the carrots are totally immersed in water, the rinsing efficiency is far higher than what we typically see in the case of a vibratory screen equipped with multiple banks of spray nozzles. The final rinse water from the scrubber-rinser is routed to classifying cyclones to recover the fine medium sand. The picture above shows a one-stage scrubber-rinser installed at Bonduelle in France.

With this technology not only is it easy to remove extraneous material from carrots, but it becomes possible to do things that were never available to the industry at a reasonable price: to separate, for example, dehydrated carrots as well as low-density green carrots from the more desirable stock. Not only are the maintenance costs associated with the processing of trash drastically reduced, but also issues regarding quality, taste and texture fall for the first time within the processor's control.

Of course, what works on carrots works equally well on all root vegetables such as potatoes, salsifies, red beets, chicory, sugar beets and even sugarcane billets. With this technology, it is easy to separate a potato of a low-dry matter content from a potato of a high-dry matter content, to separate cold-damaged, mechanically damaged or disease-infected sugar beets from the more desirable stock. The drawing below depicts the largest (400 TPH) and smallest (60 TPH) separators designed by ESR LLC.



Large or small, the logic remains the same. It's the logic of a mineral separation facility applied to the processing of root vegetables. With 16 separators in continuous operation in Europe, some for almost 20 years, it is truly remarkable that no one to this day has ever been able to establish a single separation error in the finished product. If the carrot industry wants to reduce maintenance costs and take pride in producing a thoroughly consistent and perfect product, the technology outlined in this paper is surely the way to proceed.

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