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Metal Sorting in the Plastics Recycling Process

1. ***Background:*** Metal is a common contaminant in the plastics recycling process. Single stream, curbside collected material by design contains metal packages such as aluminum and steel cans. The curbside stream also contains whatever other metal articles the consumer may place in the recycling bin. Furthermore, some plastic packages contain metal components such as caps, springs, check valves, labels and lids.

   At the MRF, the valuable metal packaging is separated from the plastic and paper materials so that it can be sold as a commodity. At the plastics reclaimer, any residual metal is separated and removed because it damages machinery and causes quality problems in the final product. This document explains the metal removal technologies employed at the MRF and the plastics reclaimer and how metal containing packages may affect or be affected by the processes.

2. ***Technologies:*** There are two major stages of the plastics recycling process - whole container processing and flake processing. A grinder or granulator sits between the two stages and creates flake from whole packages. Metal removal in whole container processing is designed to create metal material streams, improve plastic quality and protect the grinder. The grinder is an extremely expensive, high speed machine that cannot tolerate solid metal so it is critical that it be protected from heavy metal objects. Metal removal in the flake processing stage is designed to improve plastics quality as metal is a very undesirable contaminant in postconsumer plastic resin (PCR).

   Five primary technologies are used to remove metals through the recycling process. These technologies are used in combination with each other and multiple times throughout the recycling process to achieve the desired result.

   a. Magnetism: Magnets are used to remove ferrous metal and can be configured in many ways. No matter how they are configured the operating principle is the same; the article comes near or in contact with the magnet and the magnetic attraction pulls it from the material stream. Magnets are not effective in removing non-ferrous metals like stainless steel, aluminum, copper and brass.

   b. Eddy Current: An eddy current is an electrical field which repels conductive, non-ferrous metals such as aluminum and does not affect non-conductive materials such as plastic. When applied to a stream of material of an expected trajectory, the eddy current alters the trajectory of the non-ferrous material. The trajectory is created by flinging the mixed material off the end of a high-speed conveyor and into the eddy current field. A divider plate sits between the two trajectories and the materials are separated.

c. Metal detection: Metal detectors work by creating an electrical field and analyzing the interference of that field as an object passes through it. The detection of a metal component will trigger another device to divert that component from the material stream. Metal detectors can be finely adjusted but a variety of metal properties affect the field such as metal type, size, shape, surface area, distance from the sensor and orientation. As a specific example, a vacuum metalized film on a plastic substrate has negligible mass of metal, but high surface area that will trigger the metals detector. Some plastics reclaimers will use an optical flake sorter to detect metal by capitalizing on the fact that metals are opaque. This is explained below.

d. Float-Sink: Metals sink in water. Plastics may sink or float in water depending on their type. Metal can be separated from a floating plastic such as polyethylene or polypropylene by capitalizing on this difference. This process cannot be used with sinking plastics such as PET.

e. Melt filtration: Metals remain solid at the melting temperature of plastics. Therefore, metals can be removed from plastics by heating the material beyond the plastic melting point and forcing it through a screen with fine holes. The liquid plastic passes through the screen while the solid metal is retained on it.

f. Manual sortation: Although not a technology, it's important to recognize that most plastics reclaimers use manual sorters to inspect the material as it passes into the grinder. Recognizing and pulling metal containing packages from the material stream is a common function of manual sorters.

3. Employing the technology:

a. Metal removal at the MRF: MRFs sort complete packages. They use magnetism and eddy currents to separate metal packages into appropriate streams. Some of the more common magnet configurations are drum, conveyor head pulley, plate, and cross-belt. The magnets are placed as close to the material stream as possible while attempting to minimize the amount of other materials between the magnet and the metal. This makes them more likely to capture the metal item and less likely to trap non-metal items between the magnet and the metal. Eddy current separators at the MRF are placed further downstream so their performance can be optimized. They work best with a very controlled, consistent, singulated stream of material so the trajectory is well defined. Eddy currents are adjusted to primarily remove aluminum cans from the residential curbside stream.

b. Metal removal at the plastics reclaimer
   i. Whole container processing: Bales of a particular plastic enter the plastics reclaimer wrapped with steel baling wire installed at the MRF. This wire creates a known ferrous contaminant which must be removed. Wires are normally removed mechanically, either by hand or by machine but some residual wires always remain. Therefore, nearly all plastics reclaimers will employ magnets in the whole bottle stage of their process. These magnets are very similar to the magnets used in the MRF. Like the MRF, magnets are placed as close to the material stream as possible while attempting to minimize the

amount of other materials between the magnet and the metal. This makes them more likely to capture the metal item and less likely to trap non-metal items between the magnet and the metal. After magnets, the whole container stage of a plastics reclaimer's process is dependent on the polymer being processed. However, all of the reclaimers must protect the grinder from damaging metal.

1. HDPE and PP reclaimers: These polymers float so float-sink technology can be used to remove metal contaminants that will damage the grinder. However, the packages must be rendered to a form so the polymer, not the air within the bottle, determines whether the material floats or sinks. Therefore, reclaimers using float-sink to protect their grinder will use a slow speed shredder that can tolerate or protect itself from catastrophic damage to pre-cut the material before it is sent to a float-sink tank. From there it will be fed into the grinder. If a shredder-float-sink is not used, then a metal detector placed around a conveyer is used to detect metal. This detector either stops the conveyor so the material within the range of the detected metal can be removed or it triggers a diverter to remove the material.

2. PET reclaimers: PET sinks so float-sink technology cannot be used to remove metal. Therefore, the whole bottle section of a PET reclaimer is configured differently than that of a HDPE/PP reclaimer. The material entering a PET reclaimer has been baled and compressed very tightly at the MRF, causing some metal objects such as aluminum cans to be intertwined with the PET bottles. After magnets, the PET reclaimer will employ an eddy current separator to remove the aluminum cans. However, the force created by the eddy current machine may not be strong enough to divert the combined weight of the aluminum can attached to the PET bottle. Since PET end users have a low tolerance for metal, the next metal removal stage employs a metal detector capable of removing small metal items as well as these combined items. These detectors are normally installed under a conveyor belt that is part of an optical bottle sorter. The metal detector identifies a metallic item and triggers the corresponding air nozzle to remove the items from the PET stream. In this manner the PET reclaimer protects the grinder and minimizes the amount of metal introduced to the downstream equipment.

ii. Flake processing: Metal removal in the flake processing stage is relative easy for a PP or HDPE reclaimer since the polymer floats. Once ground and the metallic component is liberated from the polymer component, the material is placed in a float-sink tank. The metal components sink and are separated from the polymer stream. This is more difficult for a PET reclaimer since the metallic components and polymer both sink. The PET reclaimer will usually use magnets to remove small ferrous metal components such as sprayer springs, then an eddy current to remove small aluminum pieces, followed by a flake sorter to remove bits of metal that evade the previous technologies. Flake

sorters without metal detection sometimes remove metal by detecting it as an opaque flake.

c. Melt Filtration: Even after employing all these metal removal steps, most recycled plastic needs to be melt filtered to achieve the low levels of metal contamination required of the final product. Melt filtration can occur at the plastics reclaimer, at the end user or both.

4. The APR Metal Sorting Potential Test: The APR has developed a test, "Evaluation of Sorting Potential for Plastic Articles Utilizing Metal, Metalized or Metallic Printed Components", designed to determine the likely outcome of a metal-containing plastic article in the whole container process. This is extremely critical since plastic articles that are mis-sorted in this stage are removed from the recycling stream along with the metal, resulting in yield loss for the reclaimer and wasted plastic. This test uses magnets and metal detectors. It does not use eddy current separators since metal detectors have more stringent criteria in this process and are the limiting factor. It is important to note the factors impacting performance of metal detection. As already discussed, these machines work by creating an electrical field and analyzing the interference of that field as an object passes through it. Although the purpose of these machines in the recycling process is to protect the grinder and improve material quality, they may trigger on metal films and other small metal objects that do not affect quality or damage a grinder, just by the principle of their operation. Therefore it is extremely important to test all packaging utilizing metal, metallized or metallic printed components.

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