



Supplemental Report: *The Evolution of Mixed Waste Processing Facilities- Technology and Equipment Guide*

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May 2016

This report is a supplement to the previous report titled *The Evolution of Mixed Waste Processing Facilities, 1970-Today* – June 2015 prepared by Gershman, Brickner & Bratton, Inc. A copy of that report is located at <http://plastics.americanchemistry.com/Education-Resources/Publications/The-Evolution-of-Mixed-Waste-Processing-Facilities.pdf>.

Disclaimer – There are many global manufacturers of the equipment highlighted in this report. The pictures and details are meant only as an illustration of that type of equipment. This Report has been prepared to provide information to those interested in the recycling and recovery of plastics and other materials. This report is not intended to define or create legal rights or obligations. The American Chemistry Council (ACC) does not endorse the products or companies mentioned or pictured in this report. The ACC does not make any warranty or representation, either expressed or implied, with respect to the accuracy or completeness of the information contained in this report; nor does ACC assume any liability of any kind whatsoever resulting from the use of or reliance upon any information, conclusion, or options contained herein. ACC sponsored this report and it is protected by copyright. ACC, the owner of the copyright, hereby grants a nonexclusive royalty-free license to reproduce and distribute this work, subject to the following limitations: (1) the work must be reproduced in its entirety, without alterations; and (2) copies of the work may not be sold.

Cover Image Sources (Top to Bottom)

- CP Group
- Bulk Handling Systems
- GBB Picture taken in 2014 of the Vecoplan System, City of Edmonton, Alberta
- GBB Picture taken in 2014 of the BHS System, Montgomery, Alabama

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Key Types of Recycling Equipment, from MRFs to MWPFs

Executive Summary

The recently released report “The Evolution of Mixed Waste Processing Facilities – 1970 to Today” provided an overview of the history, evolution, and role in modern solid waste management of today’s materials recovery facilities (MRFs) and mixed waste processing facilities (MWPFs). MRFs and MWPFs are evaluated for how efficiently they divert materials from landfill by maximizing recovery of marketable commodities from source separated recyclables and/or municipal solid waste (MSW).

The success of both MRF’s and MWPFs in achieving these goals is critically dependent on the availability and application of technology. This supplemental report demonstrates that the principal technology and equipment utilized in modern MRFs is being successfully integrated into new MWPFs. The report also notes how some MRFs have been converted to MWPFs, so additional MSW constituents can be diverted from landfill through recovery as marketable materials, transformed into a feedstock for solid engineered fuels (EF), or utilized in an alternative energy conversion process.

The report reviews ten specific types of commercially proven equipment that are traditionally used or adapted for the handling of solid waste. It describes how each type of equipment is uniquely designed for certain constituents in MSW for both MRFs and MWPFs. That evaluation typically includes the quality of the finished product; the volume that is captured versus lost; and the speed at which the processing equipment works.

In addition, the report features innovative machinery that either combines equipment functions or are different adaptations of similar designs. These ongoing innovations continue to upgrade the quality, accuracy and speed of recovery processes and deliver ongoing performance improvements for MRFs and MWPFs.

1.0 New and Innovative Equipment

Equipment manufacturers have been improving and evolving their machines to better handle the diverse composition of MSW. New technology must be more efficient at sorting commodities, handling more material, and minimize clogging and jamming. Several newer types of equipment are highlighted in this section. This equipment combines functionalities or utilizes a different approach to an existing equipment type.

Equipment suppliers have modified disc screens that they claim are less prone to wrapping. An example of such a screen is shown in Figure 1. It has large rotating drums with small discs. The openings between the discs stay the same, but by varying the speed, the size of material that generally falls through will change.

Figure 1
The Following is An Example of a Screen Designed for Anti-Wrapping



Photo Credit: Van Dyk

Another manufacturer has a screen where the disc decks are at a decline, with a more pronounced angle at the waterfall section (the transition from one deck to the next) to help reduce wrapping of items, especially plastic film and bags. Figure 2 shows the side view of a decline disc screen.

Figure 2
The Following is An Example of a Declining Screen



Photo Credit: BHS

Another manufacturer offers a combination trommel and bag opener. The trommel is set up with knives or spikes within the tube of the trommel to tear open plastic bags during the rolling action of the trommel. This liberates the materials within the bag for later sorting. The rest of the length of the trommel has screening holes sized according to what materials are being targeted or separated. Figure 3 shows a schematic of the interior of the trommel tube and a view of the opening of a bag opening trommel.

Figure 3
The Following is An Example of a Trommel with Bag Opening Cutters



Photo Credit: CP Group

Another innovative combination has combined a vibratory screen with a “flip-flop” screen. A flip-flop screen has oscillating bars that move back and forth under a flexible sheet that tends to “flip” material forward, almost like a wave. This type of conveyance works very well with small and wet material. It allows the vibratory screen to have less of a fall angle which improves screening efficiency. Another positive is that it would likely take up less space in a facility. Figure 4 shows a picture of the machine and a schematic of the flip-flop section.

Figure 4
The Following is An Example of a Flip-Flow Screen

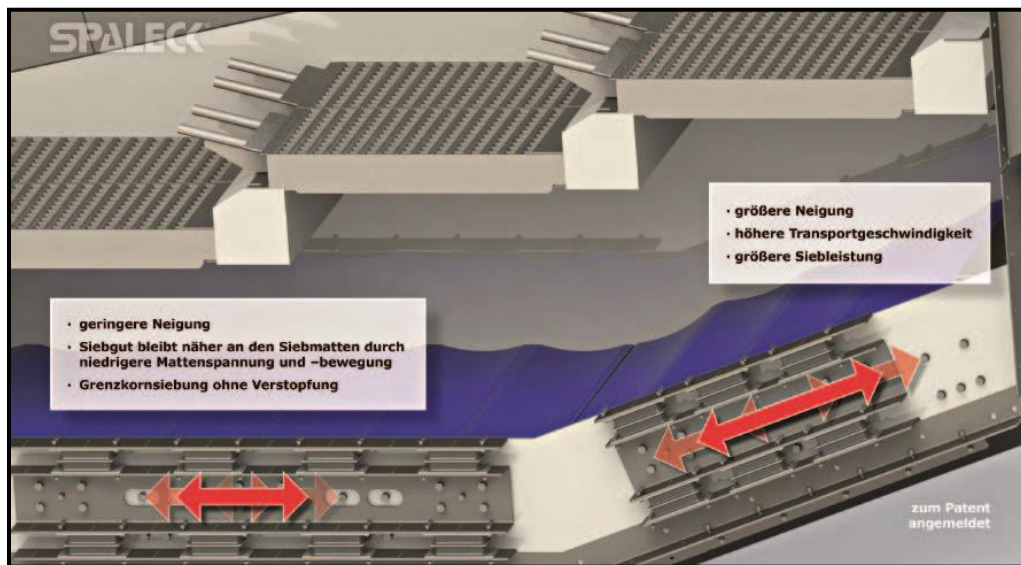
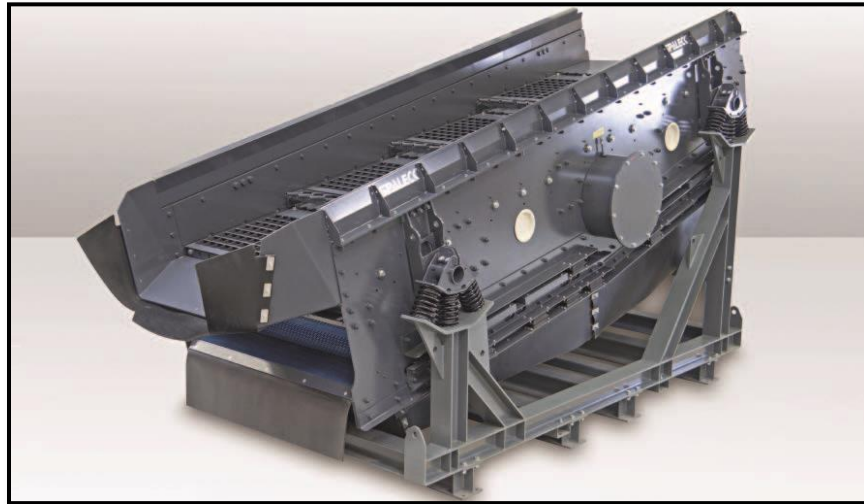


Photo Credit: Spaleck

Another interesting combination is from Bulk Handling Systems (BHS). BHS has developed a near-infrared (NIR) system that looks like a combination between an air classifying aspirator and an optical unit. This equipment is for targeting film from the MSW stream and two had been installed at the

Infinitus Renewable Energy Park's (IREP) facility in Montgomery, Alabama. The targeted plastic bags and film are ejected upward by the optical unit air nozzles. Instead of the film falling back down to a conveyor, the bags are captured by the suction of the aspirator and conveyed pneumatically to a rotary air separator (RAS) unit which deposits the film on a quality control (QC) conveyor. Figure 5 is a picture from the IREP facility showing the two optical units with the pneumatic tubes coming from the ejection chamber housing.

Figure 5
The Following is An Example of Film Optical Units with Pneumatic Transfer



Photo Credit: GBB

There are also many advances in other equipment, especially dealing with throughput, ease of maintenance, and longevity. Some of the equipment used in MRFs and MWPFs has been around for decades in all types of processing facilities. Other equipment is relatively new and much more specific to the material recovery industries. Manufacturers use the knowledge gained in their latest installations and internal research and development to further refine traditional equipment and come up with new and innovative solutions to recover more material from more waste streams.

2.0 Conveyors (Metal and Rubber Belt)

Both rubber belt and chain belt conveyors have been a part of MSW processing from the initial waste shredding systems and RDF facilities of the 1970s to the most modern MWPFs of today. Conveyors are integral to the movement of material within the facility. Their primary use is to transfer material to and from processing equipment, sort stations, and to final storage. Transfer conveyors are frequently used to move material horizontally or to transport material to higher elevations. This is so the material can drop vertically into other equipment or to reach sort stations over bunkers. Due to the composition of

the waste stream, many conveyors now include belt cleaning mechanisms to remove fines and wet materials that tend to stay on the belt.

There are generally two types of rubber belted conveyors in MSW processing applications. A slider bed is a belt that rides over a flat or shaped metal trough, and an idler conveyor is a belt that spans between idler rollers that are perpendicular to the travel of the belt. Figure 6 depicts an idler conveyor without the belt in place to show the idlers, and slider bed transfer conveyors in a MRF application. Conveyor technology is proven, yet innovations continue to be made. Improvements at MRFs and MWPFs have been focused on cleanliness, safety, ease of maintenance, and performance. Processing facilities routinely see a buildup of fines and other materials under equipment. Conveyors designs that can appropriately address these fines tend to leave less material build-up on the floors of the facility.

Figure 6
The Following are Examples of An Idler Conveyor (no belt) and Slider Conveyors



Photo Credit: Machinex; Bulk Handling Systems

A chain belt is shown in Figure 7. Chain belts are proven technology and are frequently used to move MSW and recyclable material at a steeper angle than a traditional belted conveyor. They are also used to move very heavy loads in certain applications. Their chain-link drive systems are very strong compared to rubber belted conveyors. The top speed of a chain belt is much slower than other belted conveyors, which generally means that the average depth of material on the conveyor will be greater. The depth of the material on the conveyor belt (the average height from the belt to the top of the material) is known as burden depth.

Figure 7
The Following is An Example of a Chain Belt Conveyor



Photo Credit: Krause Manufacturing/CP Group

Most in feed chain belts will run between 70-100 feet per minute (FPM). Chain belts up to 72 inches wide are common, and can transfer MSW at rates upwards of 50 to 70 tons per hour (TPH). Chain belts can be used in a variety of applications but tend to be used in MSW facilities as an in feed to the processing equipment or the pre-sort platform. Chain belts are also frequently used as the feed conveyor to a baler.

Conveyors can be used for almost all materials found in an MRF or MWPF. However, it is best to use the right conveyor for the type of material being moved. Idler conveyors are best with fine or gritty material. That material can get under the belt and wear the pan of a slider conveyor, which will not occur with idler rollers. Slider conveyors are best for sorting and for keeping material spread-out, and chain belt conveyors are best for steep applications and moving heavier materials.

All of the major North American MRF and MWPF system equipment suppliers manufacture their own conveyors. A number of other companies build conveyors exclusively that may also be integrated into such facilities.

3.0 Sorting Conveyors and Bag Openers

Sorting Conveyors

Sorting conveyors are used in applications where a person (or persons), called a “sorter,” stands next to the conveyor and picks material off of the conveyor. This differentiates sort conveyors from transfer conveyors. There are additional safety and ergonomic considerations with these conveyor designs so that the person sorting can remain safe and still be able to perform the necessary tasks. Sort conveyors are versatile and can be used in a variety of ways. The most common applications are for pre-sortation, post-sortation, and quality control (QC) of the material streams.

Pre-sort is the removal of large, bulky, or hazardous items before the main processing equipment. This protects the downstream equipment. It also removes and recovers large metals, large plastics and film, wood and cardboard, and larger prohibitive items, such as tarps or hoses. Post-sort refers to staffed areas that have various streams of recoverable materials conveyed from the processing equipment. Post-sort can also refer to some or all material conveyor lines located after the main processing equipment. Post-sorting accommodates multiple people to either pick out recoverable materials (positive sort), or to pick non-desirables from the material stream (negative sort). Positive sort indicates that a person manually grabs the desired commodity and places it elsewhere, such as a chute or bin. Negative sort indicates that the person is manually removing unwanted materials from the desired commodity stream. QC is also a form of negative sort but it tends to be used in smaller commodity streams with one or two sorters at the most. Figure 8 depicts a sorting conveyor and the product chutes for material that is “positively picked” manually.

Sort stations can also be located in other areas of the MRF or MWPF. For example, most conveyors carrying recovered commodities from an optical unit will have a QC station. Also there is potential to capture high value commodities missed elsewhere by having a QC station on the outgoing residue conveyor.

The density of the material is important in the throughput limitations for sort conveyors. Heavier materials have a lower burden depth than lighter materials at the same throughput rate. The greater the burden depth, the more difficulty manual sorters will have identifying individual items for removal or recovery. Another consideration is pick speed. A single person can identify and pick an individual item at a rate of about one item per second (or between 50 and 60 picks per minute).¹ These speeds are very dependent on the material being picked. These limits need to be taken into consideration when planning for how many sorters are needed at each area.

¹ American Plastics Council – *Sorting Plastic Bottles for Recycling* – February 2000

Figure 8
The Following is An Example of a MWP Conveyor Sorting Belt

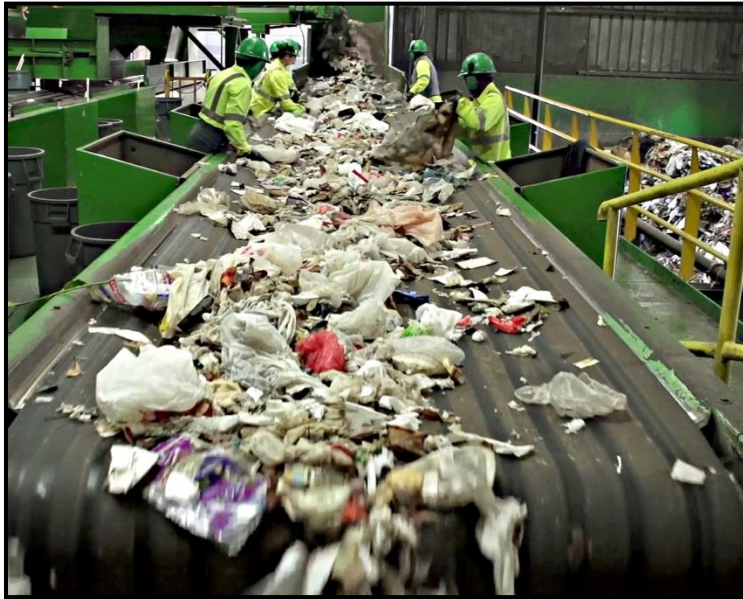


Photo Credit: Bulk Handling Systems

Bag Openers

Bag Openers are depicted in Figure 9. These specially designed machines liberate materials from closed plastic trash bags without resizing or changing its contents. Typically these are located immediately before the main pre-sort belt to allow visual and manual review of as much material as possible.

Figure 9
The Following is An Example of the Internal Rotors in Bag Openers

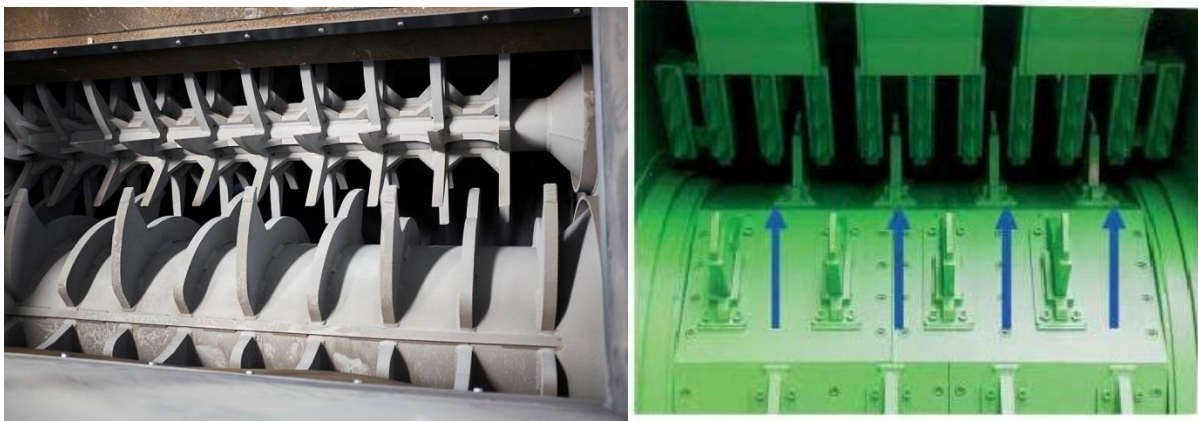


Photo Credit: BHS; Matthiassen

A bag opener will tear open most plastic bags with much of the material inside the bags remaining undisturbed. The opening of bags is necessary for processing. An unopened plastic trash bag will act as a single entity along the processing equipment, and could go over most of the process screens intact. The

bag opener rips the plastic to allow the contents to then go through the processing equipment. There are several similar bag opener designs that are commercially available.

The bags are fed near the top and release their material through the bag breaker. Most designs allow for large and unbreakable objects to pass through by exiting spring loads or other mechanisms without jamming the bag breaker. Some have logic controls to also help deal with jamming.

There are two main implementations of bag openers, “offline” and “inline”. For offline bag openers, the bags are hand-picked, usually at the pre-sort area, and conveyed or dropped into the bag opener. The resulting loose material is then reintroduced, by return conveyor, into the main stream going to the processing equipment. For an inline bag opener, the entire material stream, usually just before or after the pre-sort, goes through the bag opener. Most of the larger available bag openers have a throughput limit of between 30 to 35 TPH. It should be noted that bag openers are intended only to release the contents of plastic bags, not to reduce oversized items, which may jam the bag opener or simply be pulled through whole.

4.0 Primary Shredders

Size reduction for primary materials has been around for a long time for materials such as wood, asphalt and other breakable material. Shredders were often incorporated in the initial MWPFs of the 1970s. There are three main types of primary shredders that can be considered in material reducing for MSW applications. The differences involve the rotational speed of the shredder rotor or rotors.

Figure 10
The Following is An Example of a Horizontal Hammermill

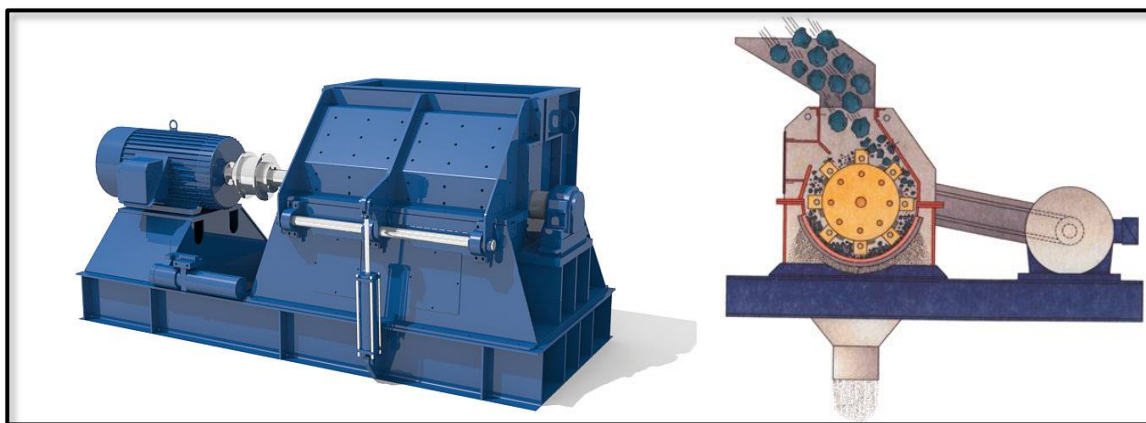


Photo Credit: West Salem Machinery; Schutte Buffalo

Figure 11
The Following are Examples of Vertical Hammermills



Photo Credit: SC Environmental

Hammermills, grinders, and high-speed shredders are all terms that describe a high-speed, high-inertia rotor with rotational speeds of generally 700 RPM or greater.² The rotor shafts can be horizontal or vertical as can be seen in Figure 10 and Figure 11. Both have been used in MWPFs in the past, and most are gravity fed. These rotors generally have some type of hammer or cutting edge. They are usually rectangular, rotate close to an anvil shearing edge, and contain screens around the rotational perimeter to size the material. The hammer from the rotor can be fixed or on a pivot. The pivot type of hammer is usually referred to as a “hammermill”, while the fixed hammer type is generally referred to as a shredder. However, there is no standardized terminology. Hammermills work well on material that fractures easily such as wood, asphalt, and softer types of aggregate such as sandstone and shale or conglomerate materials such as automobiles. Hammermills rely on impact force to smash the material.

High-speed hammermills are capable of reducing a large amount of material and the screens ensure that very few particles are larger than the screen opening. Common large hammermills are capable of reducing 150 TPH of MSW, depending on the screen size. Smaller screen sizes will increase the machine’s workload and reduce the throughput capability. However, hammermills will create a lot of dust and fines, and don’t work as well on material such as plastic film that does not shear or break easily. The impact nature of the hammermill will tend to leave ductile material that is on the upper end of the planned sizes and brittle material on the small side. Also, wet material, such as food waste, can clog the screen, which will impede throughput.

² Fitzgerald, Garrett C.; Advisor, Prof. Nickolas J. Themelis - *Technical And Economic Analysis Of Pre-Shredding Municipal Solid Wastes Prior To Disposal* – September 2009 - Department of Earth and Environmental Engineering, Columbia University, pg 21

Figure 12
The Following is An Example of a Rotary Shredder



Photo Credit: Lindner

Single-rotor, low and medium speed shredders (a low-speed shredder is shown in Figure 12) have a single rotor that usually rotates between 50 and 350 RPM.³ Shredders for MSW are generally low speed at less than 100 RPM. Single-rotor shredders have a series of fixed, offset cutter teeth that shear against an anvil that matches the shape of the cutting teeth. The rotational perimeter also may contain screens to size the material, although the material sizing is more often determined by the cutter size. Some shredders rely on gravity to feed the material to the rotor but most have a push mechanism that mechanically feeds material in batches to the rotor. Rotors are susceptible to stall if large and thick pieces of metal lodge between the rotor and anvil. If equipped, a reversing feature frequently can resolve the jam, although the metal still needs to be manually removed via an access door.

The single-rotor shredders are more limited in the throughput capabilities than other types of shredders due to the batch nature of the feed, the single rotor, and the limits on the size of cutting tooth that can be used. For MSW, larger units can process between 20 to 50 TPH, depending on the tooth size and density of waste. The size of reduced material from these shredders is very controlled, and few pieces are larger than the cutting tooth size. The shear nature of this rotor does produce fines, although not as much dust as with a hammermill. Wet and high organic content material processes well with this style shredder because of the in feed ram, lack of necessity of post-shear screens, and the close interaction of the cutter and anvil, meaning wet organics can't simply fall through the shredder.

³ Single Rotor Shredder Data obtained from Weima, Lindner, Untha, and Saturn-Granutech.

Figure 13
The Following is An Example of a Low-Speed Hydraulically Driven Shredder



Photo Credit: SSI Shredding Systems

Low-speed dual-shaft shredders have two shafts with aggressive fixed teeth or cutters which typically rotate between 10-60 RPM.⁴ These are shown in Figure 13. The rotors are generally hydraulically driven and can reverse direction. The rotations can be programmed and each shaft can be independent of the other rotor. The shearing action can occur against the other rotor or against fixed anvils. Nearly all shredders are gravity fed, and have very aggressive teeth to grab and pull the material into the rotors. Jams are very rare with any type of material because of the high torque of the rotors. However, light, bulky material can “float” on top of the rotors if the teeth are unable to grab something substantial. Briefly reversing the rotation of the shafts can help eliminate this floating effect.

The larger low-speed hydraulic shredders can process 50 to over 100 TPH of MSW, depending upon the cut size and material density. The cutting tooth and anvil locations can be arranged to allow for a wide variety of reducing sizes, typically from 8” up to 18” or more. The arrangement of the shafts and anvil allows for fines and smaller pieces to drop through without contacting the cutting surface, which reduces wear. However this arrangement also allows for long, narrow items to occasionally fall through without being reduced. In addition, large, flexible items can be pulled through the gaps by a tooth without being reduced in size. For example, a kiddie pool can fold up on itself and be pulled through an opening and then expand back once it’s through the reducer. The low speed units produce few fines but the sizes of the reduced material can vary greatly, including some items being larger than the target size. In general, the smaller the cut size the more controlled the sizing of the material.

5.0 Screens

Screening refers to the mechanical separation of material by size. Most of the machinery designs have been used in mining and other applications for more than a century. However, their adaptation into MSW processing and material separation has only been in the last 40 years or so. There are four main types of screens used in MSW applications. These screens include: vibratory screens (as shown in Figure 14), trommel screens, disc screens, and ballistic screens. The purpose of each screen is to agitate and spread out the material in order to break up loosely bound items and to separate smaller items from

⁴ Fitzgerald, *op. cit.*, pg 29

larger ones. Some specialized disc screens, as well as ballistic screens, are designed to screen small material as well as separate flat, two-dimensional (2D) items such as paper and film from intact three-dimensional (3D) items such as plastic containers.

Figure 14
The Following is An Example of a Vibratory Screen

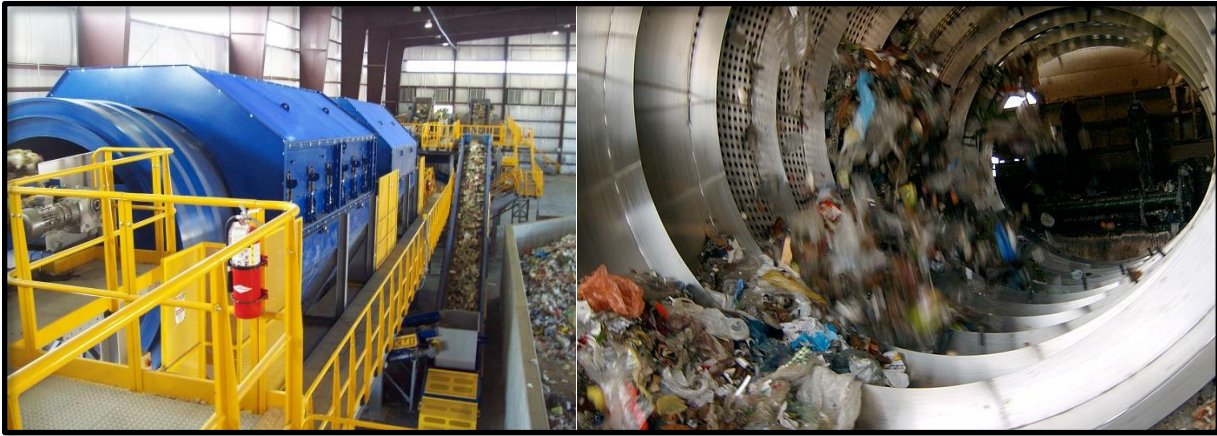


Photo Credit: Spaleck

Vibratory screens are generally shaped like a trough with a screen layer situated near the middle, and can be flat or at a forward facing angle. The screens are typically driven by an eccentric shaft or by a rotating weight. The screen can be mesh, a perforated plate, interlocking fingers with spaces, or even be another type of design. The size of the openings in the screen determines the size separation of the material. Vibratory screens do well with dry material, but can clog with wet material. Most MSW is wet and sticky, so to better process it, many MWP vibratory screens are at a very steep forward angle with no bottom pan, allowing the wet fines to fall out below the screen.

A Trommel screen is shown in Figure 15. Trommel screens are large rotating cylinders with holes in the tube to screen material. The tube sits at a shallow forward angle and may have baffles inside, which are raised pieces of metal in varying orientations within the trommel tube. The baffles help lift then drop the material to break apart and isolate the components and help move the material forward as the drum rotates. The holes in the tube wall can be of differing sizes over the length of the trommel, depending on what separation size of the material is targeted in each trommel section. Trommel screens can be driven by a chain or belt around the circumference of the tube, by gears, or by driving the wheels that the tube sits on. Trommel action is excellent at separating clumped material. However, the trommel's cascading action can cause spearing. Spearing is when long narrow items fall directly through the larger screen holes. Trommel screens can also clog with wet, sticky waste. Rotating brushes are sometimes installed near the top of the trommel tube to help keep the holes clear.

Figure 15
The Following are Examples of Trommel Screens for MSW



Sources: CP Group; www.ecocycle.org Leftovers Report

Disc screens are shown in Figure 16. Disc screens use discs mounted on a series of shafts in an interlocking pattern that rotate to both lift and move the material forward. The gaps between the discs allow smaller materials to fall through. The disc shape generally isn't round, which assists in breaking clumps apart and facilitates forward motion of the materials. Depending on the material and the purpose of the screen, most discs are made of steel or rubber. The screens can be horizontal, angled upward or even in a forward facing, declined angle.

Figure 16
The Following is An Example of a Disc Screen



Photo Credit: Bulk Handling Equipment

The space between the discs, sometimes called the Interface opening (IFO), determines the size of screened material. The pattern of the discs can also be changed to provide an impact area or to target different sizes of material. Multiple shafts can be rotated by a single motor with chain, gear, or belt drives. A single screen may have multiple sections driven by different motors at differing speeds and

may consist of several decks of disc shafts. The disc screens handle wet material fairly well as the interlocking discs tends to clean the openings on the shaft ahead of it. However, the shafts are susceptible to wrapping from long and stringy material and a hard object of the right size can lodge between two discs, causing a stall.

A 2D/3D separator screen, which is sometimes referred to as a polishing or planar screen, is a specialized disc screen used to separate flat 2D objects, such as paper or film, from 3D objects, such as containers. The disc screen shown in Figure 17 is at a steep inclined angle and has rubber discs that help to pull the flat objects up the incline, while the other 3D objects roll to the bottom or rear of the screen. Any fine materials will fall through the openings between the discs. Some screens have variable motor speeds and adjustable angles for different sections, while others employ fans and air technology to assist in the separation. The overall angle of the screen can also be adjusted and generally needs to be less steep for MSW than with single stream MRF applications.

Figure 17
The Following is An Example of a 2D/3D Screen



Photo Credit: CP Group

The ballistic screen is a relatively new technology to MSW processing plants and is in many ways a combination of a vibratory screen with a 2D/3D disc screen. This type of screen, pictured in Figure 18, is a large, rectangular box with parallel troughs on the inside that have openings with edges or sometimes serrations along the side. The troughs are driven eccentrically by a drive shaft with an action very similar to a vibratory screen, although generally not as rapidly. The troughs are at an adjustable upward angle and the function is very similar to that of the 2D/3D disc screen. Flat items, such as paper, are carried up the angle assisted by the trough edges while fines fall through the holes and 3D objects roll to the back.

The troughs are durable because they are made from steel. The openings are susceptible to clogging due to wet or sticky material.

Figure 18
The Following is An Example of a Ballistics Screen

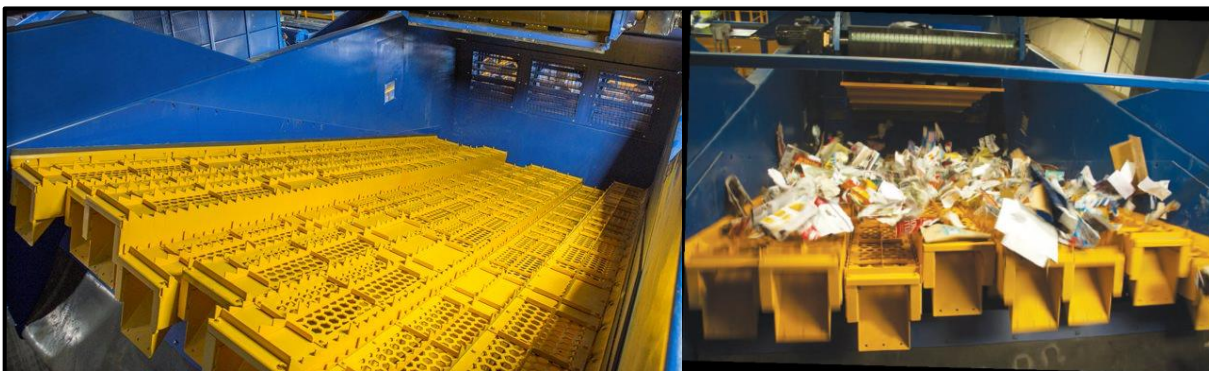


Photo Credit: Machinex

The capacity of a screen, regardless of type, is determined by the type of material and the size of the screen openings. For MSW material at a MWPF, a vibratory screen, a trommel, or a disc screen near the beginning of a system are frequently used to screen out fine material of less than 2 inches and also to break up and remove glass and organics. These all have capacities up to approximately 50 TPH for the largest screens. The more specialized 2D/3D disc and ballistic screens are more dependent on the amount of 2D material in the stream and are typically limited to between 10 and 15 TPH.

6.0 Ferrous Magnets

Ferrous magnets were one of the first tools used for material recovery from the early MSW shredding and RDF plants in the 1970s and early 1980s. They are also used extensively across many other industries for metal recovery. There are three main types of magnets used in MWPF applications: the belt magnet, the head pulley magnet, and a drum magnet.

Belt Magnet

A belt magnet is pictured in Figure 19. It consists of a cleated rubber belt that travels between two non-magnetic pulleys over a central magnet that can either be a permanent magnet or an electromagnet. The ferrous material is attracted to the magnet. It pulls the ferrous item off of the material conveyor. The motion of the magnet belt and cleats pulls the item away from the magnet, allowing it to drop away from the conveyor for collection. Belt magnets can be located over top of the conveyor belt at a right angle to the flow of the conveyor (or close to a right angle). This is called a cross-belt magnet and is effective and easy to mount. This location tends to have the greatest likelihood of damaging the belt compared to other mounting locations. Another position for the magnet is off the end of the conveyor where the belt can be oriented as a cross-belt or in-line with the flow of the conveyor. Because of the elliptical shape of the magnetic field, it is a good rule-of-thumb to have a magnet four to six inches wider than the material conveyor belt. Belt type electromagnets are readily available up to 84 inches in width.

Figure 19
The Following is An Example of a Cross Belt Magnet

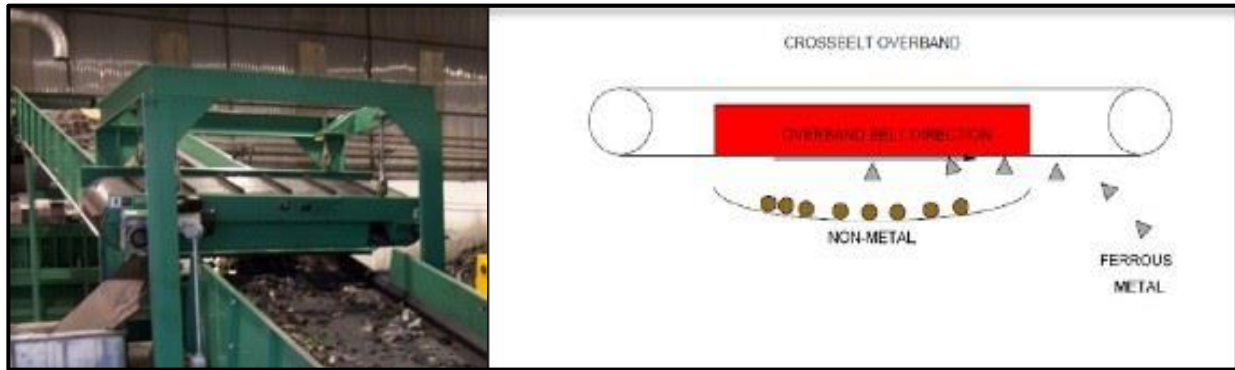


Photo Credit: Bunting Magnetics; Magnapower

Head Pulley Magnet

A head pulley magnet (shown on Figure 20) is a permanent magnet used as the head pulley of a conveyor. Ferrous material riding on a conveyor belt is attracted to the head pulley and follows the belt around the pulley instead of following the trajectory of the other material. The conveyor belt loses contact with the pulley on the underside return causing the ferrous material to fall away from the belt at the underside of the conveyor. Standard head pulley magnets can be up to 72 inches in diameter.

Figure 20
The Following is An Example of a Head Pulley Magnet

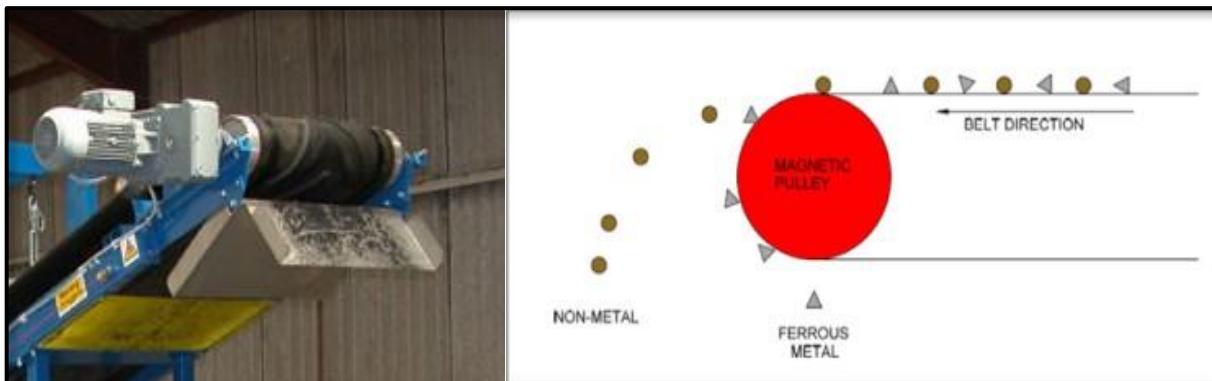


Photo Credit: Magnapower

Drum Magnets

Drum magnets (Figure 21) have non-magnetic steel covers that rotate about fixed internal permanent or electromagnets. These covers are also generally cleated to facilitate pulling the ferrous material away from the magnets. Drum magnets can also be located in a variety of ways, although the axis of rotation must be perpendicular to the direction of the conveyor. The drum can be mounted above the conveyor or off the end, either above or below the center line. Standard drum magnets vary in size up to 72 inches wide and 72 inches in diameter.

Figure 21
The Following is An Example of a Drum Magnet

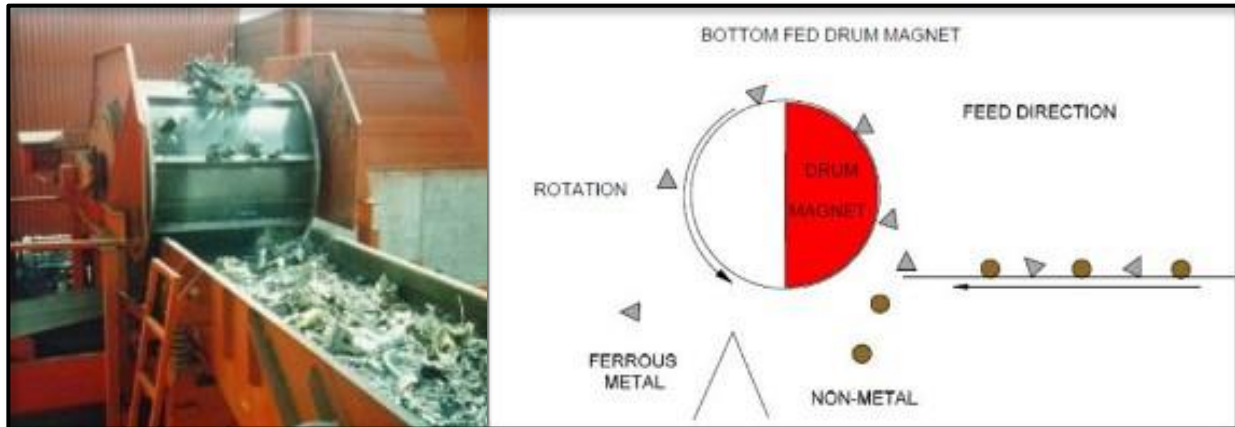


Photo Credit: Recycling Machinery.net; Magnapower

All magnets have a maximum effective distance for attracting ferrous material. This means that the mounting location and distance from the material is critical to the performance of the magnets (while still allowing the largest items to pass under). For belt type electromagnets, this distance is generally 14 to 18 inches, with smaller magnets having less effective depth than larger ones. This corresponds to the distance from the top of the material conveyor belt (or the trajectory of the material if the magnet is mounted off the end), to the base of the magnet. For belt type permanent magnets, the effective distance is much shorter, generally in the 6 to 12 inch range. This means they only tend to get used on the fines material stream. Drum magnets have similar effective depths as belt magnets, depending on whether permanent or electromagnets are used. Head pulley magnets are limited in strength and effective depth and are best used to recover small ferrous items that are near the belt or are buried under other materials.

7.0 Non-Ferrous Magnets

An Eddy Current Separator (ECS) unit, as shown in Figure 22, is a specialized magnetic device used to separate non-ferrous metals such as aluminum and copper from a material stream. This is accomplished using a conveyor that takes material over a non-metallic head drum pulley that has a series of magnets inside rotating at a faster speed than the head pulley. This induces a current in the conductive metal in the waste stream, which also causes a repelling magnetic force from the magnets rotating inside the head drum. This magnetic force pushes the non-ferrous material away from the head pulley, giving it a different trajectory from the rest of the material. A splitter bar is then used to separate the two trajectory streams. Eddy current effects are a well-known phenomenon and their uses in material recovery have been around since the early 1990s.

Figure 22
The Following is An Example of An Eddy Current Separator (ECS) Unit

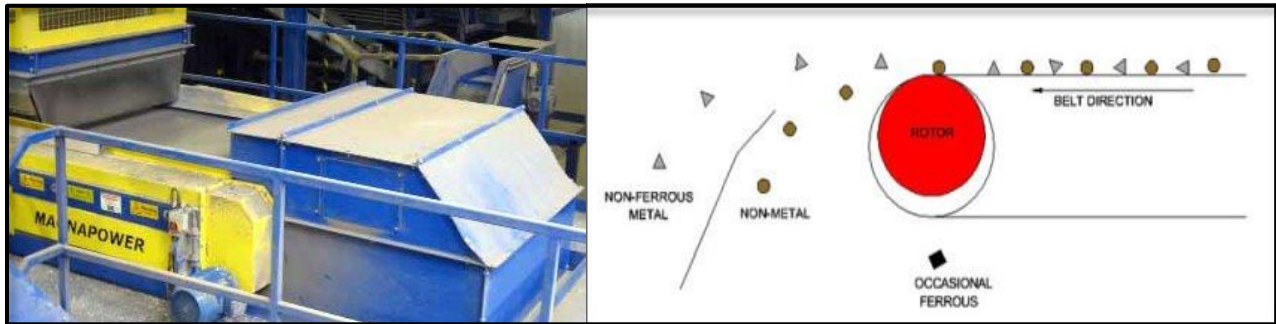


Photo Credit: Magnapower

The belt of the ECS has to give the non-ferrous objects enough forward momentum so that the trajectory of the object is clear enough of the material stream trajectory for clean separation. The belt speed for most ECS units is between 350-500 FPM. This relatively high belt speed also has the benefit of distributing material further apart, which reduces collateral objects in the recovery stream. The total material throughput, in volume, is the main factor used to size the ECS; the more volume, the wider the unit. A 60-inch-wide ECS unit can handle 6 to 8 TPH of an MSW stream with the heavy fractions removed. ECS units are also made to target an effective size range of non-ferrous materials, with a common size range used in MSW and MRF applications commonly being a half an inch to eight inches of non-ferrous objects. In general, it is a good idea to remove the ferrous materials before ECS processing as trapped ferrous metal can damage the drum, although the new eccentric rotors in certain ECS units are less susceptible to this damage.

8.0 Air Separation Systems

Air drum separators have been in use since the 1940s, and aspirators (or wind sifters) have been around for decades as well. The goal of air separation is to remove heavy or light items from the material stream, or to occasionally split high volume streams into similar composition fractions. Numerous U.S. vendors developed unique air classifiers in the 1970s when refuse derived fuel (RDF) started to become a marketable material from the MWPFs built at that time.

An air-drum separator is shown in Figure 23. It consists of a conveyor that sends the material in a trajectory toward a rotating drum. Air is pushed by a fan over this drum and into an expansion chamber which slows the air. Light material is carried with the air over the drum and then settles to a collection conveyor at the bottom of the expansion chamber. Heavier, dense material hits the drum and falls out below the drum without carrying over. In higher volumes, the drum separator can also be used to split the flow into even fractions by weight, although the light fraction will be less dense. The incoming conveyor angle and speed, the drum speed, and the air flow are all adjustable to be able to customize the drum separator to the target material.

Figure 23
The Following is An Example of An Air Drum Separator

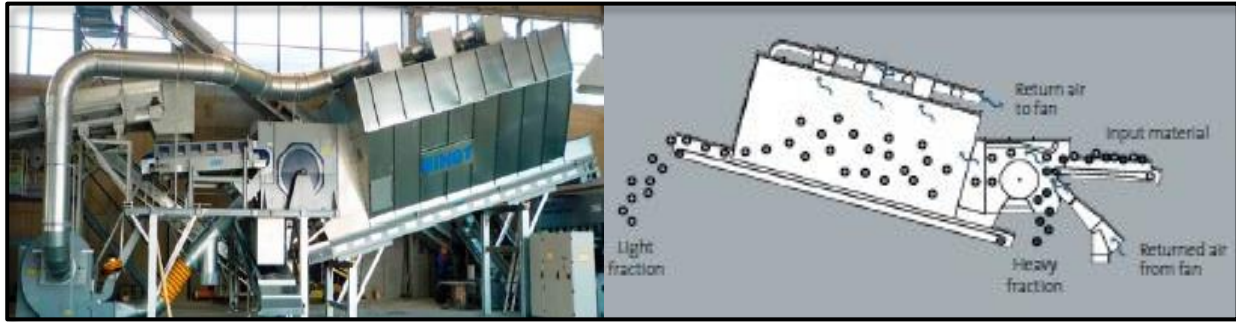


Photo Credit: Nihot

An 'aspirator' air separator is usually located off the head pulley of a conveyor. The aspirator can also be used like a vacuum off the conveyor belt. As depicted in Figure 24, the material from a head pulley falls through a chute with air pulled upward using a fan, removing the light material and fines. In some designs, push air is also provided from below the head pulley by an air knife to help separate lights from the heavier material stream. The heavier material falls out the bottom of the chute and the lights and fines are carried to an external expansion chamber or a Rotary Air Separator (RAS) to remove the light material from the air stream. The air flow and the chute shape can be adjusted for use with an aspirator for limited customization to better target the desired material.

Figure 24
The Following is An Example of An Aspirator Air Separator

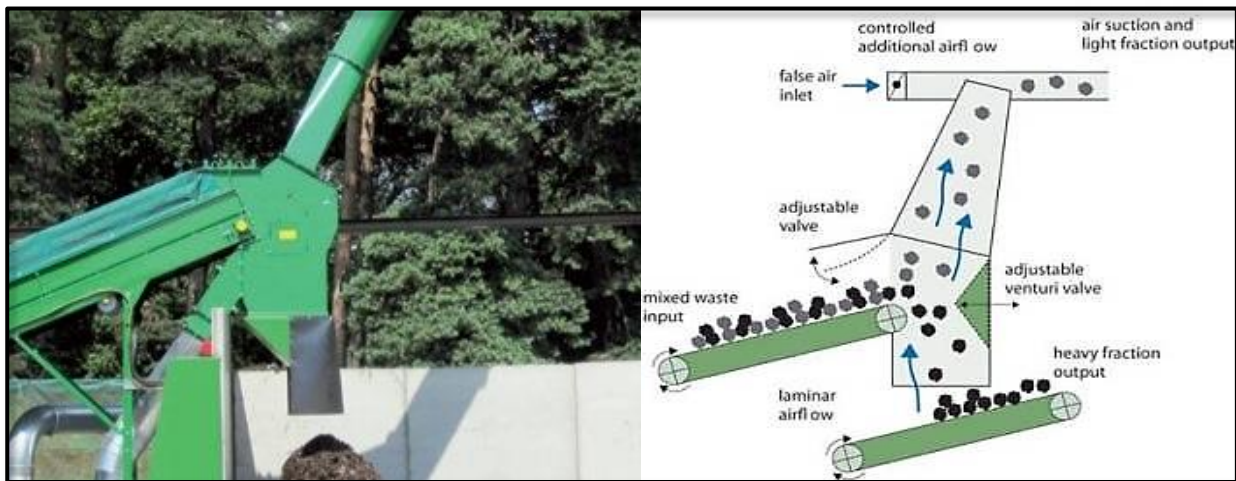


Photo Credit: Nihot

A large drum separator is capable of processing more than 100 TPH, however it is the light fraction that limits its capacity; at most, 25 TPH can go over the light fraction side. For most MWPF applications this limits the material flow to a drum separator to between 35 to 50 TPH. With MSW, a drum separator inserted after a screen that removes fines will remove heavy inerts, wet organics and other dense materials from the stream and conveys the dry paper, plastic and aluminum containers, and other light materials to the next process. The effective size range of incoming material also has limits for a drum

separator. A ratio of 1:4 to 1:6 is the general range in size for effective separation. There also is a maximum item size that can be too large and get jammed in the drum area.

An aspirator is sized to the conveyor it is on. The material flow can be up to 100 TPH, but the amount and size of the light material that the aspirator can effectively remove is comparatively low. The limit for most large aspirators is 5 TPH of lights, and a maximum object size approaching 12 inches. In MWPF applications, an aspirator works well to remove light film and paper from heavier streams where the volume of lights isn't large.

9.0 Optical Sorting Systems

The use of optical near-infrared (NIR) light and sensors to recognize different types of plastics developed in the early 1980s for plastics processing plants. These units have been used in recycling MRFs since the early 2000s and more recently in MWP systems. This technology uses a light source to illuminate the material stream and sensors that collect the reflected or transmitted light and analyze the light properties using spectrometry. Spectrometry reveals the wavelengths that are reflected by the objects. Different materials will reflect different wavelengths and the optical processor can look for specific wavelengths to determine if an object is the type of material that the optical unit is programmed to look for. If this material is detected, and as depicted in Figure 25, air nozzles are timed to fire on that object once the item's trajectory reaches the nozzle location.

Figure 25
The Following is An Example of An Optical Sorting Unit

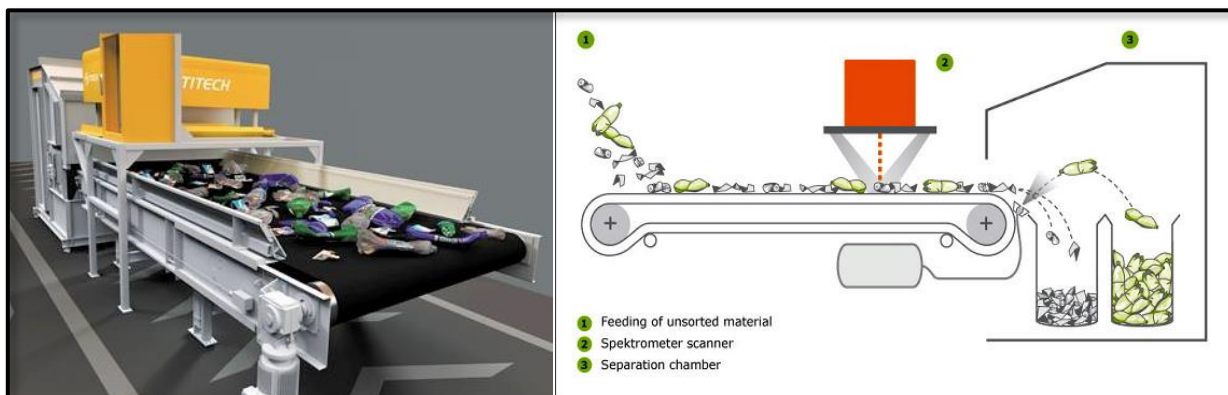


Photo Credit: Titech

The optical unit generally consists of three main components: the acceleration conveyor, the optical sensor, and the air nozzle and ejection housing. The acceleration conveyor carries the material toward the ejection nozzles at a rate that ensures a good trajectory of the material within the ejection housing. The optical sensor scans the material, either on the belt or in flight, and the nozzles eject the targeted material within the ejection housing, which needs to be large enough to not interfere with the flight of materials and have enough distance between the ejected and non-ejected materials to ensure clean separation.

The placement and speed of the acceleration conveyor is important as the timing and trajectory of the object from sensing to ejection by the air nozzles needs to be predictable for the system to work. The ejection nozzles can either eject down or up from the trajectory, and dual eject models will do both, with the default stream falling in the middle. Choosing whether to eject up or down depends on the type of materials in the stream and the material being recovered. Down eject will eject a greater percentage of the targeted material, but will tend to have more collateral impurities. Up eject will generally have a more pure product, but a higher percentage of the product may not get recovered by failing to making the flight over the splitter bar.

The material flow through the optical units is limited by the amount of material on the acceleration conveyor. It must be properly spread out so that the sensors can see each object individually. Otherwise, multiple objects will be ejected along with the target material. Some optical units and conveyors are up to eight feet wide and the belt speeds are sometimes 600 FPM or even faster. Spreading the material evenly on the belt is important, and vibratory feeders or spreader chutes located before the acceleration conveyor are frequently used to accomplish this. The widest optical units can handle up to about 10 TPH depending on the materials. There are also practical limits to how much material can be ejected. With large machines, this is estimated to be two to three TPH. Any more and the air nozzles can't reset and would be on almost all the time, ejecting everything. There is also a size limit on the material the unit will read and be able to eject. For most MSW applications the smallest plastic piece that will be targeted is between one and two inches.

10.0 Secondary Shredders

To prepare the material for RDF, densification, or other processes, additional size reduction may be required. Similar to Primary Shredders, there are three main types of secondary shredders used in MWP facilities. These include high-speed, high inertia hammermills, medium-speed single rotor shredders, and low-speed shear shredders with multiple shafts. Secondary shredders are almost always used in conjunction with a primary size reduction. Secondary shredders don't handle large objects well and multiple large items will reduce throughput. Most secondary shredders have discharge screens at the rotors to better control output material sizes. Fines production is also a consideration in secondary shredding, as fines may cause feed problems with densification machinery. An example of these units is presented in Figure 26.

Figure 26
The Following are Examples of Secondary Shredders



Photo Credit: GBB

The final material size required, which is dictated by the size of the screens in the shredders, is what primarily determines the throughput capability of each secondary shredder unit. A large hammermill with three-inch screens is generally capable of processing 25 to 35 TPH of light MSW material, but that same hammermill with one-inch screens will only be capable of 10 to 15 TPH of the same material. The other types of secondary shredders are capable of slightly less throughput with similar size screens.

Secondary shredders in series that reduce the material in incremental sizes allow for greater throughput and tend to make more uniform sizes of material. The drawback is that there are more machines required for the operation.

11.0 Densification Systems

Densification refers to any process that acts to compact the resulting material streams into a smaller, more transportable form. At a MWPF these may typically be balers for recovered plastics and fiber (see examples in Figure 27 and Figure 28) or a residue compactor that presses the residue stream into a container. At certain MWPFs, densification can also refer to extruding the RDF as a pellet or cube. Densification can be used to create a desirable fuel shape. It is mostly used to facilitate easier and economical storage and transportation of the material.

Figure 27
The Following are Examples of Single Ram Balers



Photo Credit: Bollegraaf

Figure 28
The Following are Examples of Dual Ram Balers



Photo Credit: Harris Baler

Balers and compactors are a proven and common technology used to press commodities and other material streams into compact, easily transportable shapes or containers. Balers are generally one of two types, single-ram and dual-ram. A single-ram extrusion type baler uses a push mechanism that presses material from a collection chamber or “charge box” into a narrower outlet. As more charges of material get pressed into this plug in the outlet, the dense material moves forward incrementally. At a set length the plug of material is wrapped with bale wires and is pushed out to the receiving area by the new bale forming behind it.

A compactor is similar to a single-ram baler, using a ram to push material from a charge hopper. Unlike a baler, the material is pushed into a container that can be separated from the compactor section when full and transported, usually by truck.

Dual-ram (or two-ram) balers have two mechanisms that push the material at perpendicular angles. The main ram pushes the material from a charge box to a bale-forming chamber. Once enough material has been pushed into the forming chamber a second ram pushes the bale through an outlet to be tied.

Dual-ram balers can bale most types of material with its ability to force large or loose material into the shape of the bale. The dual-ram bales of plastic or aluminum containers are more uniform and densely packed than with single ram balers. Single-ram balers work best with fiber and other flat material such as film or light residue. While single-ram balers can be used for other material, the bales tend to be not as well formed as they are with dual-ram. The throughput of fiber bales on a large single ram can be greater than that of a dual-ram. A large single-ram baler can bale up to 80 TPH of mixed fiber. A large dual-ram will typically bale closer to 50 TPH for mixed fiber. The dual-ram bale rates for plastics and metals are generally higher compared to a similar sized single-ram. Material with large objects, such as mixed rigid plastics (MRP) or large metals should only be baled with a dual-ram baler.

Pellet extruders are illustrated in Figure 29. These have been used for decades with homogenous pre-sized materials such as wood and plastics to form fuels. These are also used for plastics to be converted into raw material to be reformed. The same processes have been used to densify RDF. Pilot projects making RDF-fuel pellets date back to early MWPF from the mid-1970s. The non-homogenous nature of the material can cause feed issues with the pelletizer machine.

Figure 29
The Following is An Example of a Pelletizer

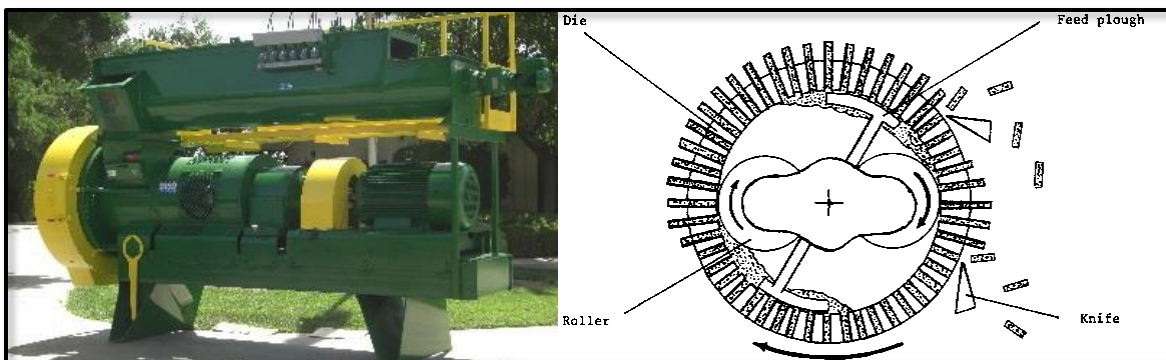


Photo Credit: Warren and Baerg, Food; Agricultural Organization

Fuel pellets or cubes refer to material that has been mechanically forced through an opening. The opening is called a die and the material is compacted into a certain shape. The diameter of the die opening creates the diameter of the pellet. The correct die temperature is also important as some heat is necessary to bind the material in the pellets. Too much heat can melt the material and cause jams or even combust some of the pellets. Not enough heat and the material may jam or not form into pellets. Moisture content also has to be low, generally in the 5 to 20 percent range.

RDF pellet extruders tend to have a narrow range of material sizes that it can handle for an input feedstock. Secondary reduction is often required. A large pellet mill can typically process between 5 and 10 TPH of light MSW material into fuel pellets. Light MSW generally consists of paper fiber, plastics, and textiles. Appropriate moisture content and some percentage of plastics are desirable for binding the material during pellet formation. Metals, stringy materials and non-combustible objects like glass and concrete can be detrimental to the formation of the pellets and to the machinery itself.

Conclusion

An array of commercially proven technologies used in MRFs today are now being adopted by new MWPFs. The equipment is designed to maximize diversion from landfill, recover marketable commodities, and produce feedstocks or energy from the non-recycled fraction. Many of the technologies are relatively mature. Yet, innovation in the sector continues as both manufacturers and operators of the equipment strive to improve the economic performance of MRFs and MWPFs. The composition of feedstocks remains a critical variable for these processing facilities. However, because of the capabilities now available in equipment, the risk for MRFs and MWPFs has been reduced and the potential for increased diversion has been enlarged.



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