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the letters designating certain features on the exhibit:

- Initial agitation to start to separate the mix of material to improve productivity of downstream processing operations (B)
- Separation of smaller material from larger material. This split usually is around an approximate diameter of 8 inches to 12 inches (20 to 30 cm) (B).
- Separation of ferrous metal to prevent damage to downstream equipment (D)
- Separation of small stones, glass pieces, sand, and grit to reduce wear and tear on downstream equipment (E)
- Separation of light, "two-dimensional" materials (e.g., paper, cardboard, and plastic film products) from smaller and/or denser "three-dimensional" materials (e.g., small containers, bottles, other objects, pieces of nonferrous metal, sticks of wood) (F)
- Separation of wood/lumber, either with optical machinery (J) or water bath
- Separation of nonferrous metal, other wood, concrete pieces, asphalt, drywall, etc. This is usually done manually on a "picking line" conveyor system (described below) (C, G, and I).

Bulk Material Recycling

The recycling of large pieces of concrete, steel-reinforced concrete, and asphalt is a process that requires specially designed, heavy-duty machines. Concrete and asphalt recycling is either done at a permanent site, or a mobile processing system can travel to the specific site if there is an extensive volume of material and bulky and heavy pieces that would be cost prohibitive to transport to the recycler. These machines can remove and recycle the steel reinforcing bars

The primary goal in a C&D recycling facility is to be highly efficient, meaning extract as much of the valuable material as possible while producing the lowest amount of residual material.

and crush the remaining concrete and aggregate to specific sizes. A bulk operation may be separate from an operation receiving a mixed wastestream with smaller pieces because of the land area required for the storage piles at the former operations.

A somewhat unique activity that is common in south Florida is the filling of rock-pit lakes with certain C&D material considered to be "clean debris." Clean debris is clean concrete, brick, soil, and rocks. Rock-pit lakes are very common in the region and are excavated to obtain the limestone, which is a popular and inexpensive source for concrete aggregate and for use in road subgrade. Later, after the quarry operation moves away, some of the lakes are back-filled with clean debris to make buildable ground.

Screening Operations

Finger screen—C&D waste is often a clump of different sizes and types of materials intertwined together. These clumps must be separated at the front end of the process in order to make the



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separation and removal of the specific material as efficient as possible in downstream operations and to reduce the potential for downstream machinery to become clogged.

A popular and effective device known as a *finger screen* is often used for this purpose. A finger screen is a heavily built, mechanized conveyor that uses an articulated, oscillating floor to break up the waste clumps. The waste material is fed into one end and the combination of oscillating motion, and the downward slope of the conveyor induces the waste to move forward and at the same time start to separate (Figure 2).

At the downstream end of the screen, another feature can provide a rough separation of waste by size and density. If this division is desired, the conveyor floor has an opening in which smaller and denser materials (e.g., stones, wood, and metal pieces, etc.) fall through the opening and are dropped onto another conveyor that takes them to another sorting process. Lighter, flatter, and/or bulkier materials (e.g., cardboard, paper, plywood, plastic film) are carried off the end of the screen conveyor and into the next piece of sorting equipment.

Trommel screen—A trommel screen can be used to accept the material from a finger screen. If no size and density separation occurred on the finger screen, then the trommel can be used for this purpose. A trommel is a device that contains a hollow perforated tube through which the waste moves. The trommel tube is perforated along its length and its circumference with holes of a specific diameter. The tube is angled similarly to the finger screen and is slowly turned on rollers by a motor. As the waste moves through the tube, the rotating action and downward slope moves the materials forward where they encounter the perforations. Pieces of waste smaller than the perforations (known as *unders*) will fall through the holes and onto a conveyor that will take that material to another sorting process. The larger pieces of material (known as the *overs*) will move through the trommel and onto the next sorting process.

Star Gear Screen—Another mechanized device used to separate waste into two size fractions is the star gear screen. A star gear is a conveyor that contains multiple rows of gears affixed to rotating axles. Each axle contains multiple gears spaced at precise intervals along the axle. The spacing of the gears is designed to control the separation of material. As waste material moves into the upstream end of the screen, it is propelled forward by the rotating gear assemblies. As the material moves over the gears, pieces that are more dense and that are smaller than the opening between the gears fall through opening. These may include stones, pieces of wood, metal, plastic, brick, and similar material. Those pieces (the *unders*) are collected by another conveyor and taken for further sorting or disposal. Lighter pieces that are larger than the opening (the *overs*) continue to move along the conveyor, essentially floating over the gears to the downstream end, where they flow into the next process. Overs may include cardboard, other papers, pieces of lumber, dry-wall, plastic film, and similar materials.

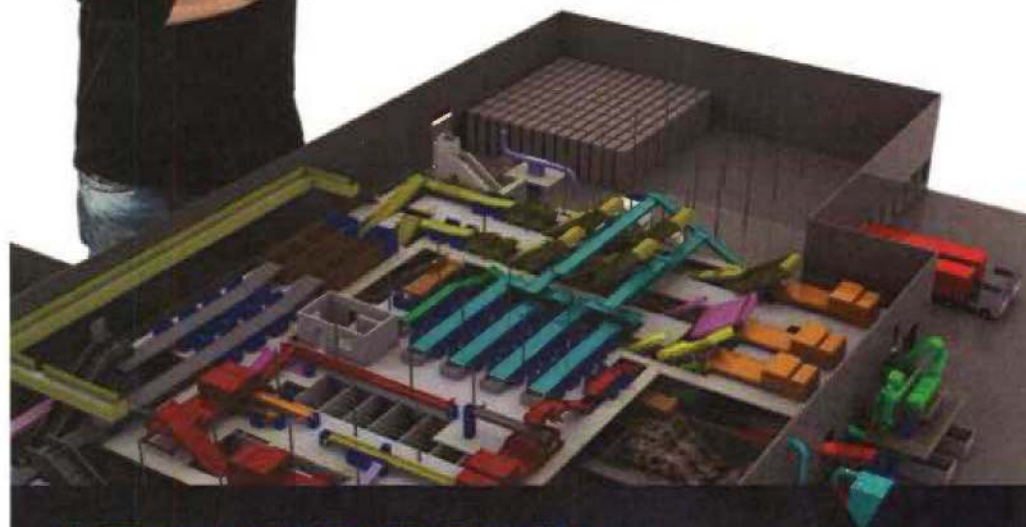
Ferrous Metal Separation and Removal

If large amounts of heavy ferrous metal objects are anticipated in the wastestream, then a device known as an *overhead magnet* is used to remove them from the other wastes. This device is essentially a large industrial magnet surrounded by a continuous looped conveyor belt. The entire device is suspended on a structural frame positioned perpendicular (at a 90-degree angle) above a conventional conveyor belt. Ferrous objects on the conventional conveyor passing



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under the energized magnet are pulled from the belt onto the magnet's moving belt and are swept away from the lower conveyor. As the looped belt passes out of the magnetized zone, the object is released and falls into a container for removal.

Other configurations of magnets are available for removal of such smaller and lighter types of ferrous waste as metal cans. These magnets, known as *pulley head magnets*, can be located within the end rotating pulley system of a conventional conveyor belt system. These magnets operate on a similar principle to the overhead magnet. Cans on the conveyor belt passing over the magnet are retained on the belt as it travels around the pulley to a point almost directly under the belt where the magnetic field ends. At that point the can falls off the belt and into a container. Nonferrous material will flow off the end of the belt and with the help of the belt's momentum, will take a trajectory away from the conveyor into a separate container.

Heavy and Light Material Separation

De-stoner/air knife—Separation of such light, "two-dimensional" materials as paper, textile plastic film, aluminum, and pieces of cardboard from heavier, bulkier materials can be accomplished in an automated device called a *de-stoner/air knife*. Figure 3 shows a schematic cross-section through a unit with two air knives. This unit uses directional air currents and a vibratory motion to stratify and separate lighter material from heavier material. The unit is mounted on heavy coil springs to reduce the transmission of vibration to the ground.

Following along on this exhibit, the waste is fed in from a star gear screen and



Figure 2. Vibrating finger screen

immediately encounters a gap in the air knife through which high-velocity but low-pressure air is flowing. The air flow is provided by a standard centrifugal blower. This flow of air blows the lighter and two-dimensional materials up and toward the downstream conveyor. The heavier and bulkier materials, including small stones and pieces of glass and metal, are unaffected by the air current, and fall through the gap onto a take-away conveyor. Thus, the designation as a *de-stoner*.

As the lighter materials are conveyed to the end of the air knife, there is another high-velocity, low-pressure air stream directed through the conveyor. This final current of air separates the very light material (mostly plastics and light paper) from other denser bulkier material. The lighter mate-

rial, with a relatively large cross-sectional area, is carried to the far end of the collection bin, while the denser, more compact material does not travel as far and drops into the bin directly at the end of the conveyor. All air is exhausted out the top of the air box. If a hood is not used over the final air discharge to capture the light product, then a grate or similar screen is used to deflect light material into the air box end bin.

Exhaust air can be captured and re-routed back to the blowers to increase efficiency and reduce discharge of dust to the environment to near zero. This feature is recommended when the unit is used inside a building and outside where migrating dust could pose a nuisance to other operations or adjacent businesses.

Optical sorter—The use of automated

machinery employing "electronic eyes" to assist in separating materials has become increasingly popular. In many cases the increased efficiency and higher purity of the targeted material provides a positive benefit/cost ratio as compared with traditional manual methods. The function of the equipment is based on the principle that all solid materials have a unique surface "signature" that reflects and absorbs light rays in varying amounts.

Figure 4 shows a general cross-section of an optical sorter than can be used to separate out large wood pieces.

Following along on this exhibit, as the waste material enters from the conveyor and passes under the control unit, a bright light illuminates the materials. A sophisticated instrument called a *spectrometer* imbedded in these machines "reads" the reflected light from the materials and, through a computerized interface tuned to see wood product, actuates a compressed-air device that sends a blast of air channeled by the computer program to specific multiple ports positioned across the end of the conveyor belt. As the materials pass over the ports, the ports that have been activated will discharge

a blast of air under the material. The air ejects larger wood pieces to a receiving hopper on the far end of the machine, while non-wood material simply rolls off the end of the conveyor belt into a separate hopper.

A *vibrating pan feed conveyor* is often used to feed the optical sorter. This type of conveyor will increase the effectiveness of the optical sorter by flattening out and separating the materials before they enter the electronic eye detection zone of the sorter.

Picking (sorting) line—Some separation of materials is still best achieved with manual labor. The *picking line*, or sorting line, is a mostly manual work station that is very common in C&D recycling facilities. Picking lines are used for removal of many potentially valuable recyclable materials, including but not limited to flat pieces of wood, nonferrous metals, asphalt and concrete pieces, and cardboard. A picking line is typically a long and narrow steel work platform elevated at least 10 feet or more above the normal working floor (Figure 5). Under the platform, steel or concrete walls form side-by-side bunkers and are used to provide additional platform support. Each bunker is dedicated to temporary storage of

a specific material.

One or more conveyors are mounted on the platform, parallel to its length, and workers stand along the length of the conveyor, usually on both sides. The conveyor is set at a fixed height so that workers have a comfortable arm reach to remove material from the moving belt. Conveyor belt widths can vary from 30 inches to approximately 72 inches in width, the maximum practical that allows a comfortable reach from either side. Workers are typically spaced about 6 to 8 feet apart. Located between each worker is a steel chute whose bottom is open through the platform floor.

Each worker is assigned to remove (i.e., pick) a specific material. As the conveyor moves material along, the workers pick their targeted material off the belt and drop it through the chute, where the material falls into a storage bunker. This is termed a *positive sort*. Any materials that are not picked from the conveyor are assumed to be of no recycling value or not practical to segregate and are allowed to flow off the end of the belt into an end bunker. This is termed the *negative sort material*, or alternately where the contaminant material is selected

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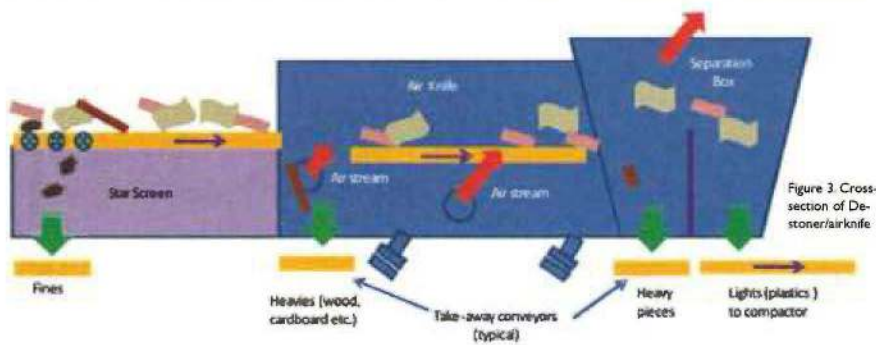


Figure 3. Cross-section of De-stoner/airknife

RECOVERING THE ORGANICS

Randy's Environmental Services of Delano, MN, had a challenge on its hands as it prepared to equip a MRF that would be accepting a wide variety of materials. The company has provided trash and recycling hauling services in the Twin Cities metropolitan area for over 30 years. Randy's is a recognized leader in recycling and source-separated organics collection. Randy's customers have expressed a growing interest in being able to recycle the organics fraction of their wastestreams, and by 2011 the company was ready to ensure it could provide this service.

The Blue Bag Organics program was a key consideration in the overall design of the new MRF.

In the Blue Bag program, customers are able to recycle food waste and yardwaste organics by putting the material into compostable blue bags that they can then place in their garbage bins. The MRF operator had to be able to pull those bags and limit the potential for the machinery to damage those bags prior to recovering them.

Jim Wollschlager and Mark Stoltman from Randy's Environmental Services conducted their research, and one vendor began to emerge as their favorite. "We toured several MRFs around the country and felt the Machinex installations were well laid out and were able to move the material without jams and bottlenecks," says Stoltman.

Randy's gave Machinex the challenge to team up with the company in designing a system that would meet its needs and allow for flexibility in the future. The system provider also worked in partnership with Randy's to design a system that allowed recovering 100% of those bags.

The Blue Bag Organics program was just one component of a wider stream that the Randy's MRF would have to handle.

The primary focus at Randy's was to be able to process both residential single-stream material as well as municipal solid waste (MSW) because of the Organics Blue Bag program.

A variety of screens

Customizing a MRF

MRF: Randy's Environmental Services, Delano, MN.

Capacity: 25 tons per hour of MSW; 12 tons per hour of residential single-stream recyclables

Equipment: Two Mach Ballistic separators, trommel screen, additional mechanical separation equipment

Process: In addition to MSW and single-stream recyclables, the MRF accepts organics in compostable blue bags that residents place in their garbage bins with other waste. At the MRF, the blue bags are not open, and the sorters remove them at a presort station and place them into a bunker, after which they go to a composting platform.

would be necessary, although Machinex had an alternative technology that turned out to be a key component. Conventional screening technologies appeared more labor and maintenance intensive, specifically because of the film and bags. The Mach Ballistic answered the client concerns and proved to be a very efficient means to separate the three fractions of fiber, containers, and fines. This versatile equipment ensures that different material types can be processed within a single system. Also, it has the advantage that the plastic film doesn't wrap around the disks.

Chris Hawn, Machinex North American sales manager, says the Machinex team took on several challenges to offer solutions for the MRF. Mach Ballistic was the right solution for several reasons.

"No conventional system, whether for MSW or single-stream, was really efficient for this application, so Machinex designed a hybrid system that includes a trommel, two Mach Ballistic separators, and mechanical separation for containers."

The combination of sorting technologies creates a great system for efficient sorting of both types of material.

After operating and observing the system in place for nearly a year, Wollschlager agrees. "The system has worked well and proved to be very dependable," he states.



Randy's Environmental Services had a challenge on its hands as it prepared to equip a MRF that would be accepting a wide variety of materials.

to be removed from the targeted material.

Periodically the bunkers will be unloaded and the materials taken away for final recycling/reuse or disposal. Bunkers can have mechanized unloading systems or be unloaded with a front-end loader.

Dust Control

The processing of C&D waste typically generates a significant amount of dust. Most of the materials in C&D are inherently dry, and when they are agitated in the various processing operations, dust particles (actually the minute pieces of some of the materials) are released into the air. Dust particles from a C&D operation can range in size from around 100 microns (concrete dust) up to 1,000 microns (textile dust).

C&D processing operations outdoors and inside a building can create a nuisance to neighbors with fugitive dust generation if it is not controlled properly. Constant uncontrolled dust can also be a health hazard to workers.

The primary sources of dust can include the following:

- Tipping floor
 - Finger screen
 - Air knife
 - Storage piles (especially for residual "fine" materials)
 - Recycled material load-out
- Dust control is mostly science (and partly an art) and too extensive a topic to cover completely here. However, fugitive dust is probably the most prevalent problem with C&D processing. Dust controls can take many forms, from basic static screening material to misting devices and mechanized filtering systems. The most common system for waste operations, the misting system, is discussed herein.

Wet systems—Dust is commonly controlled using wet spray systems where enclosing the material area is impractical. Wet systems can be applied for prevention of dust and suppression of dust. Prevention is done by applying a wet mist directly to the material to reduce liberation of dust. Suppression is applying a mist to the air around the material once it is agitated and dust is released. The type of misting system depends on the situation. Many C&D recycling operations may require both. Recycling facilities are particularly sensitive to the correct dust control. If too much water is applied, the materials may stick together and significantly reduce the effectiveness of downstream separation activities.

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Effective dust control depends on many factors, including dust particle size, wind effects, freezing temperatures, nozzle types, nozzle spray patterns, spray locations, available water pressure, use of compressed air, and use of surface wetting agents (surfactants), to name a few. The droplet size produced from the system must be compatible with the dust particle size, or removal is reduced. Dust control is best left to companies that are experts in the design and operation of these systems in waste handling operations.

Vibration—A brief discussion on vibration is in order. The type of waste processing systems described herein contain several pieces of heavy oscillating equipment, as well as a significant amount of rotating machinery in general. These systems produce steady-state (continuous) vibration, and impact (isolated) vibration. Steady-state vibration occurs during normal running operation. Impact vibration can occur when the equipment is started and stopped or a unusually heavy material is dropped into the machinery. The location of such a system should consider the potential for this equipment to transmit these vibrations to the ground, despite the vibration-dampening systems designed into most of the equipment. Vibration also results from waste-tipping operations and load-out of recyclable materials. A significant buffer zone is generally needed between the equipment and the property line to allow the ground vibration to dissipate to a background level.

Many municipalities have a standard for industrial zones that sets the maximum limit on steady-state and impact vibration. Without an adequate buffer width, vibration can be transmitted to adjacent properties where it can become a significant annoyance. The distance and strength over which vibration can be transmitted is contingent on many factors, including soil type, moisture content, frequency of vibration (i.e., number of oscillations per unit time), and others. It is recommended you consult the equipment manufacturer for guidance on a buffer distance. A buffer distance of 200 feet would be considered a good starting minimum with competent soil, a larger distance is preferred if available.

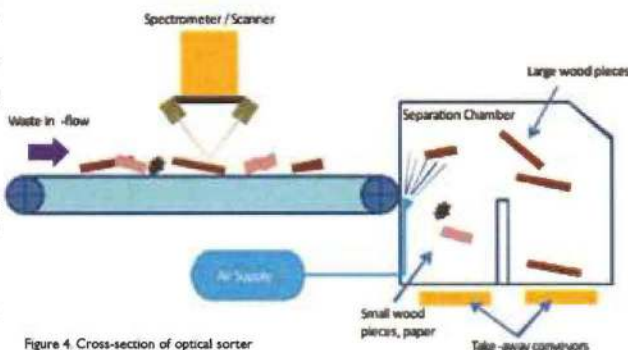


Figure 4. Cross-section of optical sorter

Recycling Byproducts

The processing of C&D waste with a certain combination of equipment can result in a residual by-product known as *recovered screen material* (RSM). RSM looks similar to soil and is mostly the combined

course, filling residential lots up to flood criteria, and similar uses where natural soil is typically used. Although some regulatory agencies have approved its use in certain conditions after an extensive chemical testing program, and it has been marketed with some limited success, extra caution is warranted. Some RSM has been found to be contaminated with chemicals that, although they are native to the virgin materials, are of environmental concern because of their potential to leach out of the RSM. These chemicals include polynuclear aromatic hydrocarbons (PAHs), lead, and arsenic.

RSM is ground-up residual from many materials. As a result, the surface area of the individual particles is increased, which can then increase their solubility when wetted. The increased solubility may result in leaching of the chemical, which can result in contamination of the natural soil and groundwater. Common materials containing these contaminants include asphalt roofing shingles (PAHs), paint (lead), and treated wood (arsenic). Removal of the offending materials from the wastestream before they go through the separation process so they do not end up in the RSM is a time-consuming and expensive process that requires constant vigilance on the part of the operator. It is recommended to steer clear of RSM. **MSW**



Figure 5. Semi-automated picking/sorting line

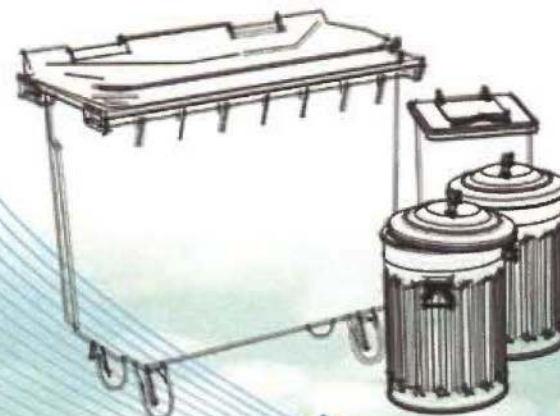
residual of some actual soil and minute pieces of friable waste that may include, drywall, paint, plaster, asphalt shingle grit, pieces of grout, cement, brick, glass, and plastic.

Some recycling companies have experimented with developing this product for use as a substitute where lighter, load-bearing, natural soil fill is acceptable. For example, in shaping contours on a golf

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Marc Rogoff and Bruce J. Clark are project directors with SCS Engineers in Tampa, FL.