HANDLING PLASTICS IN A MATERIALS RECOVERY FACILITY OPTIMIZATION OF ACTUAL OPERATIONS

FINAL REPORT

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

TABLE OF CONTENTS (cont'd)

Page

List of Tables and Figures

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1.0 Introduction

Early MRF design did not focus on the required sorting of plastics, thus, MRFs have adapted to sorting plastics as these materials were added to the stream of recovered materials. No Canadian MRFs have been designed specifically to handle recovered plastics such as, the Gartner Foundation Plastics Recovery Facility in Salem, Oregon.

Recognizing the critical need for guidance in the handling of recycled plastics from curbside to market, the plastics industry in Canada funded several key studies aimed at assisting the recycling industry. In 1992, EPIC sponsored the development of the Recycling Collection Cost Model (RCCM). This was followed in 1993 by the sponsoring of the development of the Materials Recovery Facility Processing Cost Model (MRF-PCM) and, in 1994, of the Plastics Sorting Optimization Guide.

This document focusses on the management of plastics in the MRF. However, where other opportunities (i.e., with respect to materials other than plastics) to increase efficiency, improve product quality and/or decrease processing costs presented themselves, recommendations were put forward to the MRF operators.

This report will benefit MRF operators looking to enhance the management of plastics in their facility and provides some overall guidance in the management of the facility.

1.1 Project Objectives

This project served as a demonstration of the Plastics Sorting Optimization Guide which was developed to assess the performance, policies and procedures within existing MRFs and to identify strategies for the collection of plastics that would help increase the productivity at a MRF. With the use of the Plastics Sorting Optimization Guide, the MRF operator (or designer) develops the best strategy to organize plastic sorting operations to provide streams of marketable material of required quality at an optimal cost.

This study involved working with a number of existing MRFs across Canada, varying in the quantity and types of plastics being handled. Through an analysis of their operations, the application of "hands on" engineering assistance and using the Sorting Optimization Guide as a template for the review, the objectives of the study were:

- To demonstrate that through the application of sound industrial engineering practices productivity and product quality can be improved measurably;
- To determine the impact of MRF design on rates of sorting of plastics;
- To obtain a greater level of understanding of benchmark sorting rates for different types of plastics under varying operational setups;
- To assess the impact of product quality specification requirements on rates of sorting of plastics; and
- To determine the range of plastics sorting costs.

1.2 MRFs Examined

To maintain the level of confidentiality requested by the MRF operators as a condition for participating in the study, no names of the facilities or any direct reference to individual MRF capacity or layout, materials managed, productivity or costs will be made in this report. The report has been structured to outline both the qualitative and quantitative results of the study. Through the descriptive analysis of the data, the reader will be able to compare one's individual facility to those in the study and determine what points in the MRF should be examined for the potential for improvement and then apply the recommended changes to one's facility.

To ensure applicability of the results to MRFs across Canada, MRFs were chosen from six different provinces:

- British Columbia
- Ontario
- Manitoba
- Nova Scotia
- Alberta
- Quebec

1.2.1 Plastics Managed at the MRFs

The range of plastics managed in these facilities is outlined in Table 1.1.

Table 1.1
Plastics Managed in Each of the MRFs

MRF	Plastics Managed
MRF #1	PETE, HDPE (two sorts), PP/HDPE tubs, plastic film, mixed rigid plastic containers
MRF #2	PETE, HDPE (two sorts), PP/HDPE tubs, plastic film, PVC
MRF #3	PETE, HDPE, PS, plastic film
MRF #4	PETE, HDPE, plastic film
MRF #5	PETE, HDPE (two sorts), mixed rigid plastic containers
MRF #6	PETE, HDPE, PS, PP/HDPE tubs, plastic film

1.2.2 Size of the MRFs

Although attempts were made to include a broad range of MRF capacities in the study, the facilities tended to fall within a small range. Four of the facilities processed an average of between 110 and 120 tonnes of material per day of which 2 and 5 tonnes were plastics. One facility processed an average of 10 tonnes per day of which 0.4 to 0.6 tonnes are plastics.

1.2.3 MRF Configurations

Two configurations, manual and semi-automated, were observed for the sorting of containers in the MRFs in the study

Manual Sort MRF

In the manual sort MRF, the sorting was done from a moving conveyor, where sorters (i.e., people stationed along the side of the conveyor belt) picked their designated material(s) from the belt and threw them directly or through a chute into a cage or bunker.

The sort order generally moved from the material in greatest volume (i.e., the most common) to lower volume materials. This was done to allow the sorters further down the line to see the lower volume materials (Figure 1.1).

In the manual sort MRF configuration, the level of automation used was generally limited to no more than three pieces of equipment:

1. A trommel screen (or equivalent) to remove glass cullet before the sorting conveyor;
2. A ferrous magnet to remove all steel cans;
3. An eddy current separator to remove aluminum cans.

Semi-automated Sort MRF

In these MRFs, equipment was used to do a primary separation of the material into two streams - "lights" (plastics, aluminum, polycoat) and "heavies" (glass) before the manual sorting operations were undertaken (Figure 1.2). The sorting process in the MRF was broken into four distinct areas: pre-lights/heavies separation, lights/heavies separation, heavies line, lights line.

In the semi-automated sort MRF configuration, equipment which automatically sorted or aided in the sorting process included (in order in the process):

1. A gravely screen or trommel screen (or equivalent) to remove glass cullet before the sorting conveyor;
2. A ferrous magnet to remove all steel cans;
3. An air classifier to separate the lights from the heavies; and
4. An eddy current separator to remove aluminum cans.

Sorter were stationed along the lights line and heavies line similarly to the manual sort operations outlined above. As with the manual sort facilities, the sort order generally moved from the material in greatest volume (i.e., the most common) to lower volume materials.

Figure 1.1

Schematic of a Typical Manual Sort Materials Recovery Facility

Figure 1.2

Schematic of a Typical Semi-automated Sort Materials Recovery Facility

1.3 Concurrent U.S. MRF Study

Concurrent to the EPIC study, an identical study of MRFs in the United States is being sponsored by the American Plastics Council (APC). The Study Team on the EPIC project has also had an active role in the APC study. The exposure to the additional facilities provided the Study Team with additional data and ideas to address plastics management issues at facilities in both Canada and the United States. Later in 1997, a joint publication, including the results of both studies, will be issued.

2.0 Study Methodology

Outlined in this chapter is the methodology used for the optimization study. The study was divided into four phases:

Phase I Program Establishment and Pre-MRF Contact Strategy Development

i) Establish Optimization Steering Committee (OSC)

ii) Develop process for the OSC to select MRFs

iii) Selection of the MRFs by OSC

iv) Prepare a preliminary outline of the methodology

Phase II Program Definition with MRF Operators - Examining Six MRFs

v) Define the program with the selected MRF operators

vi) Obtain baseline measurements at the MRFs

vii) Analyze baseline data to develop MRF-specific action plan

Phase III Strategy Application at Selected MRFs - Examining up to Six MRFs

viii) Implement Actions

ix) Develop monitoring methodology to measure changes

x) Measure changes

Phase IV Data Analysis and Report Preparation

xi) Outline methodologies used

xii) Prepare Draft Report and Presentation

xiii) Prepare Final Report

A Steering Committee was established and included people representing MRF operators, the plastics industry (both recyclers and end market users), EPIC, and the Study Team (including two consulting

firms specializing in waste management and a MRF designer). The Chair of the Steering Committee, representing EPIC, was a retired professional engineer from the plastics industry.

Phases II and III of the workplan were undertaken over a twelve month period. The methodology utilized a combination of observation and analytical techniques common in industrial engineering and cost accounting.

2.1 Establishing a Baseline

After each of the MRFs agreed to participate in the study, an outline of the project, along with data collection sheets (a blank copy of worksheets that comprise the Materials Recovery Facility Processing Cost Model (MRF-PCM)), were forwarded. During the visit, meetings were held with representatives of the MRF and, as appropriate, the municipality, to complete the data gathering exercise and to see the MRF in operation. The process undertaken at each MRF followed the exercises included in the Plastics Sorting Optimization Guide (Chapter 5.0). Each MRF underwent a review for health and safety, labour and equipment resource requirements, line balancing, and cost evaluation for the management of plastics.

At the MRF, a tour was given by the MRF operator and general qualitative notes were taken. The exact number of sorters used for each of the materials sorted at the MRF was determined through observation and discussion with the MRF operator and/or shift supervisor. Videotape of the operations of the entire facility was taken. The video camera was then set up to record the sorting on the containers line for a minimum of 30 minutes to permit sorter utilization studies to be done.

The data supplied by the MRF operator, combined with the data gathered during the first MRF visit, provided the baseline against which the impact of the changes made in Phase III were measured.

2.2 Identification of Productivity Improvement, Product Quality Improvement and Cost Reduction Opportunities

In order to identify productivity improvement, product quality improvement and/or cost reduction opportunities (hereinafter referred to as the goals), a number of approaches were used.

During the MRF visit, discussions were held with the MRF operator and appropriate staff to obtain their insight into facility operations and opportunities to reduce costs. In many instances, the MRF operator had ideas on how to achieve the goals of the study but either did not have the resources to implement the change or management indicated that they did not see the same problem. Therefore, the empirical data collected during the MRF visit were important as they provided support for the changes proposed.

The observations made by the Study Team members during the visit and of the videotape provided the greatest input to identifying opportunities for improvement. Part of the data analysis involved using the MRF-PCM and sorter utilization studies, although both acted as much to confirm as to identify areas for improvement.

EPIC's MRF-PCM provided the primary data collection form for the study. The model provided information to the Study Team in the examination of sorting conveyor belt speed requirements and when used in combination with sorter activity studies to evaluate sorter productivity and utilization.

Activity-based costing (ABC) methods were used to examine the cost to sort individual materials. The ABC method identifies, wherever possible, the activities, equipment, labour, etc. that are undertaken or utilized for the sorting of individual materials within a MRF. For example, a ferrous magnet is installed to sort steel containers.

All these data were combined to derive actual sorting rates (in kg/hr) and a utilization rate (i.e., the percentage of time the sorter spends doing assigned activities). The utilization rate provided a comparison of the sorters within a specific facility for a specific material compared to industry standard

(i.e., benchmark) rates for the same material. If a sorter's utilization rate was seen as low, further data analysis was undertaken to try to determine why the rate was low.

2.3 Development of MRF Action Plans

The results of the data analysis and the videotapes were reviewed by all members of the Study Team in order to gain concurrence on the findings and recommendations for improvement. Many areas within each MRF were reviewed and opportunities identified for inclusion in the MRF specific action plan.

A detailed technical memorandum, specific to each facility, was written. Each included a summary of the findings of the review of the data and videotape and the outline of an action plan for implementation by the operator. Each MRF specific action plan was reviewed by the Steering Committee. Once approval from the Steering Committee was received, the technical memorandum and action plan were sent to the individual MRFs for review. The findings of the visit and data analysis were reviewed with the operator and the MRF operator's comments were solicited.

Because of the changing of the primary function of one of the MRFs prior to the second visit, the Steering Committee decided that MRF would not be included in the next phase of the study.

2.4 Implementation of Identified Opportunities

Each recommendation of the action plan was reviewed with the MRF operators to ensure clarity of understanding and to obtain buy-in. Actions that would and would not be implemented were confirmed and a timeline for their implementation agreed upon with the MRF operator. A date for the second visit was then set up.

For a number of reasons, many of the agreed upon changes had not been made prior to the second visit to each MRF. Thus, the second MRF visit was carried out over a period of two to three days (depending on the MRF), to allow time to:

- if necessary, reconfirm the baseline (as two of the MRFs had undergone some extensive changes in size and/or function between the time of the two visits);
- implement the action plan;
- observe the impacts of the action plan;
- discuss the impacts with the MRF operators; and
- make adjustments to the changes as a result of the initial review.

As with the first MRF visit, videotape was taken of the line where the changes were made to evaluate the impact on sorter productivity. Videotape was also taken of the sorted materials and the residue stream(s) to provide input on improvements on product quality. The implementation of the changes were observed with the MRF operator to obtain his/her input. Recognizing that the sorters were the ones being impacted in most instances, a number of sorters were asked for their input on the changes and whether or not they felt the changes were positive or negative. Where changes did not have the anticipated impact, reasons were determined and alternative approaches were proposed.

At a number of facilities, meetings were held with the MRF Supervisor/Regional Manager. The impact on productivity, product quality and/or the anticipated cost reduction of each of the changes was reviewed to provide a level of cost-benefit.

2.5 Measuring the Impact of the Changes

The new data were reviewed and a follow-up report generated. The videotape was reviewed and new utilization rates and productivity levels were measured. These levels were then compared to the baseline levels to obtain the impact, as a percentage improvement, of the changes.

A determination of the anticipated (or real in some facilities) increase in product revenue was used as a measure of the improvements in product quality. With the completion of the comparison to the baseline,

an estimation of the savings in overall operating costs that could be achieved was made. For those MRFs where a capital investment was required, the payback period was determined.

The results of the implementation of the action plans was reviewed by all members of the Study Team. Each of the MRFs received a copy of the draft final report to review and to assure them, as per the initial agreement, that no confidential information was being included in the final report. The results of the study were reviewed with the Steering Committee. The final report incorporates the comments suggested during the review process.

3.0 Baseline Observations and Measurements

3.1 Baseline Sorting Rates (Productivity)

The sorting rates described within this section were determined from observations taken during the first visit to each of the MRFs. The rates are shown as a range, combining the results from all facilities (Table 3.1). It should not be inferred that all of the low end (or high end) of the range refer to one specific MRF, but rather it was common that each MRF was relatively efficient in sorting some materials and not necessarily in another material. In fact, no one MRF examined across Canada stood out from the others as having higher overall productivity.

Table 3.1
Observed Material Sorting Rates for Containers - Baseline

Material	Low (kg/hr)	High (kg/hr)
HDPE (natural)	200 kg/hr	360 kg/hr
HDPE (coloured)	225 kg/hr	360 kg/hr
HDPE (mixed)(1)	140 kg/hr	300 kg/hr
PETE	100 kg/hr	260 kg/hr
Rigid Plastic Containers	60 kg/hr	120 kg/hr
Plastic Film	25 kg/hr	50 kg/hr
Polystyrene	40 kg/hr	55 kg/hr
Glass (flint)	380 kg/hr	490 kg/hr
Glass (coloured)	200 kg/hr	525 kg/hr
Glass (mixed)(2)	380 kg/hr	500 kg/hr
Polycoat	50 kg/hr	270 kg/hr
Juice Boxes	80 kg/hr	120 kg/hr
Containers Residues	100 kg/hr	250 kg/hr

(1) Mixed HDPE includes both HDPE natural and HDPE coloured.

(2) Mixed glass includes all colours of glass.

Table 3.1 shows there is a broad range of sorting rates for each of the materials. There are a number of factors which contribute to the rates shown. These are outlined in Table 3.2, along with an indication of the impact (low, medium, high) on the sorting rates seen.

Table 3.2
Factors Affecting Sorting Rates

Factor	Impact on Sorting Rate	Reason
Number of materials being sorted from a single belt	High	• The more materials on the belt, the harder it is for each sorter to see his/her assigned material(s). • With more materials on the belt, sorters may be required to move material out of the way to get at their assigned material(s). This non-sorting action decreases sorting rates.
Plastic film/Bagged material	High	• Materials still in plastic bags or covered by plastic film caused sorters to take too much time emptying and/or moving bags to "see" the material they were responsible for sorting.
Conveyor belt speed	High	• Sorters have to be given reasonable opportunity to sort their assigned material(s). If the belt speed is too fast, they cannot react quickly enough to sort the material.
Presentation of material	High	• Sorters can only sort material if it is in front of them. If there is no material to sort (e.g., if the infeed conveyor is not kept full), then the sorters cannot sort. (See also Chapter 4.1 for a discussion of peaking).
"Re-sort" (recirculation of negatively sorted material to be resorted for higher capture rates)	High	• Because there are relatively lower quantities of each of the materials to be sorted from the re-sort and yet, because of line configuration, the same number of people are required to man sorting stations, this activity lowers overall average sorting rates.
Picking ergonomics	Medium	• Sorters who have to throw the material to their side or behind them sort at rates slower than those throwing to bins, chutes in front of them. The

		amount of motion required to sort to the front is lower than to the side or back.

Table 3.2 (cont'd)
Factors Affecting Sorting Rates

Sort Order	Medium	• Picking lower volume (lower quantity) materials ahead of high volume materials results in a lot of wasted (non-sorting) movement moving materials around on the belt looking for smaller quantities of material rather than picking material from the belt.
Glass on the sorting conveyor	Medium	• Where workers have to deal with glass on the sorting belt, for fear of being cut, they will tend to sort more slowly.
Full-time versus temporary workers	Medium	• "Temp" agency sorters generally do not sort as quickly as full time sorters. This is due to the general lack of training provided to temporary workers and the lower level of enthusiasm associated with temporary workers as they may or may not be at the facility from one day to the next.
Backsplashes	Low-Medium	• Where sorting is forward, without backsplashes at the back of the chutes (i.e., where the back and sides) of the chute are higher to catch material), sorters have to slow down to ensure the material goes into the chute rather than on the floor. With the backsplash, the relative need for throwing accuracy is reduced.
Burden depth	Low - Medium	• The burden depth generally only affects the first few sorting stations as the total quantity of material may make it difficult to sort the required material. However, this is overcome by sorting the high volume (quantity) material at the first stations (e.g., PETE or HDPE on the containers line or OCC on the fibres line).

3.2 Product Quality

The quality of the product being sorted by the MRFs included in the study varied dramatically with much of the variation being a response to the material specification requirements of the various end markets. This, in turn, affected the productivity of the MRF. The product quality requirements/issues seen in the first visit to each of the MRFs is shown in Table 3.3.

Table 3.3
MRF Product Quality Requirements/Issues

Requirement/Issue	Cause/Impact
High market specification for ONP	• ONP #9 was required/wanted by the end market. Increased sorting staff levels at the MRFs (to manually remove coloured flyers) raised costs.
High market specification for PETE	• PETE market demanded that PP caps be removed from soft drink bottles. Removal of the caps resulted in much lower sorting rates for PETE and increased costs.
Cross-contamination in storage	• Having HDPE overflow mix with PETE overflow in the holding bunker caused a downgrade in the material at the end market. In some instances bales were returned for re-sorting. Lost revenues or increased costs resulted. • ONP in mixed paper caused a downgrade of the mixed paper bales. Lost revenue resulted.
Glass on the sorting line	• Glass shards on commingled sorting lines sticking to other materials resulted in slower sorting rates and lower capture rates for plastics. Higher costs and lower revenues resulted.
Contamination in steel containers	• Materials not properly debagged (from grocery bags) would be caught by the ferrous magnet. This caused a downgrade or rejection of steel can bales at the end market. Lost revenue or increased costs resulted.
Residues in the negative sort	• With the belt moving too quickly the plastic film, OCC and boxboard was not being adequately removed from the ONP. This caused a downgrade of the #8ONP to #6ONP and a consequential reduction in revenue.
Contamination in sorted materials	• The sorting belt moving too quickly causes some sorters to overthrow material as they try to act quickly to sort the material. As a result materials get put into wrong bunkers. The material gets baled with high contamination rates. This results in the downgrade and lower revenues.

3.3 Material Processing Costs

To determine the costs to process individual materials within each of the facilities, activity-based costing (ABC) was used. For example, a ferrous magnet is installed to sort steel containers. Therefore, the capital and operating costs are assigned to steel containers only. In another example, assume a MRF

has two people assigned to the sorting of PETE and polycoat. Based on observations and sorter activity studies undertaken during the MRF visits, if it is determined that 90% of the time of the two sorters is spent sorting PETE and 10% is spent sorting polycoat, 90% of the labour cost of those two sorters would be assigned to PETE and 10% to polycoat.

The material processing costs outlined in this section (Table 3.4) incorporate:

- Equipment annualized capital costs (e.g., depreciation on capital equipment);
- Equipment operating costs; and
- Labour costs.

Because of the varying nature of the buildings, the value of real estate across the country and the differing levels of administration associated with recycling (e.g., public versus private, large company versus small company, etc.), these costs are not included. The costs included were considered to be independent of location or administrative differences. There are no revenues included in the costs shown.

There was some variation in the costs to process plastics. This was due to a number of factors. Plastic film management costs were much higher than those shown in those programs that had to debag the containers while recovering the film for recycling rather than throwing it away as a residue.

Economies of scale impacts the costs. In those facilities that relied on manual means to sort materials, if there was not enough material to keep a sorter busy 100% of the time, the cost to sort each individual material increased. Having to colour sort plastics (e.g., clear PETE and green PETE) to meet a local market specification increased the cost to sort the plastics above the cost shown in Table 3.4 as additional staff time and storage space was required.

Those MRFs located in provinces with deposit legislation on beverage containers also tended to have higher processing costs than shown as the MRF had to have sorters assigned to removing the deposit

containers from the other containers (e.g., deposit PETE soft drink containers from non-deposit juice PETE).

In an effort to increase recovery rates, many facilities recirculated the negatively sorted material. Because of the number of materials being sorted and the limitations of sorters to sort multiple materials, staffing levels had to be kept at the same level as during the first sort of the incoming material. On the re-sort, each sorter, on an hourly basis, removed much less material. However, all of each sorter's time had to be allocated to the individual materials. On a cost per tonne basis, those facilities doing re-sort generally had higher processing costs per material.

Table 3.4
Materials Processing Costs Before Changes Were Made to the MRFs (1)

Material	Processing Cost Per Tonne
PETE	$200
HDPE (natural)	$220
HDPE (coloured/mixed (2))	$270
Other Rigid Plastic Containers	$290
Plastic film	$410
Aluminum	$240
Steel Containers	$40
Polycoat/Juice Boxes	$115
Clear Glass	$40
Coloured Glass	$15
Mixed Glass (3)	$20
Residues	$15

(1) Costs shown do not include any negatively sorted costs - all materials are assumed to be positively sorted (i.e., labour and/or equipment are used to sort the material).
(2) Mixed HDPE includes natural and coloured HDPE bottles.
(3) Mixed glass includes clear glass and coloured glass.

4.0 Observations and Measurements After Changes

4.1 Common Points Where Problems Occurred and Changes Should Be/Were Made

An important aspect of the project was to take what was learned in the review of one MRF and, wherever possible, apply the knowledge to other facilities. Outlined in this section are twelve operational areas which impacted on productivity, product quality and/or operating costs in two or more of the MRFs examined. These points of review which have been divided into three areas, provide a checklist for the MRF operator against which he/she can check his/her MRF.

A) MRF Equipment and Configuration

1. Infeed Belt Angle
2. Screen Placement
3. Sorting Conveyor Belt Speed
4. Materials Movement
5. Material Storage

B) Sorters/Sorting Function

1. Plastic Film Removal
2. High Volume to Low Volume
3. "Re-sort"
4. Picking Ergonomics
5. Backsplashes

C) Administration

1. Training Investment in MRFs
2. Full-time vs. Temporary Workers

4.1.1 MRF Equipment and Configuration

1. Infeed Belt Angle

PROBLEM: Infeed conveyor too steep causing cycling of heavy and light materials

It was a common problem that the infeed conveyor to the raised sorting conveyor was too steep (i.e., greater than 40 degrees) As the heavier materials (i.e., glass and steel containers) naturally filter their way to the bottom of the pile on the tipping floor, they would tend to fill up the infeed pit and all the space between the cleats on the infeed conveyor. The lighter materials, which tend to bubble or float to the surface on the tipping floor, would be constantly displaced by the heavier materials until there finally was no heavier material to fill the infeed conveyor.

This alternate filling by one type of material (heavies) and then the other (lights) would result in peaking on the sorting conveyor. The sorters of heavy materials (glass) would be "overworked" (i.e., have to sort at an unsustainably high rate) for a period while the sorters for the light materials would have very little or nothing to sort. As the infeed conveyor would empty of heavies and fill with light materials, then the glass sorters would not have enough material to keep them busy while the lights sorters (plastics, polycoat and aluminum) would be "overworked".

One impact of this cycling of feedstock is that the utilization rate of the sorters is lower than optimal and in some cases, the MRF has to put unnecessary, additional sorters on the line to manage the peaks of material. This results in increased MRF operating costs. Another impact with peaking is that if the material is presented in too large a quantity for efficient sorting, some of the material may be missed and end up in the residue stream (assuming a negative sort on the residues). For high value materials, this reduces potential MRF revenues.

PROBLEM: Infeed conveyor too steep causing tumbling of material from conveyor

Travelling up the infeed conveyor the materials generally "lock" together and do not move. However at the top of the infeed just as it is about to drop the materials onto the sorting conveyor, the materials tend to break free with one or more tumbling back down the infeed conveyor. As the container tumbles down the conveyor, it knocks other containers loose and they too start tumbling. Soon an "avalanche" of material falls back into the infeed pit. Because the light materials, which usually float on the surface of the heavier materials, are more easily knocked loose and fall back to the infeed conveyor, this action also contributes to the peaking problem on the sorting conveyor.

This decreases the efficiency of the MRF as the material again has to travel up the infeed conveyor. Also, until a full conveyor of material reaches and passes the top, the sorters on the line have less material to sort. This lowers their overall utilization rate.

OBSERVATION FROM THE MRF VISITS:

It was noted that although the plastics float above the heavier materials, if a plastic bottle or container came free at the top of the conveyor and tumbled down, there was a much lower probability that a significant avalanche would result. The plastic bottle or container did not have enough mass or could not gather enough momentum to dislodge other materials. However, if a glass bottle or large metal can (e.g., 48 oz juice can) started tumbling, it would usually knock much more material loose, creating the avalanche.

SOLUTIONS: 1) Lower the infeed conveyor angle

2) Flatten light materials prior to sorting

In those facilities that did not have a high infeed conveyor angle, the problems of material peaking or tumbling on the infeed conveyor were not as pronounced. The light materials would stay on top of the heavier materials as they travelled up the infeed. At the top, the materials do not break free and start

tumbling back as often. The utilization of the infeed conveyor was much greater and a better mix of light and heavy materials was present on the sorting conveyor.

Lowering the infeed conveyor angle to overcome the problems of a high infeed conveyor angle, requires increasing the length of the infeed conveyor and, in many instances, extending an infloor infeed pit. In some cases, cost and space requirements make this option prohibitive.

A second means of overcoming the problems would be to flatten the light materials prior to sorting. In a test done in one facility where flattened bottles were mixed in with glass and metal containers on the tipping floor and then fed into the infeed conveyor pit, the incidences of material tumbling were almost completely eliminated. More importantly, the cycling of heavies then lights, etc. was eliminated. The overall efficiency of the MRF was increased and it was determined that if all material was received or sent up the infeed conveyor flattened, the sorting staff could be reduced by approximately 10%.

To achieve the greatest overall increase in recycling program efficiency, the flattening of the materials should be done prior to collection. "Step-on-it" programs, where the public is asked to step on their plastic and aluminum containers and squeeze the top of steel containers, are contributing to achieving the increased onboard weight of the truck. Other alternatives include the installation of flatteners in the MRF or on the collection truck. Each of these require a capital expenditure and some ongoing maintenance costs.

2. Screen Placement

PROBLEM: Screens to sort out small glass or residues placed at end of sorting conveyor

Screens are in widespread use for sorting out products (e.g., broken (aggregate) glass) or removing unwanted material (e.g., small residue). For those facilities that have one stream of commingled containers, glass management can pose problems. Many MRFs are using screens in varying configurations.

Gravely type screens have raised elongated v-shape protrusions that, with the shaking table, break up the small glass and allow it to drop through slots. The light non-breakable material travels over the top of the gravely type screen and onto the next sorting conveyor. A trommel screen is a rotating cylinder placed on a slightly declining angle with holes of one or various sizes. The material enters the front end of the trommel and as the trommel rotates, the material falls through the holes. A shaker screen is characterized by a metal mesh screen with openings of usually one size. As the material passes over the shaking screen, materials of a given size fall through the openings in the mesh.

All of these screens are used for glass screening whereas only trommels and mesh screens are generally used for residue sorting. In more than one location, the glass screen was placed at the end of the sorting conveyor. It was observed that the presence of broken glass (up to 40% by weight) on the sorting belt slows down the picking rate of the sorters, decreased the overall capture rate of the materials and increased the contamination rate of the sorted products.

SOLUTION: Place the glass screen in front of the sorting conveyor

In those facilities with the highest sorting rates for commingled containers, the glass screen was placed at the beginning of the sorting line, just after the debagging/decontamination/pre-sort station (as appropriate) and the ferrous magnet. By removing the glass up front, the sorters only have to remove whole (or almost whole) glass containers and the remaining containers. With increased sorting rates, overall labour costs are lower and ongoing maintenance costs can be reduced.

3. Sorting Conveyor Belt Speed

PROBLEM: Sorting conveyor belt moving too quickly

The problem of having the sorting conveyor moving too quickly was almost universal. The two most common reasons given for the belt moving too quickly were: 1) To increase throughput; and 2) To spread out the material so the sorters could better see the material. They theorized that if the material is

not getting adequately sorted in the time allotted, by speeding up the sorting conveyor belt, sorters would be forced to work faster. However, in reality, having the sorting conveyor belt moving too quickly led to a number of problems in the MRF:

- A high residue rate or contamination rate of the negatively sorted material (if it is decided not to recirculate the negative sort);
- Requirement to recirculate ("re-sort") the negative sort (i.e., the material that falls off the end of the line) in order to increase recovery rate;
- A high contamination rate in the sorted materials (as sorters overthrow materials and they end up in the wrong bunker) resulting in downgrades on materials and revenues received;
- Having to add more sorters to handle the material as it travels along the sorting line or to sort the re-sort, thereby increasing costs..

SOLUTION: Slow the sorting conveyor belt to optimum speed

Decreasing the belt speed at each of the facilities had various impacts on the sorter utilization rate, product capture rates and time required to sort materials. To achieve benchmark sorting rates for specific materials, it is imperative that the motions of the sorters be limited to picking materials from the belt and not having to pull material back in front of them as it has passed by them with the belt moving too quickly. Slowing down the sorting conveyor increases the time that the sorters spend sorting.

Using the Materials Recovery Facility - Processing Cost Model (MRF-PCM), estimates of required belt speeds were made and compared to the actual belt speeds used in the MRFs. The belt speed was slowed in all of the facilities.

With one exception, all MRFs where the conveyor belt was slowed (from 20% to 40%) immediately experienced increased productivity (by up to 40%), decreased residue rates (by up to 50%) and/or decreased the time required to sort the same quantity of material (by up to 33%).

OBSERVATION FROM THE MRF VISITS:

The recommendation to slow the conveyor belt speed does not apply to the infeed conveyor as this would decrease the throughput of the MRF.

It is important that the MRF have a good shift supervisor or lead sorter when slowing down the conveyor belt because on more than one occasion, when slowing down the belt, the sorters also slowed down, thinking that they did not have to sort at a fast pace.

4. Material Movement

PROBLEM: Materials being handled unnecessarily

After the material is tipped into one area by the truck, it is picked up by a front-end loader and moved to another area of the MRF. The extra handling binds materials and breaks glass, increases the difficulty of sorting, increases costs and makes sorting less safe.

Unnecessary handling or double-handling of material was a problem encountered at some facilities. In one facility, because of the discharge direction of the ferrous magnet to the bunker, the steel containers then had to be picked up and transported to the other side of the line to be placed on the infeed conveyor to the baler. This took up time of the front end loader operator.

SOLUTIONS: 1) Load the material directly to sorting process to reduce double-handling
2) Direct all material flow to reduce unnecessary handling

Material handling should be designed to eliminate double-handling as much as possible. For the containers from the tipping floor, the front end loader should pick them up once and place them in the

infeed hopper. This will reduce the glass breakage and material binding, making it safer and faster for the sorters. It will also increase the productivity of the loader operator by 50%.

In one specific example, not having to sort the double-handled materials resulting from the elimination of the re-sort, decreased sorting staff requirements by 30% on the containers line and reduced overtime by 50%.

By redirecting the ferrous magnet to discharge steel containers on the other side of the sorting conveyor, the additional handling of the steel containers by the front end loader was eliminated.

OBSERVATION FROM THE MRF VISITS:

Much of the double-handling of materials from the tipping floor to other areas of the MRF was a result of not being able to keep up with the flow of incoming material combined with having to manage the re-sort (See separate discussion on re-sort). The re-sort problem arises primarily because the sorting conveyor is moving too quickly and the sorters cannot effectively sort the material on the first pass. Slowing of the sorting conveyor eliminated, the problem of double-handling of the re-sort material from the tipping floor to a temporary storage area.

5. Material Storage

PROBLEM: Cross contamination of material on the tipping floor

Because of the nature of the tipping area, there is cross contamination of two compartments of material from the truck (e.g., ONP being mixed in with the mixed waste paper (MWP). The efficiency of the curbside separation of the materials is lost. Additional staff have to be assigned to separate the materials or, alternatively, this causes a substantial amount of revenue to be lost (e.g., ONP downgrades of the MWP).

PROBLEM: Ineffective storage space or use of storage space for sorted materials

The height of the sorting conveyor combined with the natural angle of repose of the sorted materials, restricts the quantity of material that can be effectively stored. This storage limitation was specifically a problem in those facilities that did not use screen doors or gates on one end of the bunker to hold back material. This limitation creates three problems:

- Constant need to change material being baled in order to ensure sufficient space for storage;
- Increase time requirements for the front end loader/skid steer operator to empty bunkers to keep up with storage demands; and
- Cross contamination of materials at the opening of the storage bunkers as materials spill out.

With some balers, (i.e., single-ram balers) the change from one material to another sometimes leads to the first bale of the new material bursting (usually the bottom bale wire) due to the nature of the loading of the material into the baler chamber. This would increase the time requirements for either the baler operator having to hand strap the bale (if it can be saved) or for the forklift/front end loader operator having to recirculate the material to the baler infeed conveyor to have the material rebaled.

PROBLEM: Cross contamination of the materials in the Work-In-Progress (WIP) area

Cross contamination of materials at the front of the storage areas (work-in-progress areas), pre- and post-sorting, causes another set of problems:

- Increased time requirements to resort the cross contaminated materials; and
- Downgrading of material by the end market resulting in reduced revenues.

SOLUTIONS: 1) Block off space on the tipping floor for each compartment of material
2) Use alternative storage methods for incoming material

3) Look at use of height as means of increasing storage space for sorted materials

4) Extend length of bunker walls to cut down on cross contamination of sorted materials

5) Look at use of conveyors or blowers to move materials to a larger pre-baling storage area

Generally, incoming vehicles are directed to unload each compartment of material within a given small area. Cross contamination only becomes a problem later in the day once trucks are unloading for the second time. By putting in moveable (and removable) block walls on the tipping floor, material can be better contained. This will also increase the effective storage area on the tipping floor as the material gets piled higher. This approach is in use in/and proposed for those facilities that use a front end loader to load the infeed conveyor pit.

An alternative to blocking off areas for material is to use an alternative storage method for the material. This approach was used for one MRF (See Figures 4.1 and 4.2). In the facility, cross contamination at the foot of the sorted ONP was a problem with the mixed waste paper (MWP) next to it on the tipping floor. As the ONP only had to be beneficiated on the floor (i.e., a full conveyor sort of the material was not required), extra work was constantly required to resort the mixed material and downgrades of the MWP were common.

The approach was to have the sorted ONP put into two rolloffs located in a dead space on the tipping floor. Once full, new rolloffs could be put into place.

Where materials are moved to another part of the MRF for storage, either prior to sorting or prior to baling, the efficiency of space can be increased by increasing the effective height of the storage space. For containers, and specifically plastics, this can be done through the installation of metal mesh screen walls extending up from the top of the current wall.

Figure 4.1
ONP: Old Management Process

Figure 4.2
ONP: Revised Management Process

In the WIP area where the sorted materials extend beyond the end of the bunker wall and cross contamination becomes an issue, installing metal mesh gates at the end of the walls can increase the effective storage area of the bunker (i.e., by creating a cage). Alternatively, using concrete highway barriers (typically 1m in height) placed at the edge of the bunker wall will increase the length of the bunker and decrease the opportunity for cross contamination. These barriers come in various lengths.

For those facilities that are handling a large quantity of high volume plastics, another alternative is to move the materials from the sorting bunker to a secondary area for storage prior to baling. Storing a larger quantity of each plastic resin increases the efficiency of the baling process.

The use of conveyors for glass movement from sorting to glass crushers and/or outside storage is becoming more prevalent as a means increasing the area within the MRF for the storage of other materials. Conveyors or blowers could be used to move the plastics to another part of the MRF. Using conveyors to move materials eliminates the double-handling of materials and the need for additional staff and rolling stock to move materials from one area of the MRF to another. In one facility, through the redirection of materials, one front end loader was eliminated.

4.1.2 Sorters/Sorting Function

1. Plastic Film Removal

PROBLEM: Plastic film management

In those programs that accept materials set out at the curb in plastic bags, the removal of materials from inside the plastic bags and the management of the plastic bags is a problem. If the plastic film is left on the sorting conveyor, it is very difficult for the sorters to remove their assigned materials as the film covers material or holds the materials inside the bag.. This reduces the capture rate for the materials on the belt and decreases overall sorting rates as the sorters have to move material around, searching for their assigned materials.

If steel containers remain inside plastic bags, the ferrous magnet will pick up the steel containers and all the other materials inside the bag. This results in either high contamination rates for the steel containers for which a reduced revenue is received or additional sorting time has to be devoted to removing the contaminants.

In some market areas, plastic film in fibre products will result in downgrades or render the fibres unmarketable.

The general public tying off the top of the bags and/or tying multiple bags together increases the time for processing plastic film.

SOLUTIONS: ***1) Remove all of the film at the first sorting station***

2) Educate the public about how to put material out for collection

3) For bag based programs, install a bag opener

To achieve benchmark sorting rates for specific materials, all plastic film must be removed before any of the sort stations assigned to specific containers or specific fibres. The first sort station(s) should debag the material and remove the plastic film. An effective approach implemented in one facility was to place a chain across the infeed conveyor approximately 1m above the floor. This loose chain acted to grab the plastic film for a long enough period of time that one person could effectively remove more than 80% of the film at that point. This change replaced two people removing film at the first sort station who combined were only able to remove approximately 50-60% of the film.

In removing more of the plastic film at the floor sorting station, the overall sorting rate of each of the sorters on the line increased by approximately 40% as it became much easier to see the material. Also, residue rates were also greatly decreased and the need to resort the residue materials (i.e., re-sort) was eliminated.

Education of the public on how to set materials out at the curb is still one the most important tools available to the MRF operator to increase the efficiency of the facility. Elimination of the public tying off the top of the bags can increase the rate at which the fibres or containers can be debagged at the MRF. Picking up the material, but having reminder tags to place in the curbside container asking people not to tie off bags or tie bags (or even containers - e.g., milk jugs tied together) can help educate the public. This will increase the sorting rates for each of the sorters and decrease the contamination rates.

For those facilities managing bag based collected materials, there are a few bag openers available in the marketplace to debag materials. Combined with a vacuum blower to take the film from the infeed conveyor to a film baler, the requirement to place a number of people at the front of the sorting line to debag the materials is eliminated. A debagger to handle up to 10 tonnes of containers per hour has a current installed cost of approximately $35,000-$70,000. Therefore, the payback period would be one

to two years (assuming it replaces two debagging sorters). After payback, it could save the facility approximately $35,000 per year. Depending on the configuration of the sorting line, it could remove the need of a bunker for the plastic film.

2. High Volume to Low Volume Material Sorting

PROBLEM: Material sort order impeding sorting rates

In some facilities the sort order requires that sorters "dig" through or move a lot of material to get at a relatively smaller quantity (i.e., volume) of material (e.g., picking clear glass before PETE or HDPE bottles). Having to pick through a large volume of material to pick glass also has the potential for injury as the sorter(s) cannot see a sharp edge.

SOLUTION: 1) Sort materials from the belt from high volume to lower volume

HDPE and PETE generally take up a lot of the space on the belt, are easy to identify and, because of their relative size, are easy to grab and sort. After removing the oversize materials and plastic film, removing the high volume plastics (HDPE and/or PETE) at the first sort stations allows the sorters further down the line to see the lower volume materials (e.g., aluminum cans, polycoat containers, clear and coloured glass, etc.).

This also works on the fibres line, where high volume refers to OCC and, in some programs, boxboard (OBB). These two materials tend to hide other fibres in the stream (e.g., MWP) making them difficult to sort.

3. Re-sort

PROBLEM: Recirculating and resorting materials

There are two types of re-sort that occur in MRFs:

1. The recirculation of the negative sort materials from off the end of the sorting conveyor. This material is retransported to the infeed conveyor to be sent back up the sorting conveyor for resorting to capture more material.

2. The second type of re-sort is where two or more materials are sorted into one bunker (e.g., PETE and HDPE) only to be sorted later into separate streams.

Both types of re-sort cause a number of problems for the MRF:

- Capacity lost by having to take time to do the re-sort instead of new material from new sources;
- Increased labour and operating costs to pick up the material and circulate it back from the end of the conveyor to the infeed conveyor;
- Increased labour and operating costs to sort the materials to increase the capture rate; and
- Increased wear on the conveyor belts rerunning broken glass (as applicable).

SOLUTION: 1) Examine MRF processing operations to eliminate re-sort

A. Examine the conveyor belt speed

- Assuming that the sorters are trained in their jobs and are working to a reasonable level (e.g., using both hands to sort), the primary reason seen for the sorters not being able get everything on the first pass is the conveyor belt moving too quickly (See Section 4.1.1). The missed materials have to be recirculated from the negative sort.

B. Review the sort order

- The sort order for the materials and contamination hindering the sight of the assigned materials should be examined and changed to improve the sorting rates.

C. Eliminate planned double sort

- The MRF should be configured to eliminate the double handling of material (e.g., sorting HDPE and PETE into one bin to be resorted later)..

OBSERVATION FROM THE MRF VISITS:

Re-sort was reducing the productivity and decreasing the throughput capabilities at four of the MRFs in the study. At one of the facilities, re-sort accounted for approximately 35% of the total throughput of the facility. At another facility, up to 50% of the material sorted from the line on the first pass was missed and had to be recirculated for resorting. The re-sort at these facilities resulted in overtime or an additional shift having to be put on to handle the material.

As a result of changes implemented at these facilities, re-sort has ceased and savings in excess of $300,000 per year are being realized.

To increase recovery rates and to eliminate re-sort, in all instances, in the MRFs included in the study, the conveyor belt speed was reduced (between 20% and 40%). In two facilities, the sort order was changed and in another the management of plastic film was improved. After the changes were implemented, all facilities have eliminated re-sort. These changes have helped the MRFs increase capacity by between 20% and 35%, decreased residue by up to 50% and increase sorting rates by up to 40%.

4. Picking Ergonomics

PROBLEM: Excessive reaching of sorters required to sort materials

The reasons for excessive reaching for materials varies between facilities but generally occurs when the width of the sorting belt exceeds one metre (1m) or the height of the sorting belt exceeds 1m. This causes backstrain and shoulder strain for the sorters.

PROBLEM: Sorting to chutes or bunkers behind or to the side of the sorters

A common MRF configuration is to have the sorters pull materials off the sorting conveyor and place/throw them into chutes, bunkers or bins located beside or behind them. This requires that the sorters twist to reach the depository or reach backwards which increases the strain on their shoulders. The sorters that sort in this manner tend to tire more quickly than those sorting to bunkers/chutes/bins in front of them. More importantly, sorting rates to the back or side are not as high as sorting to the front.

SOLUTION: ***1) Raise the sorting floor***

2) Put in brushes to move the materials closer to the sorters

3) Have the sorters throw materials forward into bunkers/bins/chutes

By putting in a semi-permanent or false raised floor the entire width of the sorting station (small platforms, e.g., 1m x 1m, can create a tripping hazard and, therefore, are not recommended) sorters of all heights can more effectively reach materials on the belt. The height of the outside edge of the sorting conveyor should not be any higher than a kitchen counter (i.e., approximately 90 cm from the floor). This will alleviate much of the backstrain for the sorters and increase sorting rates.

Installing brushes to move materials closer to the sorters is a common industrial engineering approach. The brush can be welded to any point along the sorting conveyor and where sorting is done from both sides can be installed on either side. This reduces the reach required by the sorters which will increase the sorting rate and decrease the strain on the back and shoulders of the sorters.

To alleviate the back and shoulder strain associated with sorting materials to the side or back of the sorters, the sorters should be reconfigured to throw the materials forward into the chutes/bunkers/bins. This may entail building a catwalk on the other side of the sorting conveyor or simply realigning them to be in front of the bunker chute on the opposite side of the sorting conveyor. In one facility where sorting rates were measured sorting to the side into chutes and forward into a bunker, it was determined

that the sorter throwing forward could maintain a sorting rate up to three times the sorter pulling the material back.

5. Backsplashes

PROBLEM: Extra time required to pick up or resort misthrown materials

Where the sorters are throwing forward into chutes or bunkers, if there are no backsplashes, it is common that materials do not hit the targetted opening, but rather end up in the wrong bunker/chute/bin or on the sorting conveyor floor where they become a tripping hazard. Also, additional time is required to cleanup the materials on the floor.

Overthrowing of material into a bunker results in material ending up in the wrong bunker. This results in additional time having to be spent resorting material or can result in downgrading of material by the end market.

SOLUTION: 1) Place backsplashes up in chutes or above the bunkers

Backsplashes at least one metre in height should be placed inside the chutes. This will help the sorters as they will not have to be as accurate in sorting the material when throwing forward. In two of the MRFs in the study, backsplashes were installed in the chutes. It was estimated that sorting rates could be increased by up to 25%.

Placing nets as backsplashes up across the bunkers will act to deflect the materials down into the bunker. This will reduce cross contamination and potentially increase sorting rates as the sorters do not have to concern themselves with overthrowing material (as can happen when a sorter has to respond to a large quantity of material passing in front of him/her over a short span of belt). The backsplashes also reduce the amount of material that has to be cleaned up from the floor at breaks and the end of the shift. Reduction of cleaning time of approximately 30 minutes per shift can occur.

4.1.3 Administration

1. Training Investment in MRFs

PROBLEM: Increased level of training required to improve operations

In a number of the facilities, training appears to be minimal for MRF staff and management. For example, in a number of facilities staff and management operated on the incorrect assumption that "if you are behind then speed up the belt". The impact of this action, e.g., sorters trying to catch and hold back material, stretching and moving on the line, contamination between bunkers, missed material requiring re-sort, adding more sorters, etc. results in higher costs, decreased throughput and decreased product quality.

SOLUTION: 1) Increase level of training for MRF staff and management

Proper training of the sorters is required to let them know that the material will not be recirculated. Limit the number of materials for which a sorter has responsibility, thereby allowing each person to focus his/her attention on only one, two or three materials. This will keep each person from sorting a small quantity of many materials. As a result, each person will sort a larger quantity of one material (See Chapter 4.2 for a discussion of benchmark sorting rates).

OBSERVATION FROM THE MRF VISITS:

Sorters in most facilities have been conditioned that when the sorting falls behind and the belt is sped up, the sorters are expected to sort faster. In moving to slow the belt to increase productivity and eliminate re-sort, the sorters, because of their conditioning, think that the slower belt means that they are ahead of schedule and, therefore, do not have to sort as quickly.

It is important that the management or lead hand explain that the slowed belt means that the material will not be recirculated and that the sorters must continue to work efficiently.

Increased training in the following areas have been identified for plant managers and supervisors:

- industrial engineering/plant operations;
- personnel management;
- project/time management; and
- continuous improvement.

The entire MRF sorting functions should be reviewed to understand how and why things happen in the MRF (e.g., why high sorting rates are not being achieved, why contamination rates are high, etc.). In all MRFs in this study (and those in the United States included in an identical study), there were opportunities to improve the efficiency, decrease the costs and/or increase the product quality. With better training for staff and management, many of these opportunities would have been recognized and changes could have been made promptly.

OBSERVATION FROM THE MRF VISITS:

Many MRF operators are constrained in what they can do in the MRF with respect to making changes as a result of directives from management and/or constraints on their time just keeping the facility operating. In speaking with the MRF operators at each of the facilities, many of them had proposed some of the changes put forward for their facilities, but they could not get approval to make the change, the money was not available to make the change which would save money for the facility in the longer term or they did not have enough staff to help implement a change.

2. Full-time vs. Temporary Workers

PROBLEM: Effectiveness of temporary staff workers as sorters

Temporary staff sorters were used by a number of facilities examined in the study. Done to save money by not having to pay higher wages and benefits, these facilities also showed:

- lower sorting rates;
- higher staffing levels;
- poorer capture rates for materials; and
- poorer material quality.

Because the staff brought in daily could vary almost daily, it is difficult for the MRF supervisor to assign people to sort materials with little or no training and know that a good job will be done. Additional time is also required by the supervisor to "keep an eye" on the staff to ensure they are working to an acceptable level. At one facility, it was noted that two of the sorters rarely if ever used more than one hand to sort materials. By default, even assuming that they used their dominant hand, they could never achieve a greater than 60% utilization rate.

SOLUTIONS: ***1) Use full-time staff***

2) Have a full-time lead hand/lead sorter

It was apparent that the most effective sorters were full-time staff. This also alludes to the issue of training, as full-time staff do not require as much training and the operations do not have to incur a learning curve on as frequent a basis.

At a minimum, a full-time lead sorter should be hired by MRFs to keep sorters moving at a reasonable rate and to report to the MRF supervisor. This system would help the supervisor when calling for temporary staff workers to know who to request or avoid.

4.2 Benchmark Sorting Rates

A benchmark is defined as a value against which others (i.e., facilities, sorters, etc.) are measured and compared. Benchmark sorting rates are defined as the highest sustainable sorting rate (i.e., sorting was maintained over a continuous period). The benchmark sorting rates are a culmination of results from the six MRFs studied in Canada and the six MRFs examined in the United States (Table 4.2). It should

be noted that the highest sorting rates for plastics and glass were seen in those facilities that used an air classifier system to separate the lights from the heavies (i.e., the plastics and aluminum from the glass). All rates shown are per sorter.

Peak sorting rate is defined as the rate at which a sorter can sort material over a short (ten minutes or less) period of time only (i.e., it is not sustainable over a full shift). Peak sorting rates were measured for PETE and HDPE at one facility in the United States. The study showed that sorters, when required, could sort at levels approximately 20-40% higher than the benchmark sorting rates shown in Table 4.1.

Because of the nature of the fibres markets and changing fibres streams that are sorted, deriving standard or benchmark sorting rates for fibres can be difficult. The numbers presented here (Table 4.2) are based on observations from the MRFs in the study and discussions with MRF operators. All rates shown are per sorter.

Table 4.1
Plastics and Glass Benchmark Sorting Rates

Material	Benchmark (kg/hr/sorter)
HDPE (natural)	450 kg/hr
HDPE (coloured)	420 kg/hr
HDPE (mixed)(1)	450 kg/hr
PETE	450 kg/hr
Tubs (mixed plastics)	200 kg/hr
Glass (flint)	600 kg/hr
Glass (coloured)	600 kg/hr

(1) Mixed HDPE includes both HDPE natural and HDPE coloured.

Table 4.2
Paper Benchmark Sorting Rates

Material	Benchmark (kg/hr/sorter)
Old Corrugated Containers (OCC)	400 kg/hr
Boxboard (OBB)	300 kg/hr
Mixed Waste Paper (MWP)	450 kg/hr
Hardpak (OBB/OCC)	350 kg/hr

4.2.1 Productivity Increases

The sorting rates outlined within this section were determined based on observations taken during the two visits to each of the MRFs. The rates are shown as a range, combining the results from all facilities (Table 4.3). It should not be inferred that all of the lower end (or higher end) of the range refer to one specific MRF, but rather it was common that each MRF was relatively efficient at some materials and not necessarily at another. The magnitude of the impact of a change made within one MRF did not mean that another MRF achieved the same success. However, it should be mentioned that as a result of making changes to five facilities, all of which involved at least two or more of the changes outlined in Chapter 4.1, increases in the productivity per sorter as outlined below were achieved.

Overall, as a result of implementing the changes over the course of the study, the following increases in productivity were recorded:

- Plastics 32%
- Glass 8%
- Polycoat/Juice Boxes 6%
- Container Line Residues (where removed from the sorting belt) 28%

With the increase in sorting rates achieved by sorters at the MRFs, an equivalent of 16 full-time sorters and equipment operator positions have been saved over the five facilities. Overtime has been eliminated at two facilities and material run times have been reduced by up to 33%.

Because the focus of the study was on containers sorting, and more specifically on plastics, not as much time was spent examining the fibres side of the MRFs. Therefore, because the size of the dataset is not of sufficient size, sorting rates for fibres are not available. Over the course of the study, in two of the facilities, the fibre streams that were being sorted changed to accommodate the end markets. This resulted in sorting line configuration changes and new assignments for sorters.

Table 4.3
Observed Material Sorting Rates for Containers - After Changes

	Before Changes Made		After Changes Made	
	Low (kg/hr)	**High (kg/hr)**	**Low (kg/hr)**	**High (kg/hr)**
HDPE (natural)	200 kg/hr	360 kg/hr	250 kg/hr	420 kg/hr
HDPE (coloured)	225 kg/hr	360 kg/hr	300 kg/hr	420 kg/hr
HDPE (mixed)(1)	140 kg/hr	300 kg/hr	250 kg/hr	330 kg/hr
PETE	100 kg/hr	260 kg/hr	150 kg/hr	400 kg/hr
Tubs (mixed plastics)	60 kg/hr	120 kg/hr	90 kg/hr	120 kg/hr
Plastic Film	25 kg/hr	50 kg/hr	45 kg/hr	50 kg/hr
Polystyrene	40 kg/hr	55 kg/hr	40 kg/hr	60 kg/hr
Glass (flint)	380 kg/hr	490 kg/hr	400 kg/hr	490 kg/hr
Glass (coloured)	200 kg/hr	525 kg/hr	350 kg/hr	525 kg/hr
Glass (mixed)(2)	380 kg/hr	500 kg/hr	400 kg/hr	500 kg/hr
Polycoat	50 kg/hr	270 kg/hr	75 kg/hr	270 kg/hr
Juice Boxes	80 kg/hr	120 kg/hr	80 kg/hr	120 kg/hr
Containers Residues	100 kg/hr	250 kg/hr	150 kg/hr	300 kg/hr

(1) Mixed HDPE includes both HDPE natural and HDPE coloured.
(2) Mixed glass includes all colours of glass.

4.3 Product Quality Improvements

During the course of this study, product quality was examined within the MRFs focussing on:

- the amount of money being lost to material downgrades;
- why product quality problems were occurring;
- cost to the MRF to increase the product quality due to operational problems; and
- cost to the MRF to increase the product quality to increase market value of materials (i.e., highgrading).

To specifically address product quality issues, changes were made at three of the MRFs in the study. An outline of what was done and the impact is outlined in Table 4.4.

Table 4.4
Changes Made to MRFs to Address Product Quality

Change Made	Materials Targetted	Impact
• Changed MRF configuration to remove a greater percentage of the plastic film prior to material sorting	All	• Decrease in pre-baling sorting time to remove contamination • Increase in material capture rates in same sorting time (increased revenues and decreased residue disposal costs) • Improvement of #6 ONP to #8 ONP
• Use of rolloffs for storage for ONP	ONP	• Elimination of cross contamination of MWP in ONP storage • Elimination of downgrades
• Installation of eddy current separator	Aluminum	• No further downgrades of aluminum due to contamination from other materials
• Installation of backsplashes on chutes and bunkers	All	• Reduction in cross contamination of materials • Decrease in pre-baling sorting time to remove contamination

Table 4.4 (cont'd)
Changes Made to MRFs to Address Product Quality

Change Made	Materials Targetted	Impact
• Reconfiguration of tipping floor storage for materials	OCC	• Elimination of cross contamination of OCC with other materials on tipping floor
• Reconfiguration of tipping floor storage for materials	MWP Containers	• Elimination of cross contamination of materials on tipping floor • Decrease in sorting time for both streams of materials

Overall, the changes made resulted in the MRFs no longer suffering from downgrades or, in some instances, having bales of materials returned for not meeting specifications. Revenues increased while, in most instances, the changes also resulted in lower staffing levels being required to ready the materials for markets.

4.4 Savings Realized as a Result of the Implemented Changes

Detailed cost data were gathered during the first visit to each of the facilities. These data were important in order to determine cost centres and to identify the amount of money that would be saved with the implementation of each of the changes. To maintain the confidential nature of the cost data for these facilities, the actual costs to operate each MRF before and after the changes were made will not be presented. In Chapter 5.0, individual case studies are presented outlining the process operations in each of the MRFs, the changes made, the costs to implement the changes and the relative savings and/or increased revenues realized as a result of the changes.

Over the five facilities where changes were made (because the nature of the business at the sixth MRF changed so dramatically after the first visit, the Steering Committee decided that to try and measure changes at that facility would not prove feasible) gross costs to the MRFs were reduced by

approximately $0.7 million annually. In many instances, the cost savings were realized through a reduction in staffing levels at each of the MRFs.

In addition to the cost savings, in many facilities, the improvements to product quality improved revenues to facilities by more than $350,000 annually.

Overall, combining cost savings and increased revenues, the net to the MRFs will be more than $1 million dollars annually.

The material processing costs outlined in this section (Table 4.5) use the same assumptions as outlined in Chapter 3.0 and incorporate:

- Annual equipment capital costs (depreciation on capital equipment);
- Equipment operating costs; and
- Labour costs.

Because of the varying nature of the buildings, the value of real estate across the country and the differing levels of administration associated with recycling (e.g., public versus private, large company versus small company, etc.), these costs are not included. The costs included were considered to be independent of location or administrative differences and therefore could be compared. The costs shown are based on the costs to process the materials identified after the changes were made to the MRFs

Not all of the facilities were able to achieve the costs shown in Table 4.5. However, in most instances, it was possible to attribute the increased costs to such things as equipment and building design, etc. In spite of this, a number of facilities that had increased processing costs were, in many instances, able to achieve significant cost reductions within their own facilities through processes described in this chapter. As a result of the changes suggested, the MRFs involved were able to achieve annual savings of $1 million.

Table 4.5
A Comparison of Materials Processing Costs Before and After Changes Were Made (1)

	Before Changes Made	After Changes Made	Improvement
PETE	$200	$150	$50 (25%)
HDPE (natural)	$220	$190	$30 (13.6%)
HDPE (coloured/mixed) (2)	$270	$270	-
Rigid Plastic Containers	$290	$290	-
Plastic Film	$410	$410	-
Aluminum	$240	$115	$125 (52.1%)
Steel Containers	$40	$40	-
Polycoat/Juice Boxes	$115	$115	-
Glass (flint)	$40	$40	-
Glass (coloured)	$15	$15	-
Glass (mixed)(3)	$20	$20	-
Containers Residues	$15	$15	-

(1) Costs shown do not include any negatively sorted costs - all materials are assumed to be positively sorted (i.e., labour and/or equipment are used to sort the material). No revenues are included in costs.
(2) Mixed HDPE includes natural and coloured HDPE.
(3) Mixed glass includes clear glass and coloured glass.

5.0 Conclusions and Recommendations

Action plans were developed for five MRFs across Canada to help them improve productivity, improve product quality and/or decrease overall program costs. Over the five facilities, although more than 30 recommendations for improvement were made, most fell within one of twelve categories. The range and number of changes made at each of the facilities varied although there was one problem that occurred at every facility - the speed of the sorting conveyor. MRF operators indicated that the sorting conveyor speed was most often increased to either:

- increase the throughput; or
- to spread out the material to allow the sorters to better see the material.

Unfortunately this most often lead to:

- sorters spending more time pulling material back in front of them to sort the material;
- unnecessarily increasing the number of sorters to make sure all the material was sorted; and/or
- having to recirculate the negative sort to have it resorted to increase the capture rate.

All three of these activities had impacts on all three goals of the project - productivity, product quality and cost.

Benchmark manual sorting rates were established for containers (i.e., plastics, aluminum, polycoat, and glass). The data used to derive the rates were a combination of the MRFs examined in Canada and the United States. A number of the MRFs in this study are at or approaching the benchmark for a number of materials, although for the two main plastics categories, PETE and HDPE, none are achieving the benchmark rate. The benchmark rate was measured at a MRF in the United States that handles HDPE natural, HDPE coloured, PETE and mixed plastics (#3 through #7) on one sorting line.

In summary, there appears to be a great deal of money being wasted in the sorting of recyclable materials. As a result of changes made at the five facilities, the overall "cost of recycling" was reduced by more than $1 million. If the assumption is made that these savings could be realized across all facilities across Canada (and in the United States where the same problems exist), there is a vast quantity of money being spent on recycling programs unnecessarily.

Much of this is the result of the immaturity of the recycling industry. Most facilities do not employ industrial engineers to run the facilities and training for management and staff is lacking. MRF designers are only now starting to recognize the flexibility required of facilities and equipment as municipalities look to add to the number of materials being collected. Many earlier MRF designs, still in existence today, simply cannot manage the current stream of materials. This leads to low productivity, poor material quality and higher costs than necessary.

End markets also have a large impact on MRF operations. In times of high demand, product quality specifications are relaxed and in times of low demand, material quality specifications often tighten, leading to higher labour costs. Unfortunately, at times of low market prices, MRFs cannot afford the increased costs. Therefore, it is important for MRFs to work with end markets on market specifications and, more importantly, that MRFs bank extra money in times of higher market prices to carry them through low price periods.

MRF designers, MRF operators, supervisors and management all have to work together with the host municipality(ies) to overcome the shortfalls in the current recycling system. Education of the public is also key as some of the problems in the MRFs can be overcome without making any direct changes to current operations but rather educating the public on how to recycle.

Outlined in Section 5.1 are the recommendations coming out of this study. The recommendations are limited to outlining a series of questions that each MRF operator/supervisor should ask respecting their facility. Formulating answers to the problems arising from asking the questions will go a long way to

reaching the goals of increased productivity, improved product quality and decreased program costs not only for plastics but for all materials within the MRF.

5.1 Recommendations

Using the twelve categories of change or improvement as a checklist, there were a series of questions which the Study Team asked or investigated at each facility to help quickly identify opportunities for improvement. These categories and questions are outlined in Table 5.1

Table 5.1
MRF Operations Efficiency Checklist

Category	Questions
A) MRF Equipment and Configuration	
1. Infeed Belt Angle	• Is the angle too great? • Does material tumble back down causing peaking on the sorting lines?
2. Screen Placement	• Is it effective where it is? • Should it be/is it at the front of the sorting line?
3. Sorting Conveyor Belt Speed	• What is the capture rate of the material? • How many sorters are being used to sort X quantity of material? • Do the sorters have to pull material back in front of them to efficiently sort it? • Is it moving too quickly?

4. Materials Movement	• Is there double handling of material?
	• Is there cross contamination of materials
	  • on the tipping floor?
	  • in the storage bunkers?

5. Material Storage	• Is there sufficient storage
	  • on the tipping floor without cross contamination?
	  • in the storage bunkers pre-baling?
	  • in the bale storage areas?

Table 5.1 (cont'd)
MRF Operations Efficiency Checklist

Category	Questions
B) Sorters/Sorting Function	
1. Plastic Film Removal	• Is the plastic film being removed to allow efficient sorting of materials? • Is there a better location to remove the film?
2. High Volume to Low Volume	• Are the materials being removed from the sorting belt in order of high volume to low volume? • Does the sorting order need to be changed to improve sorting rates?
3. Re-sort	• Is negatively sorted material being recirculated for additional sorting? • Are cross contamination problems causing additional sorting? • What is the capture rate for the materials on the sorting belt? • Is the sorting conveyor moving too quickly?
4. Picking Ergonomics	• Do sorters throw forward or pull back? • Do sorters have to twist to sort materials? • Do sorters have to bend forward too far to sort materials? • Is the sorting conveyor too high for the sorters? • Do the sorters complain of bad backs?
5. Backsplashes	• Are there backsplashes installed in bunkers for forward throwing from the conveyor? • Do they allow sorters to side sort when material is too heavy to throw forward?
C) Administration	
1. Training Investment in MRFs	• Were the sorters trained on their materials? • Does the MRF operator know the cost centres in the MRF? • Does the MRF operator know why problems exist? • Do the MRF operator and MRF supervisor/manager and management work together to derive solutions? • Does the MRF work with the collection system in place? • Is the public educated on how to recycle?
2. Full-time vs. Temporary Workers	• Are full-time sorters used or temporary employment agency sorters? • If temporary sorters, is the lead sorter full time? • Are there reasons why full time sorters are not used?

If the MRF operator, supervisor and upper level management ask the questions outlined in Table 5.1, it is estimated that between 60% and 80% of the problems that the Study Team identified across the MRFs in the study would be identified by the MRF itself.

Asking the questions above will inherently lead to discovering other questions, more specific to each MRF which will identify further areas for improvement. Using the tools available in examining MRFs, including the series of models and guides developed by EPIC, in combination with common sense, will help provide most of the answers needed to improve recycling.

6.0 Synthethis of the Outcome of the Study - A Hypothetical MRF

This chapter collates the knowledge learned about MRFs and the management of material over the course of the study and describes a hypothetical MRF. By incorporating the best elements of MRFs reviewed both in Canada and in the United States, theoretically this MRF would have the lowest operating costs, the highest throughput capacity and be able to achieve any quality specification for any material as dictated by ever changing markets. Although, to the knowledge of the Steering Committee there is no MRF exactly like the one outlined here, there are some excellent examples of MRFs in North America that include many of the components of this MRF.

This MRF, designed to handle approximately 100 tonnes per day (over one shift) or 25,000 tonnes per year, sorts for the following products:

Fibres:

- Old Newspapers (ONP#8)
- Old Corrugated Containers (OCC)
- (Boxboard) OBB
- Mixed Waste Paper
- Fibre Stream Residues

Containers:

- High Density Polyethylene (natural) (HDPE nat.)
- High Density Polyethylene (coloured (HDPE col.)
- Polyethylene Terephthalate (PETE)
- Mixed Plastics
- Plastic Film
- Polycoat Milk/Juice Cartons
- Clear Glass
- Coloured Glass

- Steel Containers
- Aluminum Cans
- Container Stream Residues

6.1 Collection Method

As previous work for other studies has shown that two stream (i.e., fibres and containers) collection at the curb, combined with a well engineered MRF capable of handling the two streams is less expensive and more productive than a system incorporating multiple curbside sorts, it is assumed that the material is received in two streams. Also, as it is human nature for people to bag materials before setting them out at the curb for collection, it is assumed that bag (and plastic film) management must be included in the MRF.

6.2 Overall MRF Configuration

The MRF would have a dedicated sorting line for fibres and a dedicated line for containers. The MRF schematic for the fibres line is shown in Figure 6.1 and for the containers line in Figure 6.2. The infeed conveyor angle for the fibres would be set at no more than 40^{o} and for the containers no more than 35^{o}. The infeed conveyor pit for both the fibres and containers line would be approximately 5m in length and be infloor to allow straight in loading from a front end loader.

Both conveyors (the containers conveyor splits into two lines - lights and heavies - See Section 6.4 for more details) would be raised above the floor to a height of approximately 5 to 6m to allow ample room for the bunkers. All conveyors would be run by variable speed motors.

The fibres would be dropped into chutes into bunkers. Walking floors would be used in the fibres bunkers to move the materials to the baler infeed conveyor, located on one side of the fibres bunkers.

Figure 6.1

Hypothetical MRF Fibres Line Configuration

Figure 6.2

Hypothetical MRF Containers Line Configuration

Metal mesh gates would keep the sorted containers in their bunkers until opened for baling. The floor of the bunkers for the containers would be set at a five degree angle so that when the gate was opened, the bunker would automatically empty. A baler infeed conveyor to the second baler, for the containers would be located on one side of the lights line.

6.3 Handling the Fibres

At the front end of the fibres line, just at the end of the infeed conveyor would be a small (6m) conveyor where debagging, decontamination (residue removal), and oversize OCC removal would occur. There would be two sorting stations on each side of the 150cm (60") wide conveyor. Located just above the conveyor would be a vacuum pipe that would be used to transport the bags taken off the fibres line. The plastic would be transferred to a dedicated plastic film baler.

The main fibres conveyor would be approximately 150cm (60") in width, 95cm above the sorter floor and sorting would be undertaken from both sides. There would be eight bunkers for the fibres with the first, for OCC being 5m in width in order to allow a longer period of time between required baling (OCC volume is a limiting factor in some facilities). There would be room for two sorters on each side of the sorting conveyor and the sorters would throw material forward into chutes which have 1.5m high backsplashes on them, wrapped around the sides of the chute, but tapered to allow sorters to dump heavy oversize material directly to their side as required.

The second through sixth bunkers would be the same size at approximately 4m in width. There would be room for three sorting stations at each bunker with the sorters again configured to throw forward into backsplashed bunkers. The overall sort order, of course contingent on the final volume of each material to be received is outlined in Table 6.1.

It is anticipated that there would be approximately 65 to 70 tonnes per day of fibres to process. This would require approximately 12-14 sorters over one shift. One additional sorter would be required at the decontamination and debagging station.

Table 6.1
Fibres Stream Sort Order

Bunker	Bunker Width	Material
Bunker #1	split - 2.5m/2.5m	Oversized OCC/Oversize residues
Bunker #2	5m	OCC
Bunker #3	4m	OBB
Bunker #4	4m	Mixed Waste Paper
Bunker #5	4m	Mixed Waste Paper (or Fine Paper, Magazines, as markets dictate, become available, etc.)
Bunker #6	4m	Residues
Bunker #7	4m	Spare (e.g., with reconfiguration would allow for sorting for ONP#9, etc.)
Bunker #8	6m	The negative sort, falling into the final bunker would be ONP#8

6.4 Handling Containers

The containers line would be separate from the fibres line and would be located at the other end of the facility. At the front end of the containers line, just at the end of the infeed conveyor would be a small (6m) conveyor where debagging, decontamination (residue removal), and oversize materials (primarily metals) removal would be undertaken. There would be two sorting station on each side of the 150cm (60") wide infeed conveyor. Located just above the conveyor would be a vacuum pipe that would be used for the bags taken off the containers line. The plastic would be transferred to the dedicated plastic film baler (the same one used for the fibres line plastic film).

The main containers conveyor would be approximately 90cm (36") in width, 95cm above the sorter floor and sorting would be undertaken from one side only. Prior to any manual sorting, at the first station the material would pass under a ferrous magnet. The magnet would take the steel containers and drop them onto a conveyor which would then take the containers and drop them into a bunker on the

lights side of the containers line (so it is inline with the infeed conveyor for the baler). After the ferrous magnet, the stream would then pass over a gravely-type glass screen where glass fines would be removed. They would drop onto a conveyor and be conveyed outside to a glass bunker (or 40 cubic yard rolloff if close to the glass market).

After the glass shaker screen, the material would then be air classified into lights (plastics, polycoat containers and aluminum) and heavies, glass.

6.4.1 Heavies (Glass) Line

On the glass line conveyor, at the first sorting station the sorting conveyor would split into two where the sorters would throw the coloured glass to the back half of the sorting conveyor. The conveyor would travel along to the end of the belt where the coloured glass would drop off onto another conveyor which would then carry the glass outside to a glass bunker or 40 cubic yard rolloff container.

At the next station a person would be assigned to remove residues. These would be thrown forward into a chute which would drop onto a conveyor which would travel to and meet up with the residues conveyor from the lights line. This line would then carry the residue outside to a 40 cubic yard rolloff container.

The flint (clear) glass would be negatively sorted and drop onto a conveyor and be conveyed directly outside into a 40 cubic yard container or bunker after passing under another ferrous magnet to ensure all tin had been removed from the glass.

6.4.2 Lights (Plastics, Polycoat and Aluminum) Line

The lights line would run parallel to the glass line and would be 90cm (36”) in width. All sorting would be done from one side of the conveyor only. The sorting order for the lights line would be contingent on

the quantity of HDPE natural present but assuming the MRF has to handle HDPE natural separately, the order would be as follows (Table 6.2):

Table 6.2
Lights Stream Sort Order

Bunker	Bunker Width	Material
Bunker #1	6m	HDPE Natural
Bunker #2	6m	PETE
Bunker #3	6m	HDPE Coloured
Bunker #4	5m	Polycoat
Bunker #5	4m	Plastic Tubs
Bunker #6	4m	Mixed Plastics
Bunker #7	4m	Spare (for PS, PVC, PP or other material)

The aluminum would be thrown forward off the end of the lights line using an eddy current separator. The aluminum would then be conveyed to a dedicated biscuit baler. The negative sort off the end of the conveyor would be residues which would be conveyed outside to a 40 cubic yard rolloff container (along with the residues from the glass line).

It is anticipated that there would be approximately 30 to 35 tonnes per day of containers to process. This would require approximately 5-7 sorters over one shift. Two additional sorters would be required at the decontamination and debagging station.

6.5 Baling Material

Having a trouble-free good quality baler is imperative. For this reason, both the fibres line and containers line balers would be double ram balers. This is particularly important for the containers side of the MRF. In speaking to operators using single versus double ram balers, with the problems associated with bursting bales using a single ram balers, the double ram would keep the baler from being a bottleneck to the facility.

Baling would continue during the lunch hour to ensure that there was sufficient room in the bunkers to accept more material after lunch.

6.6 Conclusions

The equipment added to the facility on the containers side would enhance sorting rates and reduce material handling requirements. Having the fibres line and containers line separate would keep cross contamination at a minimum and would increase the utility of the MRF.

Because of the increased capital cost that would be associated with the MRF, it would be in best interest of the facility to maximize the throughput. This would decrease the capital cost per throughput tonne. Overall, this semi-automated system would be capable of handling up to 250 tonnes of material per day using between 20 and 24 sorters per shift (a *very* conservative estimate).

6.7 Alternative MRF Configurations - Automated Sorting of Plastics and Glass

The automation of the sorting functions in the MRF have primarily focussed on containers rather than fibres. This is due to the fact that containers can be sorted by size and density whereas fibres are generally the same two dimensional shape and are all within a small range of density, automated sorting is more difficult.

Plastics Sorting

The automated sorting of plastics is being done both by resin type and by colour within a resin type. The automated system, through the use of a singulator, moves the material into single file. The individual bottles or tubs are then scanned to sort the PVC from the other containers (More specifically PETE). Once located, the PVC bottle is diverted from the stream by a "shot" of air. That moves the container onto a separate conveyor which transports the material to a holding bunker or cage (Figure 6.3). This process is continued using various other optical scanners to

Figure 6.3

Schematic of an Automated Plastics Sorting System

sort the containers into PET, HDPE and PP. These categories can be subdivided into colours. For example, in one facility in the United States, the HDPE is colour separated into ROY (Red, Orange, Yellow), BW (Blue, White) and natural. A high volume of plastic is required to make an automated sorting system cost effective. Because of the fragmented nature of recycling programs in Canada (i.e., done on a municipality scale basis), there are no automated plastics sorting facilities here at the present time.

OBSERVATION FROM U.S. MRF STUDY:

No automated sorting for plastics is proposed at this time. The current technology is capable of sorting approximately 1,200 to 1,400 pounds per hour (550 kg to 640 kg) (based on U.S. studies) to an efficiency of between 50-60% (for mixed plastics) and 80-95% (for a stream primarily of HDPE natural). As there are examples of MRFs where the sorters are capable of doing 450 to 500 kg per hour of plastics (PETE and HDPE), considering the capital cost of the equipment, it is not recommended.

Glass Sorting

Using optical scanners for colour bands (i.e., light frequencies), the system sorts the bottles and jars into individual colours. The only automated glass sorting system in Canada is in Quebec.

6.0 Synthethis of the Outcome of the Study - A Hypothetical MRF

This chapter collates the knowledge learned about MRFs and the management of material over the course of the study and describes a hypothetical MRF. By incorporating the best elements of MRFs reviewed both in Canada and in the United States, theoretically this MRF would have the lowest operating costs, the highest throughput capacity and be able to achieve any quality specification for any material as dictated by ever changing markets. Although, to the knowledge of the Steering Committee there is no MRF exactly like the one outlined here, there are some excellent examples of MRFs in North America that include many of the components of this MRF.

This MRF, designed to handle approximately 100 tonnes per day (over one shift) or 25,000 tonnes per year, sorts for the following products:

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- (Boxboard) OBB
- Mixed Waste Paper
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Containers:

- High Density Polyethylene (natural) (HDPE nat.)
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- Mixed Plastics
- Plastic Film
- Polycoat Milk/Juice Cartons
- Clear Glass
- Coloured Glass

- Steel Containers
- Aluminum Cans
- Container Stream Residues

6.1 Collection Method

As previous work for other studies has shown that two stream (i.e., fibres and containers) collection at the curb, combined with a well engineered MRF capable of handling the two streams is less expensive and more productive than a system incorporating multiple curbside sorts, it is assumed that the material is received in two streams. Also, as it is human nature for people to bag materials before setting them out at the curb for collection, it is assumed that bag (and plastic film) management must be included in the MRF.

6.2 Overall MRF Configuration

The MRF would have a dedicated sorting line for fibres and a dedicated line for containers. The MRF schematic for the fibres line is shown in Figure 6.1 and for the containers line in Figure 6.2. The infeed conveyor angle for the fibres would be set at no more than 40^{o} and for the containers no more than 35^{o}. The infeed conveyor pit for both the fibres and containers line would be approximately 5m in length and be infloor to allow straight in loading from a front end loader.

Both conveyors (the containers conveyor splits into two lines - lights and heavies - See Section 6.4 for more details) would be raised above the floor to a height of approximately 5 to 6m to allow ample room for the bunkers. All conveyors would be run by variable speed motors.

The fibres would be dropped into chutes into bunkers. Walking floors would be used in the fibres bunkers to move the materials to the baler infeed conveyor, located on one side of the fibres bunkers.

Figure 6.1

Hypothetical MRF Fibres Line Configuration

Figure 6.2

Hypothetical MRF Containers Line Configuration

Metal mesh gates would keep the sorted containers in their bunkers until opened for baling. The floor of the bunkers for the containers would be set at a five degree angle so that when the gate was opened, the bunker would automatically empty. A second baler infeed conveyor to the second baler, for the containers would be located on one side of the lights line.

6.3 Handling the Fibres

At the front end of the fibres line, just at the end of the infeed conveyor would be a small (6m) conveyor where debagging, decontamination (residue removal), and oversize OCC removal would occur. There would be two sorting stations on each side of the 150cm (60") wide conveyor. Located just above the conveyor would be a vacuum pipe that would be used to transport the bags taken off the fibres line. The plastic would be transferred to a dedicated plastic film baler.

The main fibres conveyor would be approximately 150cm (60") in width and sorting would be undertaken from both sides. There would be eight bunkers for the fibres with the first, for OCC being 5m in width in order to allow a longer period of time between required baling (OCC volume is a limiting factor in some facilities). There would be room for two sorters on each side of the sorting conveyor and the sorters would throw material forward into chutes which have 1.5m high backsplashes on them, wrapped around the sides of the chute, but tapered to allow sorters to dump heavy oversize material directly to their side as required.

The second through sixth bunkers would be the same size at approximately 4m in width. There would be room for three sorting stations at each bunker with the sorters again configured to throw forward into backsplashed bunkers. The overall sort order, of course contingent on the final volume of each material to be received is outlined in Table 6.1.

It is anticipated that there would be approximately 65 to 70 tonnes per day of fibres to process. This would require approximately 12-14 sorters over one shift. One additional sorter would be required at the decontamination and debagging station.

Table 6.1
Fibres Stream Sort Order

Bunker	Bunker Width	Material
Bunker #1	split - 2.5m/2.5m	Oversized OCC/Oversize residues
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Bunker #7	4m	Spare (e.g., with reconfiguration would allow for sorting for ONP#9, etc.)
Bunker #8	6m	The negative sort, falling into the final bunker would be ONP#8

6.4 Handling Containers

The containers line would be separate from the fibres line and would be located at the other end of the facility. At the front end of the containers line, just at the end of the infeed conveyor would be a small (6m) conveyor where debagging, decontamination (residue removal), and oversize materials (primarily metals) removal would be undertaken. There would be two sorting station on each side of the 150cm (60") wide infeed conveyor. Located just above the conveyor would be a vacuum pipe that would be used for the bags taken off the containers line. The plastic would be transferred to the dedicated plastic film baler (the same one used for the fibres line plastic film).

The main containers conveyor would be approximately 90cm (36") in width and sorting would be undertaken from one side only. Prior to any manual sorting, at the first station the material would pass under a ferrous magnet. The magnet would take the steel containers and drop them onto a conveyor which would then take the containers and drop them into a bunker on the lights side of the containers

line (so it is inline with the infeed conveyor for the baler). After the ferrous magnet, the stream would then pass over a gravely-type glass screen where glass fines would be removed. They would drop onto a conveyor and be conveyed outside to a glass bunker (or 40 cubic yard rolloff if close to the glass market).

After the glass shaker screen, the material would then be air classified into lights (plastics, polycoat containers and aluminum) and heavies, glass.

6.4.1 Heavies (Glass) Line

On the glass line conveyor, at the first sorting station the sorting conveyor would split into two where the sorters would throw the coloured glass to the back half of the sorting conveyor. The conveyor would travel along to the end of the belt where the coloured glass would drop off onto another conveyor which would then carry the glass outside to a glass bunker or 40 cubic yard rolloff container.

At the next station a person would be assigned to remove residues. These would be thrown forward into a chute which would drop onto a conveyor which would travel to and meet up with the residues conveyor from the lights line. This line would then carry the residue outside to a 40 cubic yard rolloff container.

The flint (clear) glass would be negatively sorted and drop onto a conveyor and be conveyed directly outside into a 40 cubic yard container or bunker after passing under another ferrous magnet to ensure all tin had been removed from the glass.

6.4.2 Lights (Plastics, Polycoat and Aluminum) Line

The lights line would run parallel to the glass line and would be 90cm (36”) in width. All sorting would be done from one side of the conveyor only. The sorting order for the lights line would be contingent on

the quantity of HDPE natural present but assuming the MRF has to handle HDPE natural separately, the order would be as follows (Table 6.2):

Table 6.2
Lights Stream Sort Order

Bunker	Bunker Width	Material
Bunker #1	6m	HDPE Natural
Bunker #2	6m	PETE
Bunker #3	6m	HDPE Coloured
Bunker #4	5m	Polycoat
Bunker #5	4m	Plastic Tubs
Bunker #6	4m	Mixed Plastics
Bunker #7	4m	Spare (for PS, PVC, PP or other material)

The aluminum would be thrown forward off the end of the lights line using an eddy current separator. The aluminum would then be conveyed to a dedicated biscuit baler. The negative sort off the end of the conveyor would be residues which would be conveyed outside to a 40 cubic yard rolloff container (along with the residues from the glass line).

It is anticipated that there would be approximately 30 to 35 tonnes per day of containers to process. This would require approximately 5-7 sorters over one shift. Two additional sorters would be required at the decontamination and debagging station.

OBSERVATION FROM U.S. MRF STUDY:

No automated sorting for plastics is proposed at this time. The current technology is capable of sorting approximately 1,200 to 1,400 pounds per hour (550 kg to 640 kg) (based on U.S. studies) to an efficiency of between 50-60% (for mixed plastics) and 80-95% (for a stream primarily of HDPE natural). As there are examples of MRFs where the sorters are capable of doing 450 to 500 kg per hour of plastics (PETE and HDPE), considering the capital cost of the equipment, it is not recommended.

6.5 Baling Material

Having a trouble-free good quality baler is imperative. For this reason, both the fibres line and containers line balers would be double ram balers. This is particularly important for the containers side of the MRF. In speaking to operators using single versus double ram balers, with the problems associated with bursting bales using a single ram balers, the double ram would keep the baler from being a bottleneck to the facility.

Baling would continue during the lunch hour to ensure that there was sufficient room in the bunkers to accept more material after lunch.

6.6 Conclusions

The equipment added to the facility on the containers side would enhance sorting rates and reduce material handling requirements. Having the fibres line and containers line separate would keep cross contamination at a minimum and would increase the utility of the MRF.

Because of the increased capital cost that would be associated with the MRF, it would be in best interest of the facility to maximize the throughput. This would decrease the capital cost per throughput tonne. Overall, this semi-automated system would be capable of handling up to 250 tonnes of material per day using between 20 and 24 sorters per shift (a *very* conservative estimate).

6.7 Alternative MRF Configurations - Automated Sorting of Plastics and Glass

The automation of the sorting functions in the MRF have primarily focussed on containers rather than fibres. This is due to the fact that containers can be sorted by size and density whereas fibres are generally the same two dimensional shape and are all within a small range of density, automated sorting is more difficult.

Plastics Sorting

The automated sorting of plastics is being done both by resin type and by colour within a resin type. The automated system, through the use of a singulator, moves the material into single file. The individual bottles or tubs are then scanned to sort the PVC from the other containers (More specifically PETE). Once located, the PVC bottle is diverted from the stream by a "shot" of air. That moves the container onto a separate conveyor which transports the material to a holding bunker or cage (Figure 6.3). This process is continued using various other optical scanners to sort the containers into PET, HDPE and PP. These categories can be subdivided into colours. For example, in one facility in the United States, the HDPE is colour separated into ROY (Red, Orange, Yellow), BW (Blue, White) and natural. A high volume of plastic is required to make an automated sorting system cost effective. Because of the fragmented nature of recycling programs in Canada (i.e., done on a municipality scale basis), there are no automated plastics sorting facilities here at the present time.

Glass Sorting

Using optical scanners for colour bands (i.e., light frequencies), the system sorts the bottles and jars into individual colours. The only automated glass sorting system in Canada is in Quebec.

Figure 6.3

Schematic of an Automated Plastics Sorting System

Appendix A Material Recovery Facility Case Studies

Outlined in this chapter are one page profiles, i.e., case studies, examining each of the MRFs included in this study. To maintain the required level of confidentiality, a condition for participating in the study, there is no reference to:

- the location of the MRF;
- the number of sorters used in total or for individual materials; or
- any costs for the equipment, operations, labour or administration of the MRF.

Although every effort was made to try to have all changes made to the MRFs operations prior to visiting the MRF for the second time, because of the extent of the some of the changes, not all were implemented. The costs to implement the changes are either actual or based on preliminary design cost estimates (depending on the extent of the proposed changes) The annual cost savings are estimated based on the changes that have been implemented, extrapolated to a one year period.

MRF Case Study #1	
Average Daily Throughput = 115-125 tonnes	
Materials Processed - Fibres Line • ONP • OCC/OBB • Mixed Paper • Telephone Books • Plastic Film	
Materials Processed - Containers Line • Milk Cartons • PETE • HDPE • Steel Containers • Aluminum • Mixed Glass • Plastic Film	
Processing Description	Single raised conveyor line with manual sorting for all materials except steel containers (ferrous magnet) and glass (curbside sorted into own compartment). Sorting is from both sides of the conveyor. The negative sort for both streams - fibres and containers - is residue. Fibres are received commingled. Containers are received commingled.
Study Focus	• Improve plastic film management • Improve material throughput rate • Decrease residue rate (i.e., increase material recovery rates)
Limiting Factors to Change	• Minimal capital dollars available for equipment purchase • Inability to change sorting conveyor configuration due to space constraints • Use of temp workers for sorting staff
Changes to Operations	• Debagging from grocery bags done on floor at bottom of infeed conveyor instead of first sorting station • Decrease of sorting belt speed by 33% • Addition of backsplashes to sorting chutes • Move to throwing forward to sort instead of sorting to side • Proposal for use of full-time staff in key positions (i.e., shift supervisor, lead sorter)
Impact of Changes	• 33% decrease in number of sorters used • 40% increase in material capture rates • 40% decrease in residue rates • Better plastic film bales
Cost to Implement Changes	$0
Annual Cost Savings	It is anticipated that operational costs will decrease approximately $300,000 annually. Additional revenues from the increased value of sorted products are not known.

MRF Case Study #2	
Average Daily Throughput = 110-115 tonnes	
Materials Processed - Fibres Line • ONP • OCC • Fine Paper	
Materials Processed - Containers Line • HDPE • PETE • Plastic Film • Mixed RPCs • Polystyrene • Polycoat • Glass • Steel Containers • Aluminum • Aluminum foil	
Processing Description	Single raised conveyor line for containers with single side sorting of all materials except steel containers (ferrous magnet) and a front end shaker to remove the small glass. Much of the glass is sorted at curbside, although not all. The containers are received commingled. The negative sort is aluminum. Paper fibres are sorted on a separate line. The OCC and fine papers are received separate from the ONP. The negative sort is ONP.
Study Focus	• Eliminate positive sorting of residue • Eliminate redo • Improve plastics and aluminum product quality
Limiting Factors to Change	• Minimal capital dollars available for equipment purchase • Low plant ceiling height • Restrictions on making changes to facilities (i.e., floor) • Use of temp workers for sorting staff
Changes to Operations	• Decrease of sorting belt speed by 40% • Installation of an eddy current • Splitting of plastics bunker (HDPE and PETE) bunkers at end of the line • Installation of backsplashes • Eliminating slow cautious placing of glass by sorter
Impact of Changes	• 30% reduction of sorters on containers line • Elimination of redo • Estimated 50% reduction of overtime • Better plastic bales • Higher capture rate of plastics • Better quality in aluminum
Cost to Implement Changes	Approximately $70,000, not including management time.
Annual Cost Savings	It is expected that operational costs will decrease approximately $80,000 annually. Product revenues are expected to increase by $10,000 per year..

MRF Case Study #3	
Average Daily Throughput = 115-120 tonnes	
Materials Processed - Fibres Line • #8ONP • OCC • Mixed Paper • Telephone Books • Plastic Film • #9ONP • OBB • Catalogues/Magazines	
Materials Processed - Containers Line • Milk Cartons • PETE • HDPE • Tin • Aluminum • Clear Glass • Coloured Glass • Mixed RPCs • Juice Cartons • Deposit Containers • Aggregate • Plastic Film	
Processing Description	Single raised conveyor line for containers with manual sorting for all materials except tin (ferrous magnet). Sorting is from one side only. Aggregate glass is the negative sort. Double raised conveyor for fibres. Sorting is one side of the conveyor for one and from both sides for the other. The negative sort for fibres is #8ONP. Fibres are received commingled. Containers are received commingled. Plastic film is collected in a large bag at the curb.
Study Focus	• Improve containers sorting • Identify plan for installation of a glass screen • Eliminate redo • Identify other opportunities to reduce costs
Limiting Factors to Change	• Limited capital dollars available for equipment purchase • Small bunkers for fibres • Overcoming slowing of workers with slowing of line
Changes to Operations	• Rerunning of glass screen redo without need for sorters (steel containers are the primary items removed on redo) • Attempt to reduce fibres sorting belt speed by 20% • Design of front end process for containers line to manage aggregate glass
Impact of Changes	• Removal of overtime for redo • Identification of opportunity to reduce fibres sorters (administration to decide on final change) • With installation of front end for containers line (administration to decide on approval), improvement of sorting rates on containers line • Identification of need for variable speed motor on lower part of fibres line
Cost to Implement Changes	Initial estimate for front end is $150,000 installed. No estimate of management cost to retrain fibres sorters.
Annual Cost	It is anticipated that operational costs will decrease between $20,000 and $100,000

Savings	annually.

MRF Case Study #4	
Average Daily Throughput = 120-130 tonnes	
Materials Processed - Fibres Line • ONP • OCC • Fine Paper • Mixed Paper	
Materials Processed - Containers Line • HDPE (nat.) • HDPE (col.) • PETE • PVC • Plastic Film • Mixed RPCs • Polycoat • Glass • Steel Containers • Aluminum	
Processing Description	Single raised conveyor for fibres and containers. Fibres are received as ONP, OCC and mixed papers. Containers are received mixed. Some material is received in blue bags. Negative sort for containers is passed through a trommel and then re-run on the line. Mixed papers are the only fibres on the line. ONP and OCC are floor sorted with contamination pulled out.
Study Focus	• Eliminate contamination in plastics bales • Eliminate redo (primarily plastics) • Improve material throughput • Improve storage capacity • Improve material handling
Limiting Factors to Change	• Building design • Large quantity of material backlog
Changes to Operations	• Decreased sorting belt speed by 33% • Installing large silos for storing plastics (e.g., HDPE) and steel containers • Use of blowers to move plastics from the conveyor line • Sorting ONP directly into rolloffs • Sorting and transporting OCC on the conveyor line, requiring raising the magnet • Change direction of the magnet and install a conveyor • Stop putting the residue back in the infeed • Train the sorters
Impact of Changes	• Elimination of contamination of plastics work-in-progress area • Improved plastic bales • Reduction of one forklift • Reduction of one quality assurance staff • Increased ONP throughput • Reduced ONP downgrading • Estimated 15% decrease in sorters
Cost to Implement Changes	An estimated $120,000
Annual Cost Savings	Estimated at $565,000 annually. This is comprised of approximately $250,000 in operational cost savings and the remainder in recovered product revenues.

MRF Case Study #5	
Average Daily Throughput = 8-10 tonnes	
Materials Processed - Fibres Line • #9ONP • OCC • Fine Paper • Mixed Paper	
Materials Processed - Containers Line • Milk Cartons • PETE • HDPE (mix.) • Steel Containers • Aluminum • Clear Glass • Coloured Glass • Aggregate • Plastic Film • Deposit Containers	
Processing Description	Single raised conveyor line for fibres with manual sorting for all materials (ONP is the negative sort). Containers are air classified into lights and heavies. Sorting is from one side of each of the two split conveyors. Fibres are received commingled. Containers are received commingled in blue bags.
Study Focus	• Improve ergonomics for lights line sorters • Reduce speed on lights line to reduce sorting staff requirements • Design for installation of an additional fibres line bunker • Identify additional bale storage
Limiting Factors to Change	• Mandatory sorting and counting of deposit containers • Building underdesigned for material throughput quantities (i.e., length of storage requirements)
Changes to Operations	• Installation of brushes on lights line • Installation of variable speed motor on lights line • Reduction in speed of lights line conveyor by 33% • Installation of catwalk on other side at front of containers line • Design of fibres line extension to accommodate new fibre product
Impact of Changes	• Better debagging and decontamination at front of lights line. • Better ergonomics at front of lights line (sorters not hitting each other) • Better ergonomics on lights line • 33% reduction in lights line sorters
Cost to Implement Changes	$10,000 for the new wall, extension of fibres conveyor and installation of variable speed motor for plastics line.
Annual Cost Savings	It is anticipated that operational costs will decrease approximately $20,000 annually. Additional revenues (unknown) will be received for new fibres product.