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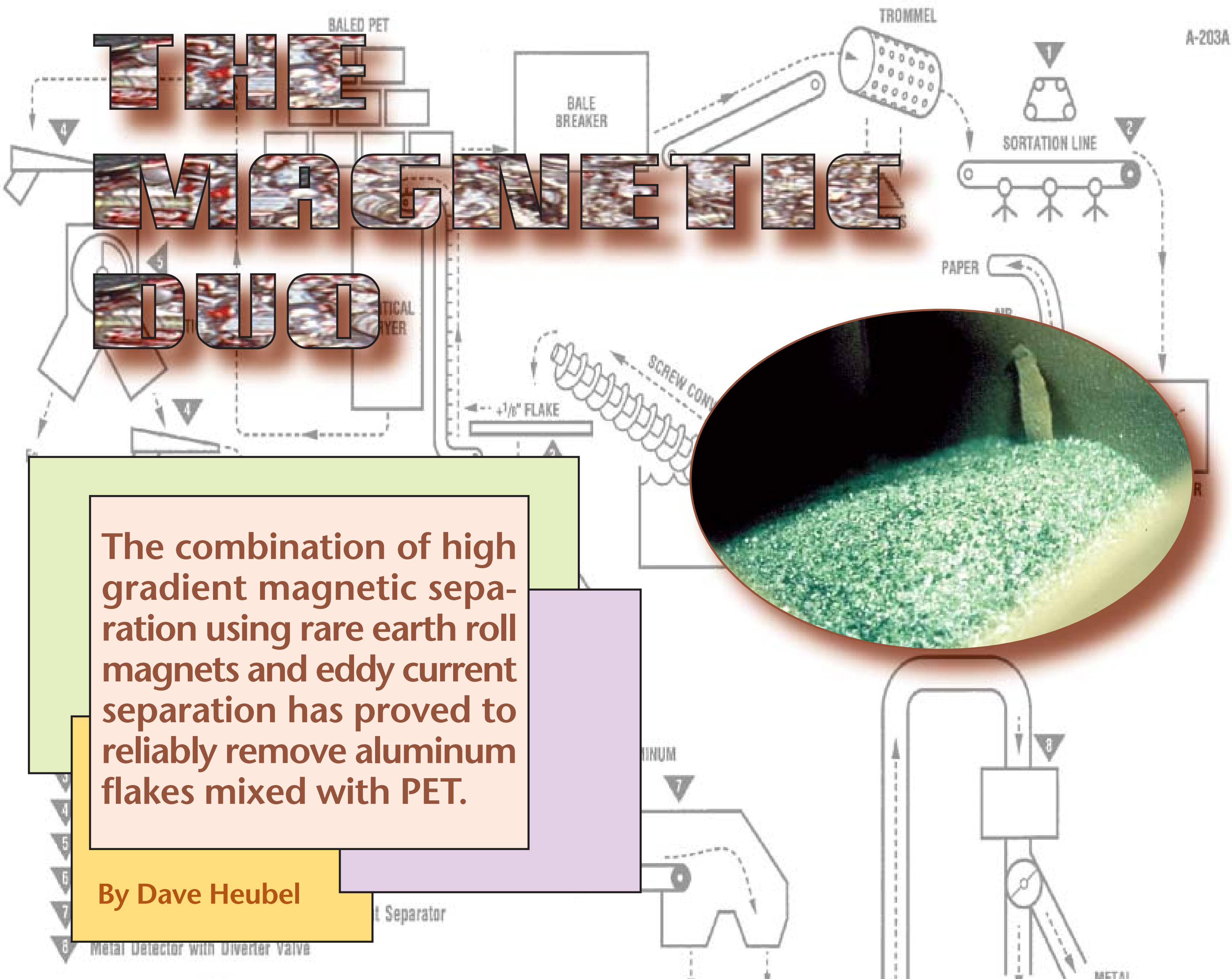
THE MAGNETIC DUO



The combination of high gradient magnetic separation using rare earth roll magnets and eddy current separation has proved to reliably remove aluminum flakes mixed with PET.

By Dave Heubel

Recycling of plastic beverage containers made from polyethylene terephthalate (PET) has been a growth industry for the past two decades. Recycled PET can be used in such diverse products as carpet, containers, auto parts, tool handles and sleeping bag insulation; however, commonly used processing methods leave aluminum flakes mixed with the PET at an average contamination level of about 2,000 parts per million.

Much has been learned over the years regarding how to remove the aluminum contaminants, both in terms of cost-effective methodology and the totality of the extraction. A closer look at the genesis of the industry and a review of separation processes learned over the years will improve the profitability of PET recycling by leaping processors over the learning curve.

PET processing and aluminum contamination

PET usually arrives at the plant in bails. A typical PET processing flow sheet would sort the HDPE and PVC containers from the main flow. Normally, these plastics are processed separately. The PET is color sorted before shredding to about 0.28-inch flake, and then washed to remove glue and labels. The washed PET is screened at 18 mesh, to eliminate a small amount (less than one percent) of fines and then dried.

Early attempts to remove aluminum from

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the PET concentrated on electrostatic separation (ES). Process improvements have boosted the PET grade to between 50- and 100-parts-per-million residual aluminum, with PET recoveries averaging 92 to 94 percent. Despite these advancements, ES separation remains vulnerable to fluctuations in atmospheric humidity and is sensitive to product temperature. Plus, considerable demand has emerged for higher-grade PET flake – i.e., flake with considerably less allowable aluminum contaminant. Aluminum clogs the trash screens of plastic extruders, increasing their maintenance requirements.

Heavy media extensions

A variety of methods, such as heavy media separation, have been attempted to improve the final PET grade. Regular salt solutions can float the PET, leaving the aluminum literally in the sink. However, chlorides and all other salts attack the polymer bonding in the PET. Since a reduced viscosity is disadvantageous in molding plastics, the product value is reduced. This unwanted side effect hindered attempts to extend heavy media separation to the removal of aluminum from PET.

Rare earth roll

The attractive power of magnets makes their use a natural approach for the separation and removal of fine magnetic particulate from processing streams. For PET recycling, the use of rare earth (RE) magnets became another milestone. Rare earth magnets are only one of a number of power sources used in the design of high-intensity permanent magnet circuits; however, these magnet circuits generate a magnetic force many times greater than the force generated by conventional ferrite magnets.

The rare earth roll, a very high gradient dry magnetic separator, was found to be very effective at separating aluminum from the PET. Testing showed that the RE roll produced higher grades and recoveries than ES in many cases, but not all. In the end, the RE roll did not show enough advantages over ES to displace the older technology.

A combination of the two technologies was proposed in 1990 and performance improved to between 96 and 98 percent recovery. Further, feed rates could be nearly doubled.

Eddy current separation

A different technology – tried with limited early success – was eddy current separation (ECS).

The most common ECS was a slide chute lined with alternating permanent magnets. The low-strength ferrite magnets used in these devices limited their availability to deal with product variations and attempts to upgrade these slide chutes with rare magnets brought about erratic results. The second major type of ECS developed used electromagnetic circuits that generate a pulsed field when a conducting material is sensed. This type of ECS did not prove practical for small particles.

Table 1 Summary of test results (aluminum by percentage)

Pass #	RE Roll	Removal ECS
1	42.1	88.5
2	42.1	88.2
3	42.1	67.4
4	42.1	48.7

Source: Eriez Magnetics, 2004.

Table 2 Removal of aluminum by the ECS with and without RE roll magnetic prepass (aluminum by percentage)

Pass #	ECS ONLY	RE Roll Prepass
1	83.5	92.4
2	72.4	91.0
3	64.2	73.9
4	48.7	—

Source: Eriez Magnetics, 2004.

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The technology changed

The modern ECS changed everything. The key technological advancement in today's ECS is the magnetic rotor and the resultant rotating magnetic field. These modern systems feed PET flake onto a conveyor belt, which moves it across a magnetic rotor where separation occurs.

When a piece of nonferrous metal, such as aluminum, passes over the rotating separator at high speeds, eddy currents are created in the aluminum, which generates a magnetic field around the aluminum. When the polarity of that magnetic field is the same as the rotating magnet, the aluminum is repelled from the magnet. PET continues on its path while the aluminum is cast at a new trajectory and the two streams of material discharge into a housing that has a splitter, completing the separation.

Although eddy-current repulsive forces are generated in ferrous metal, the magnetic attractive force is very powerful. The high intensity magnetic field produced by the rotor requires that all ferrous metal be removed prior to the eddy-current separation.

The rotating-magnet-field ECS employs powerful rare earth magnets to produce its separation force. The rotating-permanent-magnetic-field ECS is the most effective in capital cost, operating cost and separation efficiency. Testing established that this new ECS could produce high grade PET at very high recoveries.

Testing the modern ECS

A sample of PET, which had been commercially processed up to the point of aluminum separation and had a feed grade averaging 1,700-parts-per-million aluminum, was obtained. Its size distribution was narrow, with 92 percent passing 0.25 inches and only 15 percent passing 0.11 inches. A series of four-pass tests were performed using 33-pound splits from this feedstock.

All combinations of ECS and RE roll separators were tested, subject to the constraint that any magnetic separation would occur before ECS. A feed sample was split before testing. Samples of 24 to 48 ounces were split from the products after each pass. Larger samples were taken after each stage to compensate for increasing PET purity. The aluminum from these samples was separated by hand and with a metal detector. Aluminum locked to plastic was separated before weighing to obtain the true contamination level. The rejected fractions were analyzed to determine plastic loss and check the material balance of the aluminum separation.

The RE roll yielded a constant removal percentage for each pass, meaning that a very high number of passes would be required to achieve the target grades. At 16.5 percent, the test variability was fairly high. Duplicate tests shed no light on systematic sources for this high variability. PET recoveries were very stable at better than 98 percent per pass with little inconsistency.

The first two passes on the ECS yielded equal percentages of removal per pass at more than double the efficiency of the RE roll. Again, the variability was high and could not be explained. The succeeding two passes showed rapidly declining efficiencies of separation. The decline was initially attributed to a change in aluminum feed size since the first two passes were so efficient; however, coarse non-separated aluminum was found in some of the fourth-pass PET samples. These samples came from those tests that had no magnetic separation.

Test results were reorganized as shown in Table 2. Without magnetic prepasses, the efficiency starts lower than the overall average and rapidly declines. Tests that had one or more magnetic prepasses behaved differently.

The efficiency was somewhat high for the first passes after the magnetic separation, and was nearly constant. The efficiency for the third pass was as high as that for the second pass of the AECS only tests. Only two tests were performed under these conditions resulting in extreme variability for this result as well. These samples were found to contain primarily very fine aluminum. A lower efficiency of separation based upon a lower separation force should be expected. No formal sizing was done on these particles, as there were fewer than 15 in both samples combined. The recovery of PET was high, at 99 percent or better per pass, which indicates that even four passes would result in 96 percent total recovery.

Table 3 **Percentage of aluminum remaining after each pass**

Pass #	4 RE roll 1 ECS	3 RE roll 2 ECS	2 RE roll 3 ECS	1 RE roll	4 ECS
1	57.9	57.9	57.9	57.9	15.1
2	33.5	33.5	33.5	4.4	4.0
3	19.4	19.4	2.5	0.40	1.45
4	11.2	1.5	0.23	0.10	0.74

Source: Eriez Magnetics, 2004.

If the RE roll data is sorted to remove presumably bad results, a slightly higher efficiency of separation is found for the first pass. This data and the ECS data indicate that some fraction of separation efficiency of the later stages of separation, which means that a magnetic separation is mandatory in order to achieve the target purities.

Selection based on the presented testing

Table 3 shows the expected percentage of aluminum after pass using several combinations of RE roll and ECS. The table shows that the most efficient systems are one or two RE rolls followed by two or more ECS. The most economical system is one RE followed by two ECS. If the PET starts at 1,500-parts-per-million aluminum, then this combination should reduce the concentration in the product to about six-parts-per-million aluminum. One commercial operation using this configuration produced a product averaging less than 5.9-parts-per-million aluminum with a PET loss of between 0.5 and 0.9 percent.**RR**

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