A Review of Optical Technology to Sort Plastics & Other Containers

A study sponsored by: the Environment and Plastics Industry Council (EPIC) and Corporations Supporting Recycling (CSR)

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1.0 INTRODUCTION

In January, 2002, the Environment and Plastics Industry Council (EPIC) and Corporations Supporting Recycling (CSR) contracted with Entec Consulting Ltd. to review and report on any new developments in plastic sorting technologies. This technical report presents the findings of that review. This report was also prepared as an appendix to a broader study on the "State-of-the-Art Single Stream Recycling in Various North American Jurisdictions" (yet to be completed).

2.0 SORTING TECHNOLOGIES

There are two general technologies to feed and sort plastics: singulated feed systems that require objects to be fed to the sensor one-by-one, and mass feed systems that require the waste stream to be spread out in a single-layer fashion over the width of a wide belt. Reflective near infrared (NIR) sensors are used on dirtier MRF materials where the mixed input material stream does not allow the use of transmission sensor designs. Mass feed systems are increasingly becoming the preferred choice of technology and, as such, this report focuses on this particular type of technology.

Mass flow systems have high throughputs and fewer mechanical systems to maintain. However, at least one sensor typically is required for each type of plastic sorted. Manufacturers claim sort purities of 90-95% (depending on the contaminant level of the infeed). Two sensors can be used in series to increase the sorting purity or to sort another stream. Manual quality control sorting normally is required as a final step using this equipment should only one pass be done automatically.

Mass flow systems typically are used on a commingled plastics and paperboard (aseptic, polycoat) stream after other recyclables such as paper and glass have been removed.

There are a few primary manufacturers of mass sorting equipment who have made an inroad into MRF processing in North America: MSS, Inc., National Recovery Technologies Inc. (NRT), Pellenc Selective Technologies Inc., S&S Separation and Sorting Technology GmbH and TiTech. The equipment produced by each manufacturer is reviewed below.

2.1 MSS Inc.

MSS, based in Nashville, Tennessee, produces the Aladdin and Sapphire models for plastics sorting. The company was acquired by CP Manufacturing in August 2003.

2.1.1 Sapphire –

- sorts specific plastic resins, aseptic cartons, paper or mixed plastics (that are positioned in a single layer on an accelerator conveyor) from a commingled stream of mixed plastics and paperboard waste using near infrared (NIR) detectors, high speed microprocessors and air jets
- this equipment has no ability to discriminate between colours (i.e. cannot distinguish a clear PET bottle from a green PET bottle, or distinguish a PET bottle [any colour] from a PET bakery tray)
- this line is suitable for high capacity, mass feed applications
- able to prepare one split at a time (2 output stream from one input stream) with the option of separating multiple resins from a mixed plastics and paperboard stream (for example PET and HDPE from the main stream)
- There are currently 32 systems installed, with five in North America
- 5 models varying in throughput capacity from 1,500 to 3,000 kg/hr
- removal efficiency is greater than 80%
- typical product purity is greater than 90%
- recommended for MRF applications because of simple design and price

MRF in New Jersey

- Processes 8–10 tons/hour of commingled containers: plastic, glass, aluminum and tin containers (no fibre)
- Equipment installed April 2004
- Single Eject of all PET from aluminum cans and residue
- Manual Sorting upstream of Natural and Coloured HDPE
- Previous system performance –
  - 5 sorters/shift (10 total)

- Current system performance – 100 lbs/hr more of PET
  - 2 sorters/shift (4 total)

Illustration of a Sapphire Sorting Unit

2.1.2 Aladdin –

- The Alladin uses a user-friendly color touch screen interface and provides modern connection for factory upgrades and diagnostics
- This model is able to process up to 4,000 kg/hr and is used in high-capacity US MRFs and plastics processing plants
- The Aladdin can do all the things that a Sapphire can do, and in addition, it has an integrated colour sensor (it can, for instance, differentiate between a clear and green PET bottle, a PET bottle [transparent] and a PET yogurt container [opaque])

- It is also capable of distinguishing between a coloured HDPE bottle and natural HDPE bottle. It could separate a HDPE tub from a HDPE bottle if the tub had a distinguishing colour signature.
- Able to possibly identify and separate two eject streams from one pass stream (three output streams from one input stream) (e.g. the Alladin can individually separate Natural HDPE and PET from coloured HDPE)
- Also counts bottles separated by type and size
- There are 34 installations (14 in North America) currently using this equipment:
  - MRF in Pennsylvania
  - PET processor in Quebec
  - Müller Recycling, Frauenfeld, Switzerland (a plastic recycler)
  - A PET sorting centre in Switzerland
  - Confidential customer in the Midwest US (three machines)

Aladdin Overview

New Jersey MRF-

- Processes about 12-14 tons per hour (two shifts) of plastic, glass, aluminum and steel containers (no fibre)
- Equipment installed February, 2002
- Eject Up: PET
- Eject Down: Natural HDPE
- Pass Through: Coloured HDPE & Residue
- Counts bottles by size and colour
- Input composition (estimate): 45-50% PET, 20-25% Colored HDPE, 15-20% Natural HDPE, 5-10% cans & trash
- PET output purity (ejected upward): 90-95%
- Natural HDPE output purity (ejected downward): 90%

- Previous system performance – 2,000-2,200 kg/hr of commingled plastic containers
    - 10 sorters/shift (20 total)

- Current system performance – 2,700-3,200 kg/hr of commingled plastic containers
    - 6 sorters/shift (12 total)

- 4 sorters saved/per shift (8 total) = $160,000/yr (U.S.)
- total system costs (incl. structures, wiring, etc.) = $US 240,000
- payback on labour only = 18 months
- overall, Aladdin increased production by 30% and decreased manpower by 40%

PET processor in Quebec -

- currently processes more than 110 tonnes/day of PET bottles and aluminum cans from deposit/return systems
- equipment installed May 2002
- also has washing line and grinders
- positively sorts coloured transparent PET from clear PET and counts bottles by colour and size

- Previous system performance – 1,800-2,200 kg/hr PET bottles
    - Purity of clear PET > 95%
    - Purity of coloured PET > 85%

- Current system performance – 2,950-3,400 kg/hr PET bottles
    - Purity of clear PET > 99.5% (>98% removal efficiency)
    - Purity of coloured PET > 94%
    - Loss of clear PET into coloured PET < 2%

PET sorting centre in Switzerland –

- Processes more than 30 tons/day of PET bottles collected from drop-off bins
- Equipment installed November, 2001
- Positive sort of green/amber/blue and light blue PET from clear PET

- Previous system performance – 1,360-1,590 kg/hr
  - 5 sorters (one shift only)

- Current system performance – 3,200-3,600 kg/hr
  - 5 sorters (one shift only)

- more than double throughput with same staff level

MSS suggests that a throughput of at least 1,500 kg/hr is necessary for justification of automated plastic sorting equipment in North America.

2.1.3 MultiWave –

- MSS' latest generation sensor technology is the MultiWave, which is available to MRFs and plastic processors
- The first installation of the MultiWave will be in the northeastern United States.

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2.2 National Recovery Technologies Inc. (NRT)

NRT, also based in Nashville, is an equipment manufacturing and engineering company providing a number of different pieces of equipment for sorting plastics:

2.2.1 MultiSort IR System

- a mass sort system that uses IR sensing technology to sort one designated plastic polymer type from a commingled stream of mixed plastics and paperboard
- Sorts only by polymer type, not by colour (typically PET, HDPE, PS, etc. from a mixed bale of plastic bottles
- Uses a touch screen operator interface for material selection
- Provides modem connection to the factory for diagnostic checks and adjustments
- Throughput rate of up to 4545 kg/hr
- Equipment can be specially designed for lower throughput capacities
- Approximate capital cost of $150,000 US

Illustration of NRT MultiSort IR System

2.2.2 MultiSort ES System

- Designed to sort plastic bottles over a wide range of colours, tints and transparencies
- Performs one sort at a time, but colours can be selected and grouped together. (e.g. sort PET from HDPE, sort clear PET from all coloured PET, sort natural from coloured HDPE, etc)
- For multiple sorts, two or more machines can be joined together but the identification and separation steps of each machine are independent
- Throughput rates up to 3630 kg/hr
- Approximate capital cost of $100,000 US

- Sample installations (details not available):

  - Western Finger Lakes Solid Waste Authority
    Lyons, NY

  - Evergreen Plastics
    Clyde, Ohio

2.2.3 NRT VinylCycle

In 1991, NRT, with assistance from the US EPA, the Vinyl Institute and other industry sources developed equipment capable of separating polyvinyl chloride (PVC) from a mixed stream of whole or crushed plastic bottles. Even small traces of PVC in a batch of PET sill cause structural problem in the recycling process.

- The VinylCycle system is in commercial operation at various plastic processors and waste companies in the US and throughout the world (the manufacturer declined a request to identify these for concerns of confidentiality)
- The equipment comes in two throughput sizes:

  - 6 bottles/sec
  - 10 bottles/sec.

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2.3 TiTech

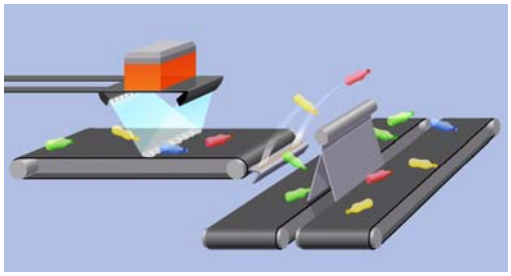
TiTech Visionsort AS

TiTech is a pioneer in the automation of waste sorting. Founded in 1993, TiTech developed the world's first NIR (Near InfraRed) sensor for waste-sorting applications. With a strong focus on R&D (Research & Development), TiTech continues to spearhead the development of this market by offering cutting-edge technology for the sorting of recyclables.

TiTech in brief:

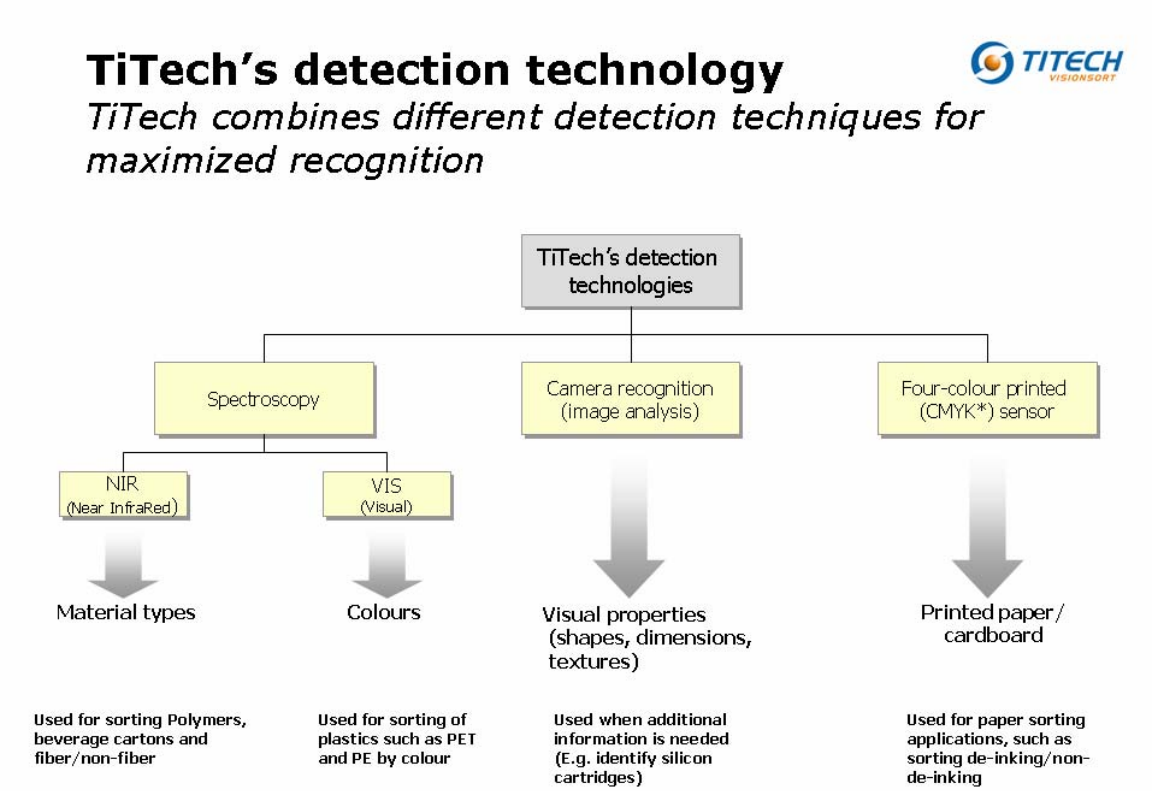
- About 850 units installed in 16 countries
- More than 8 millions accumulated hours in operation
- More than 20 billion items sorted
- Worldwide sales and service coverage:
    - Offices in Norway, Germany, Spain and Korea
    - Distributors in North America, Italy, Australia, Japan, Austria, Switzerland, the United Kingdom and Korea
- More than 50 employees
- Annual investment in R&D close to USD 2 million.

Technology



TiTech's innovative sorting technology makes it possible to fully automate separation of recyclable materials. The input stream is analyzed by a fast-scanning sensor installed over a conveyor belt. It rapidly identifies materials, shapes, textures and colours as well as the object position. TiTech blows the defined sorting fraction onto a second transport system while the residual fraction is brought to a third belt for further sorting or disposal.

TiTech uses up to four detection techniques in order to detect material types, colours, shapes, textures and paper grades. These techniques can be used alone or in any combination, allowing maximized recognition and customized solutions.



The system's high precision and high speed makes it possible to sort an input stream up to 10 t/h with high performance. Our systems create high amounts of labour savings and increase the sorting quality at the same time. Typical efficiency and purity rates are in the 90 – 98% range.

Our product range

TiTech's product range is highly flexible can accommodate a wide variety of needs:

- **TiTech PolySort®** - Material type sorting (PET, PET-G, PE, PP, PS, EPS, ABS, PVC, beverage cartons, paper)
- **TiTech ColourSort®** - colour sorting (PET clear, light blue, blue, green, other colours; PE natural, white, coloured, etc)
- **TiTech PaperSort®** - printed paper and carton, paper vs. carton, dyed paper, brown and grey cardboard
- **TiTech AutoSort MF / ColNIR** – able to perform all sorting tasks mention above – **able to perform material type and colour sorting at the same time**.

Options:

- **MultiFunctional option** - Allows you to upgrade your system for the full flexible system TiTech AutoSort MF, able to perform material type, colour and paper sorting

- **Double valve block** - Sorting of three different fractions with a single sorting system
- **Special valve blocks** - 4 types of valve blocks can be chosen depending on the application
- **Metal detector** - Sort out metal contaminants from the valuable fractions by having a metal detector integrated in the same conveyor belt as the scanner
- **High Resolution sorters** - For sorting of objects down to 12mm large.

TiTech systems are delivered with:

- Detection system (scanner) with lamps
- Control panel with modem
- Valve block(s) and air regulator
- Documentation (available in English, German, Spanish, Italian and French)

References

TiTech systems are installed in more than 250 MRF's worldwide. Onyx, Cleanaway and Remondis are among the company's customers in Europe, where TiTech works in close cooperation with recovery materials associations / consortia such as the DSD (Germany), Eco-Embes (Spain), Fost Plus (Belgium) and COREPLA (Italy).

In North America, close to 24 MRF's have approximately 60 TiTech systems installed. (as of 2/12/2006).

TiTech systems are working with a wide variety of input streams (commingled household, single stream, packaging waste, mixed plastics, PET bottles, paper, commercial and industrial, etc) and performing many sorting tasks (material type, polymers by colour, paper, RDF production, etc). Among the company's references are the following:

Allied Waste Industries – Brockton
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City Fibers West Valley
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Contact: Mr. Todd Jones

Colgate Paper Stock
12 Industrial Drive
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EDCO Disposal
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FCR, Inc
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Lemon Grove, CA 91945
Tel: (619) 287-5696
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FCR, Inc.
2201 Mount Ephrian Avenue, Bldg. 10
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655 Christian Lane
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Tel: (860) 223-3601
Contact: Mr. Kenny Bloom

WMRA - Minneapolis
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Contact: Mr. Mike Lunow

Integrated Paper Recyclers, Inc.
21 North Clark Street
North Andover, MA 01801
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Deffenbaugh Recycling Company
8905 Kaw Drive
Kansas City, KS 66111
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TFC Recycling
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WMRA Spiegel
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CAMCO Recycling, Inc
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Tel: (514) 457-0499
Contact: Mr. Jonathan Boisvert

Sims Hugo Neu Company, LLC
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WMRA Raleigh
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Raleigh, NC 27604
Tel: (919) 838-4417
Contact: Dwight King

WMRA Kit Kat Road
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Tel: (443) 755-9497
Contact: Mr. Dave Taylor

Sunset Waste Paper
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Tel: (559) 499-1595
Contact: Mr. Bill Mohoff

Schupan Recycling
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2.4 Pellenc Selective Technologies

PELLENC Selective Technologies (PST) is based in Pertuis, in the south of France near Marseille. The company produces automatic sorting systems to optimize waste separation. One hundred machines have been installed around the world in the last three years, sold to recycling centres and waste management facilities. The company produces two plastics sorting systems. The Mistral is a multi-material sorting system that uses NIR technology to identify all materials in one pass. The Sirocco uses Vision (sorting of hollow bodies by colour vision) to identify each object by location, shape, transparency and colour. Sirocco has the ability to identify classes of plastics, such as light blue, clean and green transparent objects and opaque objects. Models range from 800mm to 2400mm belt width, varying in output capacity from 2 to 3 t/hour to 8 to 10 t/hour. Purity levels of 90 to 98 per cent are achieved. Efficiency is 90 to 96 per cent.

A metal separator option is available for each system. The machines can handle plastic (PET, PE, PP, PS, HDPE), paper, metal and tetra packs. Random speed is 2.5 to 2.8 m/s distribution on a conveyor belt on a single layer. The systems use pneumatic ejection and can accommodate two types of separation. The first is a binary separation that can separate the stream into two fractions: ejected and non ejected. The other option is a ternary separation that divides the stream into three fractions: two of which are ejected simultaneously and the third non ejected.

The Mistral has recently been installed, through Pellenc's local partner Machinex, in the City of Ottawa's MRF. The Mistral is designed to sort PE/HDPE and PET. The goal at the Ottawa facility, Metrowaste, was to increase the quantity of the stream treated per day but to maintain the same work force. The multi-material sorting machine receives an input stream of 2400 kg/h. The composition of the input stream is 360 kg of HDPE, 240 kg of PS and PP tubs; 720 kg of PET, 600 kg of aluminum and 480 kg of residue. The stream contains no plastic bags or paper. The size of the objects is between 50 and 400 mm.

The system has to receive a constant and regular input stream of bottles from a de-baling and de-clumping system. A combination of mechanical and/or manual pre-sorting removes bulky objects, as well as paper, plastic bags and cardboard ahead of the machine. The Ottawa system itself includes a Mistral M1 1205T, in a 1200 mm working width, with ternary separation of the input stream into three fractions (of which PET and HDPE are ejected).

The purity on the PET ejected fraction is 95 per cent and the efficiency is 92 per cent. The purity on the HDPE ejected fraction is 93 per cent and the efficiency is 90 per cent. The distance between the detection line and the ejection line is only 15 cm. This allows for a better efficiency of ejection of the rolling objects, which can move on the belt before the ejection line – a major cause of "lost" material.

The Belgium SITEL site is another Pellenc case study. The situation at the site, prior to the Pellenc equipment installation, was the sorting of 25 t of plastics, aluminum and steel containers a day. It involved no fibre or glass. Two teams achieved an annual capacity of 6,000 t. The site installed: a Mistral ternary ejection system for PET and HDPE, a Mistral multi-material sorting machine (beverage and carton); a Sirocco colour sorting machine for PET blue and another for PET green. The result was an increase in sorting from 25 t to 65 to 75 t per day, keeping the same number of workers. Annual capacity went up to 18,000 t.

Approximate cost is US$100,000 to US$250,000, depending on sizes and options (i.e. binary, ternary).

Also, Pellenc has introduced a new machine for plastic sorting of electronic scrap: the Mistral High Resolution for WEEE.

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website: www.pellencst.com

2.5 S&S Separation and Sorting Technology GmbH

S&S Separation and Sorting Technology GmbH is based in Schönberg, Germany, but has recently formed a joint venture with a company called Tectron Engineering, which is based in Laguna Hills, California.

S&S produces automatic sorting systems to optimize waste separation. Five hundred machines have been installed around the world for the sorting of plastics, glass and metals. The company produces the Varisort machine for whole bottle sorting. The Varisort allows for fitting of different sensors (i.e. Near-Infrared Spectroscopy, colour image analysis, multi-channel metal detection and X-ray technology) with an acceleration belt and high-speed air jets on the end of the belt. The system also accommodates different sensors on one separation unit. Purity rate is 99.5 per cent.

The system uses different sensors to localize the correct position of the bottles. The desired air jets are activated by the microprocessor-based control unit to hit the bottle to be rejected.

The mass sort system works with different polymer types, colours and metals, as well as a commingled stream of mixed plastics. The unit has an output capacity of up to 6,000 kg/hour and comes in four different belt widths that vary from 500 mm to 2000 mm.

Capital costs for the Varisort Series range from US$50,000 to US$250,000, depending on the combination of detectors used.

S&S also offers a second-generation of SPEKTRUM colour sorters. These machines generate high-value, single colour fractions – even if the initial level of colour contamination is in excess of 10 per cent. A typical application of this unit is the separation of off-colour plastics in PET recycling. The SPEKTRUM colour sorter facilitates production of pure colour PET flakes.

Additionally, S&S offers the PETMAG metal separation system, capable of detecting contaminants from 0.6mm in size – even if the metal is bonded or incorporated in the plastic. The system uses compressed air from a bank of ejection nozzles to remove the metal contaminants from the rest of the material. Capacity ranges from 500 kg/hour to 4 t/hour.

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3.0 EVALUATION

Many municipalities are interested in reducing collection costs by increasingly co-mingling materials at the curb.

As more municipalities expand their collection programs and move to single stream, 2 stream or 3 stream collection systems, interest in automated sorting of the container stream at a MRF will increase. It is therefore interesting to assess how the sorting technologies described might work in a sample container stream. For demonstration purposes only, the MSS Aladdin system was chosen and configured to sort a stream consisting of:

- plastic bottles made of PET, HDPE, PVC, PP, #7 bottles
- plastic tubs made of PP and HDPE
- residual plastics
- aseptic and polycoat containers.

Figure 1 illustrates how the MSS Aladdin system might be configured to provide a sorting solution for these materials. Assuming a fully commingled container stream, ferrous and glass would be removed (using conventional sorting and separation technologies - e.g. overhead magnet and air classifier) prior to the sorting of any plastic, aseptic and polycoat containers. In addition, any plastic film would require manual removal early in the sorting sequence to maximize the efficiency of the remaining sorting systems.

A flattener/perforator prepares the plastic containers so as to reduce rolling on the sensing conveyor and a disc screen removes fines, bottle caps and broken glass that still remain with the plastic and other containers and distributes the material across the width of the sorting system. Assume that the intent is to sort the following:

- Aseptic/Polycoat
- PET bottles
- HDPE bottles
- Tubs
- Other Plastics

The Aladdin equipment can be arranged in a “split” configuration to process two streams of material parallel but independent from each other. The main input stream is processed through one side of the machine to create two ejected fractions and the remaining materials are re-circulated back to the other side of the machine to get another two ejected fractions plus the last pass fraction (in other words: 5 output streams out of one machine). The Aladdin uses the standard NIR and color sensors to identify and separate PET, PS, PP, HDPE and polycoat/aseptics.

On the first side of the Aladdin, aseptics and polycoat would be ejected in one stream, and HDPE into another one (HDPE Natural and HPDE Colored would both be included here). The NIR sensor is able to sense the amount of "paper" in an object, therefore pure plastic bottles can be separated from polycoat/aseptics (that have a thin plastic layer on top of paper) and from pure paper objects. As an alternative, the Aladdin could be equipped with a metal detector upgrade so as to sense metal and tell the difference between polycoat and aseptics (aluminum foil as a barrier layer).

The remaining material would be taken to the other side of the Aladdin. There, PET and the PS could be positively separated, with PP going into the pass fraction. Having the other side of the split Aladdin provides the opportunity to do further sorts and provides flexibility to set the sorts to what communities collect. Providing a separation of PS from PET will resolve the problems with PET trays getting into the PS bales for communities collecting PS.

Since PET and the HDPE are most likely to be the most valuable plastic commodities, one inspector would likely be required for each to ensure quality before the bottles go into a bunker.

The commodities coming out of the Aladdin should be in the range of 95% pure. At present, there is no efficient automated means of sorting out PET trays from PET bottles, and HDPE tubs from HDPE bottles. These items would need to be positively sorted from each of the resin streams, and could be handled by the quality control sorter.

A budget estimate (US dollars) for this sorting equipment configuration is:

standard Aladdin	$190,500
split upgrade	$4,500
disc screen (optional)	$35,000
perforator/flattener (optional)	$25,000
sub-total	$195,000 - $255,500
misc. (platforms, stairs, electrical controls, etc.)	$35,000
Total estimated cost	$230,000

Ultimately, the sorting equipment configuration at each MRF would be designed as to makes the most economic sense in each case. There is also the opportunity to colour sort the PET stream, where it makes sense.

4.0 SUMMARY

The following table summarizes the properties of each sorting technology:

Item	MSS Aladdin	MSS Sapphire	NRT MultiSort IR	NRT MultiSort ES	TiTech AutoSort (6 models)	PST MultiSort	S&S Varisort
Ability to accept baled material	√	√	√	√	√	√	√
Requires singulation	×	×	×	×	×	×	×
Quoted throughput capacity (kg/hr)	5,400	1,500-3,000	4,545	3,630	900 – 10,000	900 – 3,000 or 8,000-10,000	500 - 6,000
Conveyor width (mm)	1600	800-1,600	NA	NA	500-2,800	800 -2400	500 -2000
Colour identification	√	×	×	√	√	√	√
Shape recognition	optional	optional	×	×	√	√	√
Plastics sorted at one time (plus residue)	2*	1	1	1	2*	1	2
Colour sorting capabilities	√	×	×	√	√	√	√
Ability to sort polycoat & aseptic	√	×	×	×	√	√	√
Suggested Capital Cost (US $000)	$186 (64”)	$105 - $135 (64”)	$150	$100	$100-$450	$100-$250	$50-$250

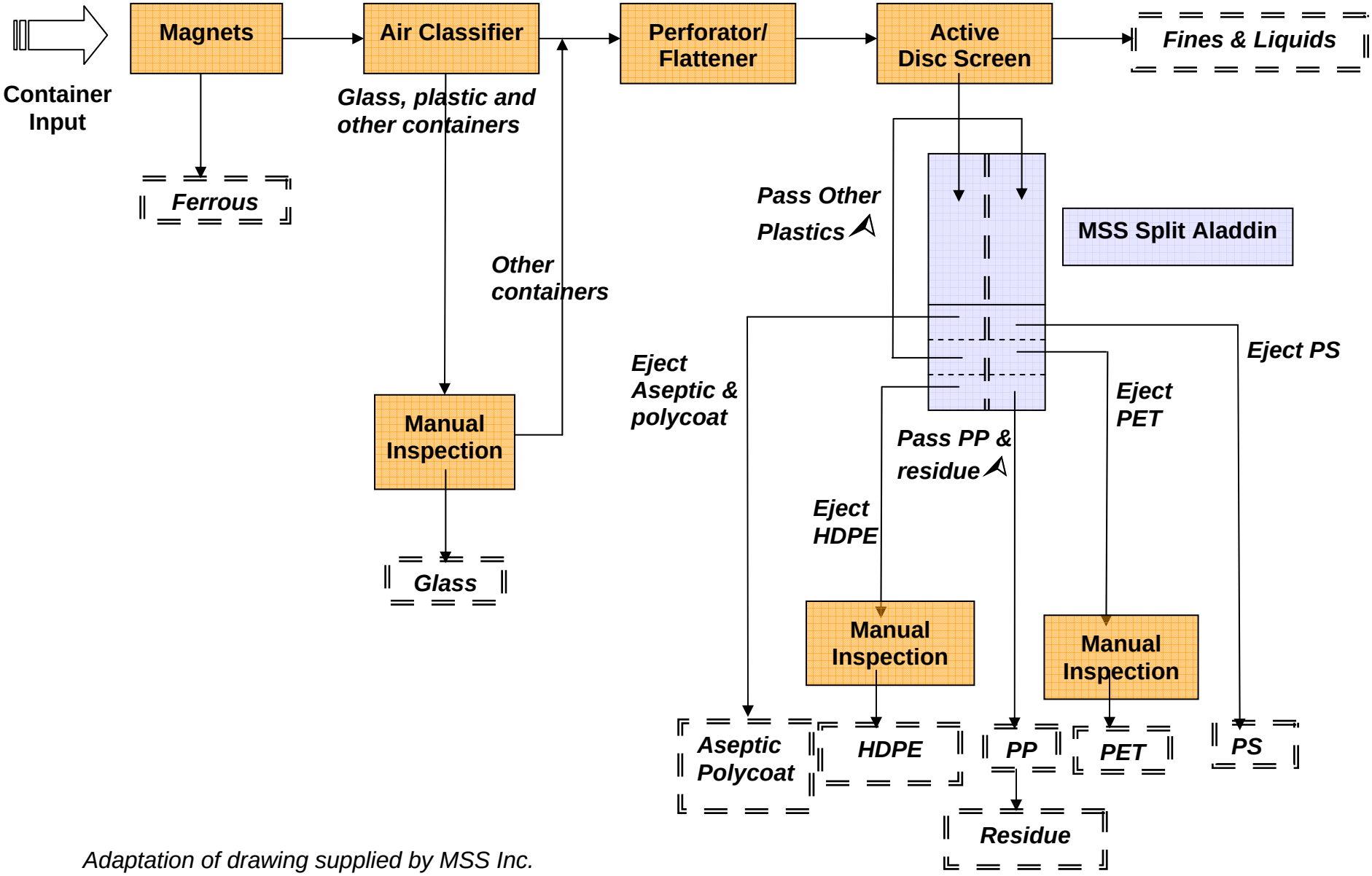
*Will remove two different polymers, two different colours or two different mixed polymer groups.

Selection of an optical sorting system to be used in any facility is a function of the throughput of the materials to be sorted, the market value of the product and the economics tradeoffs between manual versus mechanical sorting.

The Rofin system is not yet commercially available in North America and the capital cost is also not yet known.

Decisions regarding the use of available automated plastic sorting technologies are very much one of economics, based on equipment capital and financing costs, material throughput volumes, the cost of manual sorting and revenues associated with the final products.

Figure 1 - Sample Flow Diagram for Container Processing



Adaptation of drawing supplied by MSS Inc.