

# A COMPARISON OF INTERMEDIATE PROCESSING CENTER REFERENCE DESIGNS AND COSTS

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## ABSTRACT

With the evolution in the recycling industry over the last 20 years, the Intermediate Processing Center (IPC) has become a well defined and essential service standing between municipal recycling programs and competitive recyclable end markets. Today, the IPC is a cornerstone in a region's integrated solid waste management plan, which is designed to provide a long-term alternative to the high costs for waste disposal.

The waste processing industry has responded to the growth in municipal and commercial recycling programs with more efficient and reliable IPCs. Today's IPC uses enhanced technologies and diverse processing system designs; some developed by entrepreneurs, some borrowed from other material handling industries (gravel, coal), and others licensed from foreign manufacturers, modified to suit the American waste stream.

Cost effective and functional IPC process system designs are beginning to emerge. These process systems may be divided into categories based on throughput capacity. IPCs in each of these categories share common, well defined functions. This paper defines four IPC reference plant designs based on throughput capacities from 1 to 300 tons per day (TPD) and their associated costs.

## INTRODUCTION

Based on single shift operation, reference IPC designs are categorized into the following sizes:

- (a) 1-30 TPD (1/30 IPC)
- (b) 30-80 TPD (30/80 IPC)
- (c) 80-150 TPD (80/150 IPC)
- (d) 150-300 TPD (150/300 IPC)

The four reference plant designs may vary depending on availability of: technology and labor; vendor or procuring community preferences; and market and licensing conditions.

This paper does not consider IPCs over 300 TPD on a single-shift basis. IPCs larger than this size should be considered in light of the cost of collection and haul distances to the IPC, where two smaller IPCs may be more economical, given collection costs, than one large IPC.

This paper discusses IPC: site and building reference designs; feedstock and collection system assumptions; reference process system designs, and what to look for in future IPCs.

## DISCUSSION

### Feedstock

Process system design is defined by several key parameters, including the quantity (system throughput) and composition (raw materials) of the incoming recyclables feedstock and the end market specifications (manufactured product).

The reference IPC plant design is based on two streams of source separated (dry) recyclables: wastepaper and commingled bottles, cans and plastics. Nearly

75% of all planned IPCs [1] are designed to accept both paper and commingled materials in two separate streams. IPCs serving modern recycling programs process the following two material streams:

(a) Wastepaper—old newspaper (ONP), old corrugated cardboard (OCC), magazines (OMG), and high grade paper.

(b) Commingled—amber, emerald, and flint glass; ferrous and bi-metal containers; aluminum containers and foil; HDPE and PET mixed colored plastics.

Other recyclable material, such as small amounts of scrap ferrous or scrap aluminum, can be processed at these facilities. This material arrives as contamination in both material streams at the IPCs, but may be removed at picking stations, placed in 55-gal drums or storage bins adjacent to the sorters, and marketed to scrap dealers (usually not counted as process residue).

### Collection Methods

Recyclables are delivered to the reference IPCs using two methods: separated stream delivery in which wastepaper and commingled containers are delivered in compartmentalized recycling vehicles and drop-off containers; or mixed stream delivery in which refuse packer vehicles collect commingled in bags and wastepaper loosely bundled. In mixed stream programs, a bag opener may be added to the front end of the reference IPC design. The bag opener can be comprised of two rotating tine wheels that break open the bags or a screw conveyor and hopper arrangement at the IPC. Through-put on bag openers is limited to approximately 10 ton/hr, and it is reported that paper in the bags can jam the machines. Another concern is the marketability of paper impregnated by broken glass, and the ability to process the paper and remove glass particles.

### Building and Site Design

The reference site is oriented so that all traffic rotates one way — counter clockwise. Counter clockwise vehicle movement assists driver's visibility when backing into the IPC for tipping. Employee and visitor vehicles are routed off of truck access roads soon after entry through the site gate to mitigate congestion and safety concerns. Railroad access to the site is considered preferable, especially where baled paper can be back-hauled to end markets in empty freight cars.

One 60-ft long truck scale (pit or pitless), with adjoining scale house and computer weight system, is provided for IPCs up to 150 TPD. Over 150 TPD, a second

scale may be added, separating incoming and outgoing traffic.

To comply with National Fire Prevention Association (N.F.P.A.) requirements, on-site fire protection includes hydrants within 250 ft of each other around the building's exterior. The tipping and process areas are sprinklered for high hazard coverage. Depending on available water pressure and flow, a fire pump and fire water storage tank may be provided on site. Floor drains at vehicle doors drain to an oil/water separator and grease trap before being discharged.

The cost assumptions for the reference IPCs include construction of a new, pre-engineered metal building. Automatic roll up doors at least 27 ft in height are provided for access into the recyclables receiving and tipping area. The clear height under the roof steel in the tipping area should be at least 30 ft to allow for tipping of 50 cu yd transfer roll offs. Loading dock doors are provided for direct access into box trailers or railcars by forklifts transferring bales from the processed material storage areas.

The building height over the process area may be lower than the tipping area, depending on process equipment maintenance requirements and building design economics. Depending on the needs of the operator, employee facilities may be provided for the workers.

A minimum 1-day storage capacity is provided for as received, on floor commingled and wastepaper. A critical consideration of the tipping floor is for safe and efficient operation. All material received is normally processed the same day. Scheduled maintenance and routine equipment outages are performed at night or on the weekend. Processed material storage areas are sized to accommodate 1 day of finished product, protected from the weather.

All infeed and sorting conveyors are provided with variable speed drives with an adjustable range of 20–60 fpm.

A full inventory of spare parts is necessary to ensure plant reliability and maintainability.

### 1/30 and 30/80 TPD Process Designs

The first reference design, depicted in Fig. 1, is for an IPC that processes less than 30 TPD of wastepaper and commingled. The 1/30 IPC is sometimes known as a small material recovery facility, or SMRF. It has a small sorting platform available prefabricated from several vendors, and low capacity vertical or horizontal balers.

The 30/80 IPC depicted in Fig. 2, varies from the 1/30 IPC in that it includes a baler infeed pit conveyor

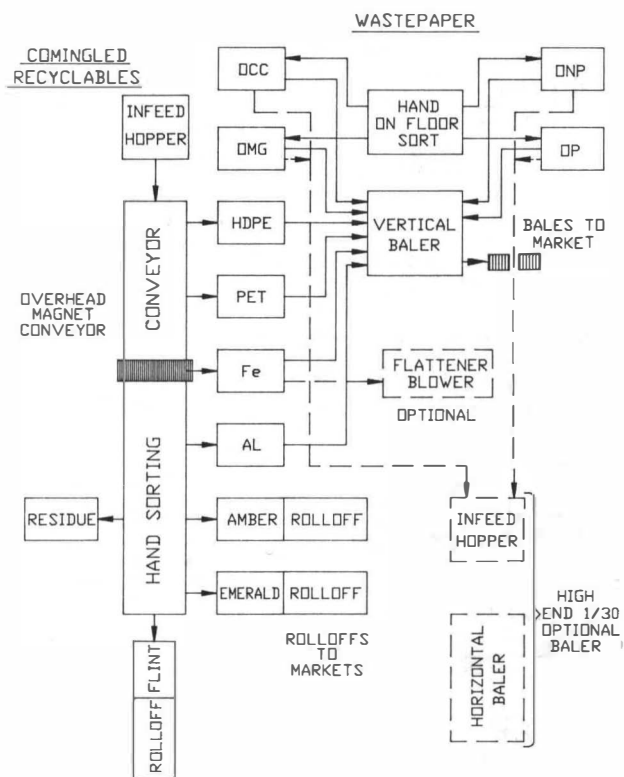


FIG. 1 1/30 IPC PROCESS FLOW DIAGRAM

recessed in the floor and a larger elevated sorting platform with material storage bins located underneath. The sorting platform can be batch fed with commingled and wastepaper. Clean loads of ONP and OCC can by-pass the sorting platform and be baled directly.

### Material Receiving

Commingled and wastepaper are tipped separately on the receiving tipping floor. Personnel in the receiving area visually spot-check the vehicle loads prior to tipping to determine that nonprocessable items are not left at the facility. Commingled loads are further inspected after the material is tipped on the floor, and any nonrecyclable material is manually sorted into a roll-off container for later disposal off-site.

After wastepaper is tipped on the receiving floor, pickers bend and stoop to remove wastepaper from kraft bags and to cut tied bundles. The material is gathered by a bobcat payloador and either pushed into storage piles or deposited directly into a vertical baler or the infeed hopper of a horizontal baler. Commingled is fed into another hopper and up a small, cleated conveyor to the sorting conveyor.

In the 1/30 IPC, wastepaper is tossed by the pickers into various piles of ONP, OCC, OMG, and high grade

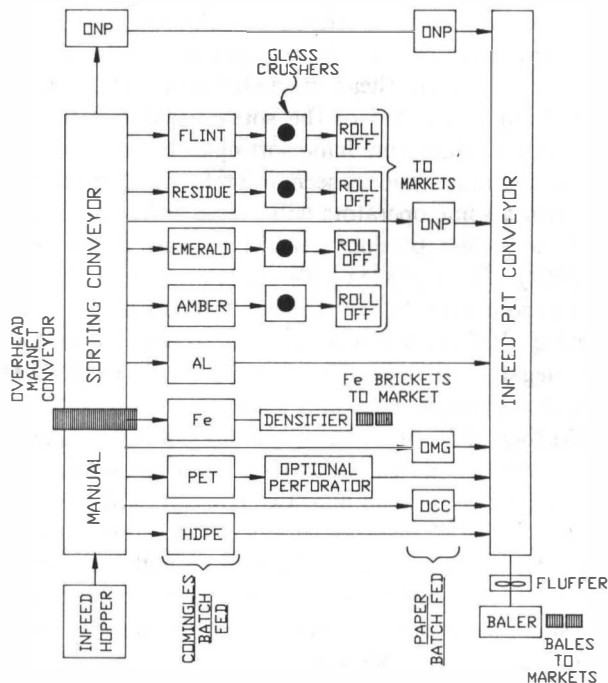


FIG. 2 30/80 IPC PROCESS FLOW DIAGRAM

paper. In the 30/80 IPC, commingled and wastepaper can be batch fed to the same sorting platform. OCC sorting should be done on the receiving floor in either case to avoid the expense of additional sorters and a wider sorting conveyor (48–60 in.) to accommodate the OCC.

### Sorting

The sorting conveyor is used primarily for the separation of commingled. Small sorting platforms for low-end 1/30 IPCs (less than 15 TPD) are nothing more than conveyors mounted directly on the floor. Up to four sorters stand on floor mats or grating. The sorting conveyor is nominally 2 ft wide. As the commingled passes down the sorting conveyor, manual sorters remove plastic, aluminum, and glass. This material is tossed into 3–5 cu yd bins adjacent to the sorting conveyor.

In the 30/80 TPD IPC, the in-feed conveyor carries the commingled to a one-sided, multistation sorting conveyor where up to six manual sorters can pick out plastic, glass, and aluminum. This material is dropped through chutes into storage bins beneath the sorting platform. If both commingled and wastepaper are batch fed for sorting, OCC, OMG, and high grade paper can be picked off the belt. Newspaper is conveyed past the sorting station and proceeds directly to a container at the end of the sorting platform (that is, a negative sort).

Depending on the preference of the equipment vendor and IPC operator, ferrous and bi-metal cans are removed by an overhead magnetic conveyor belt positioned on either end of the sorting platform. Glass, plastic, and aluminum hand sorting can be done in any order, but most vendors seem to prefer doing glass last. However, some operators will prefer to hand pick the glass to ensure product quality. Because of the high quantity of flint glass in collection programs, it may be more economical to have the flint fall off the end of the sorting platform into a pre-positioned flint bin or roll-off (negative sort). Residue is removed by hand so as not to contaminate the flint glass.

Sorting platforms can be purchased with a light/heavy fraction air knife classifier. The classifier divides the stream of material onto two conveyors for manual sorting. The IPC designer should evaluate the function, benefits, and cost of automation in small scale IPCs to ensure that higher equipment and electrical power consumption requirements do not offset any real savings in labor and operation.

### Baling and Crushing

In the 1/30 IPC, a bobcat loader gathers the aluminum, ferrous, and plastic recyclables from the storage bins and loads them into the vertical baler or horizontal baler feed hopper. The payload also transports the sorted wastepaper from the storage piles on the tipping floor to the baler. Small vertical balers (less than 1 ton/hr) are hand fed.

Two vertical balers can bale up to 10 TPD of sorted wastepaper and recyclables. IPCs with a capacity over 10 TPD should consider a horizontal extrusion, manual tie baler for paper, plastic and aluminum.

A PET perforator can be used upstream of the baler if dense plastic bales are needed to reduce transportation costs.

The 30/80 IPC uses a horizontal extrusion baler. For low end 30–50 IPCs, a hand tie baler may be used. For high end 50–80 TPD IPCs, an automatic baler and tying system or dual ram closed chamber baler is best. The advantage of an extrusion baler in this multi-feed batch system is that if not enough infeed material is available for a full bale, it can make “short” bales, whereas the two ram baler cannot make short bales. Once the material is baled, a forklift carries the bale to the bale storage area.

Various grades of plastic (HDPE and PET), ONP, OCC, other paper grades, aluminum, and bi-metal cans are batch fed and baled separately.

1/30 IPCs should have room for two box trailer loading docks. In 1/30 IPCs, glass may be deposited without crushing into roll offs for direct transportation

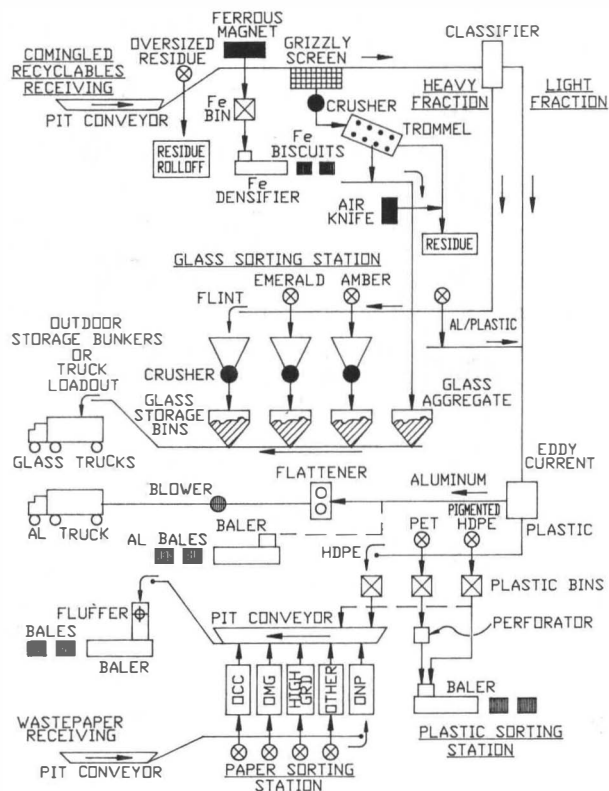


FIG. 3 80/150 MRF

to end market. In 30/80 IPCs, depending on markets and cost effectiveness between labor and hauling, glass may be fed to a glass crusher prior to load out.

### 80/150 and 150/300 TPD Processing Designs

The 80/150 IPC depicted in Fig. 3 is distinguished from the smaller IPCs by a marked increase in the level of automation of the comingled process line and a separate paper in-feed and sorting platform. Where material is separated manually in the smaller, less technologically sophisticated IPCs, the larger 80/150 IPC utilizes a large ferrous magnetic separator, a classifier to automatically separate the light from heavy fractions, and an eddy current machine to separate aluminum from the light fraction. The increased level of automated processing in the 80/150 IPC translates into higher capital costs for the processing equipment, but lower tip fees for the reduction in operation and maintenance costs.

The 150/300 IPC depicted in Fig. 4, displays the same fundamentals and technology as the smaller 80/150 IPC. The differences between the two is that the larger 150/300 IPC may offer: wider conveyors; dual sided conveyor sorting platforms; splitter gates to divide the comingled flow into two equal fractions feed-

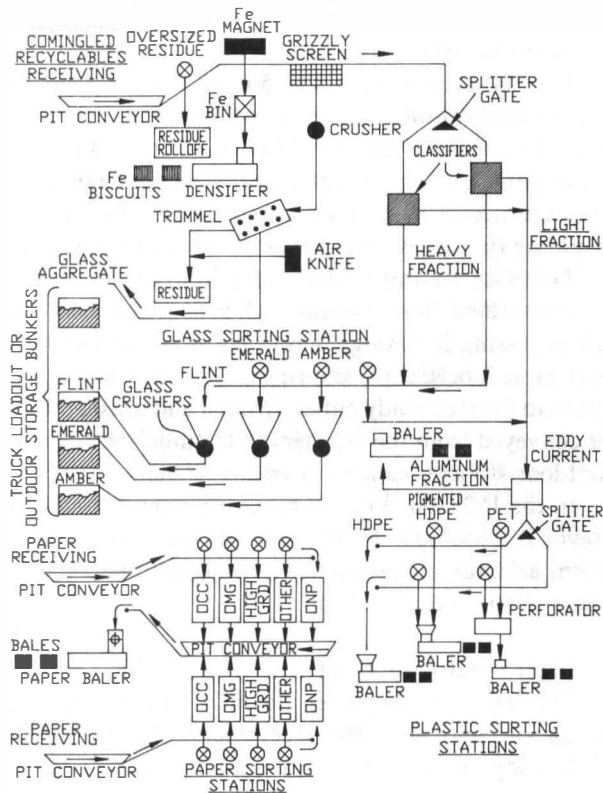


FIG. 4 150/300 MRF

ing parallel downstream processes; wider and more powerful magnetic overhead conveyors and eddy current machines; enlarged, or side-by-side classifiers; dedicated balers, densifiers, and other end process equipment; and two wastepaper sorting lines, feeding one larger baler.

### Material Receiving

Material receiving, inspection, and paper unbundling is the same as in the smaller IPCs.

Commingled is pushed by a payloader onto the in-feed pit conveyor for this material. The pit conveyor has an increased storage capacity for surcharging the inclined feed conveyor. Commingled is transported up the inclined conveyor, where it may be metered to ensure a steady flow, past a residue picking station. The picking station removes large pieces of residue and contamination. The residue picking station is sometimes placed on the inclined portion of the conveyor, or just as the conveyor levels off before the ferrous magnet.

### Ferrous Separation

As in Fig. 3, the commingled is next conveyed under an overhead magnetic belt conveyor. The magnetic belt extracts the ferrous containers and deposits them either directly into a storage bunker for later processing, or onto a conveyor feeding a dedicated densifier baler, or slitter (depending on end market demand).

In lieu of the overhead magnetic belt, some systems use a magnetic head pulley. The magnetic head pulley can be used in conjunction with an air knife for classification.

Systems that use air classification should be designated to accommodate the ferrous magnet before the classifier in order to prevent denser, flattened ferrous containers from passing through the air classification system with the heavy glass fraction; adding to the residue in the glass line needing manual separation.

### Grizzly Screening

An inclined, vibrating grizzly conveyor is widely used at this point in the commingled process system, before classification, to remove small pieces of broken glass and other contaminants. Small, broken pieces of glass might otherwise pass through an air classifier in the light fraction and end up on the plastic sorting line. The grizzly conveyor is made of heavy wire mesh, steel ribs parallel to the material flow, or punched steel plate with small holes (2 in. diameter or less); sized to prevent whole cans and bottles and large broken glass from passing through the openings.

The broken glass and residue that falls through the grizzly is conveyed to a glass crusher and trommel where broken glass is beneficiated and processed down to  $\frac{3}{8}$  in. for sale as aggregate to asphalt plants.

### Classification

After passing under the ferrous magnet, the remaining glass, plastic, and aluminum containers are conveyed through a classifier that separates light from heavy fractions. The heavy fraction includes flint, amber, and emerald glass. The light fraction includes plastic and aluminum containers.

Ineffective classification can be the achilles heel of an IPC. Air and mechanical classification systems use material density and size as a means of separation. Vertical, air knife, and vibrating inclined air classifiers can all be applied to commingled processing with a moderate degree of success.

An air knife classifier is the most commonly used air classifier system in IPCs. It directs a thin stream of high velocity air through the commingled material as

it falls off a head pulley at the end of a conveyor. The heavy fraction passes through the air stream and onto the glass sorting conveyor while the light fraction is redirected onto the light fraction conveyor. Air classification systems are designed with adjustable air pulse controls to allow for a fine adjustment over a wide range. The air classifier must be able to distinguish between crushed plastic milk jugs, large pieces of broken glass, and small glass bottles.

Mechanical classifiers use density or size to effect desired separations. One form of mechanical classification by density separation uses a rotating chain curtain and an inclined table to separate light and heavy fractions. Heavier glass bottles roll down the inclined table, passing through the rotating chain curtain. Lighter plastics and aluminum containers are stopped by the chain curtain. The traveling chain curtain directs the lighter fraction sideways, off the inclined table and onto downstream conveyors. Mechanical classification by size separation uses a vibrating grizzly screen with openings sized to allow aluminum containers to pass through and most plastic containers to pass over the screen.

As shown in Fig. 4, the flow of commingled through the process system in 150/300 IPCs is essentially the same as in the smaller 80/150 IPC. The feed conveyor is wider (from 48 to over 60 in.). The overhead magnetic conveyor is longer, wider, and more powerful. The vibratory grizzly conveyor is wider and longer to accommodate the higher material throughput. Trommels are larger and glass crusher shafts are longer to accommodate increased product flows.

After the grizzly and before the classifier, the commingled is divided into two equal fractions by a splitter gate. This allows two of the same size classifiers used in the 80/150 IPC to satisfy the higher flow rates of the 150/300 IPC, without the problems and costs associated with upscaling the 80/150 IPC classifier. Redundant classification also allows a classifier to be down for maintenance while the IPC can continue to function at half, or greater, system capacity.

### Heavy Fraction Sorting

After classification, the mixed colored glass, comprising the heavy fraction, is transported on a conveyor past a manual sorting station. Automatic glass separators that can distinguish colors are commercially available as prototypes, but are not in wide use in the United States as yet. Systems being developed in Europe are undergoing trial operations, but are designed for the smaller volumes of glass in the European waste streams. In the United States, colored glass sorting remains a manually intensive process. The sorted glass is dropped

down chutes to storage bunkers below, or conveyed to storage bunkers elsewhere.

The flint glass in most 80/150 IPC designs passes by the sorting station, and drops off the head end of the conveyor directly into the storage bunker. This process of negative sorting has its advantage in eliminating the expense necessary to otherwise pick and "positively" separate the largest component of the material stream.

The color separated glass is fed from the bunkers to glass crushers. Some vendors will beneficate the broken glass passing it through a rotating trommel to screen out paper labels, caps, and rings, upgrading the broken glass to furnace ready cullet. Broken and crushed glass is conveyed from the crushers or trommels to covered, outdoor storage bunkers or tractor trailers.

In the 150/300 IPC, the heavy fraction sorting conveyor is wider (36–48 hr.), and the glass sorting platform accommodates manual picking stations on both sides of the conveyor belt.

### Light Fraction Sorting

The light fraction, after classification, is composed of plastic and aluminum recyclables. In the 80/150 IPC, eddy current technology is used to separate aluminum cans from the plastics. Eddy current technology uses magnets of opposite polarity arranged under, above, or to the side of the conveyor belt to create a high degree of magnetic flux. Rapid pulsations in the flux field induce and propel the aluminum from the material stream.

The Dutch have led the advancement of eddy current technology by mounting the magnets on parallel disks and spinning the disks on a horizontal axis to create much higher fluxes than are achieved by stationary magnets. The material stream is then dropped between the two rotating disks, usually at the head end of a conveyor. This has the advantage of mechanical simplicity and allows high rotational speeds resulting in significant fluxes; overcoming the speed of free fall [2].

The aluminum is conveyed to a dedicated baler or flattener, depending on end market demand. Some aluminum end markets will provide a flattener, blower, and box trailer at no cost. The mixed plastics pass unaffected through the eddy current and fall onto a plastic sorting conveyor where they are sorted manually.

Depending on market demand and transportation costs, separated plastic is conveyed from storage bins to either dedicated baler(s) or granulators. A perforator is required for smaller horsepower, shear type extrusion balers in order to obtain optimum densities for baled PET.

In 150/300 IPCs, after classification, the light fraction passes through a larger eddy current machine. Remaining plastics are divided by a splitter gate into two sorting lines with natural HDPE negatively sorted.

Separated PET and HDPE are conveyed to dedicated extrusion balers. Instead of dedicated balers, 150/300 IPCs may feed their plastic from storage bins into the paper baler infeed pit conveyor, using a large extrusion or dual ram baler for both paper and plastic. Depending on end market demands and transportation costs, most facility operators now bale their plastic, though some still prefer to pelletize it.

### Wastepaper Processing

For 80/150 and 150/300 IPCs, mixed wastepaper is received and tipped on the tipping floor, pushed into the in-feed pit conveyor, and metered and conveyed up the inclined feed conveyor, past the manual sorting station.

OCC is manually sorted first to remove its bulk from the conveyor and to expose other paper underneath. Most modern IPCs will negatively sort newspaper, allowing it to pass by the sorting station and, via transfer conveyor, be fed directly into the paper baler. Other paper recyclables, including magazines, high grade computer and ledger paper, and kraft bags are manually picked off the conveyor and dropped into their storage bunkers below. Residue and contaminants are picked off the conveyor as well.

Recycled paper is pushed from the storage bunkers, or conveyed in live bottom (conveyor or "walking floor") bunkers, to the baler infeed pit conveyor. Different grades of paper are subsequently batch fed to the paper baler.

As depicted in Fig. 4, 150/300 IPCs may have two redundant paper infeed pit conveyors and two parallel paper sorting platforms. The sorting platforms provide access to both sides of the conveyor for picking. The baler in-feed pit conveyor is positioned parallel to and between the two rows of paper sorting platforms and their storage bins.

A large paper baler is used in the 150/300 IPC, with a capacity that exceeds 30 tons of OCC per hour. Typical balers used in this application range from 100 hp extrusion balers to dual ram shear balers with 200-400 hp motors.

### Reference IPC Costs

The range in capital construction costs based on reference IPC designs is shown in Fig. 5, and the range in operation and maintenance costs is shown in Fig. 6.

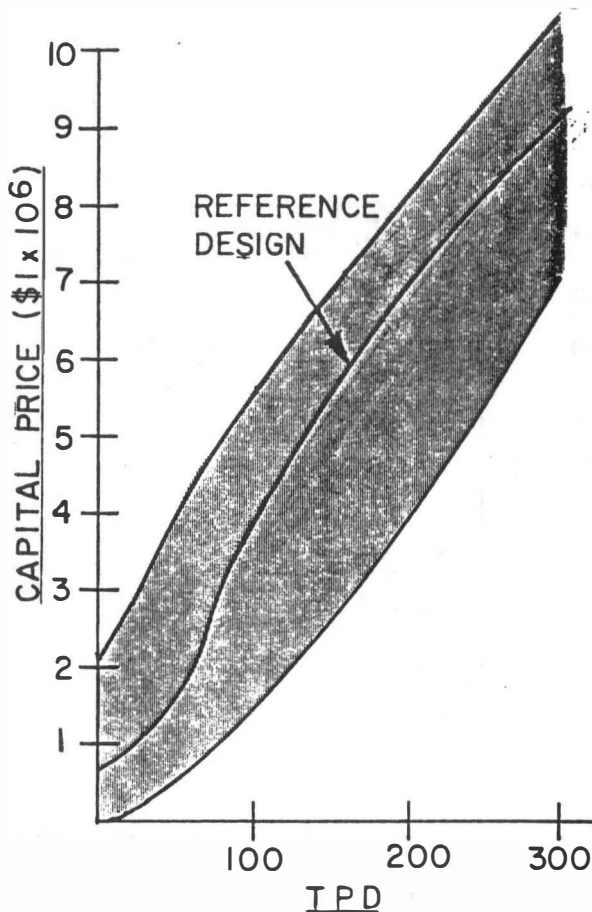


FIG. 5 CAPITAL CONSTRUCTION PRICE REFERENCE IPC DESIGN

The costs, revenues, and tips fees for a reference IPC design are dependent on whether:

- (a) The IPC site is in a bottle bill or nonbottle bill state (greater IPC capacity is required for the same population base in a nonbottle bill state, and greater total revenue sales would be expected).
- (b) The watershed is rural or urban (there is usually less ONP in more rural areas).
- (c) Private and public entity equity contributions or state grant monies offset capital expenditures and debt service.
- (d) The financing is public or private and tax exempt.
- (e) Land acquisition was necessary, its expense, and whether the IPC is sited on a new or existing site.
- (f) Union versus nonunion labor is used for construction and operation.
- (g) Subsidies for residential IPC tip fees come from higher commercial tip fees set by a regulating authority,

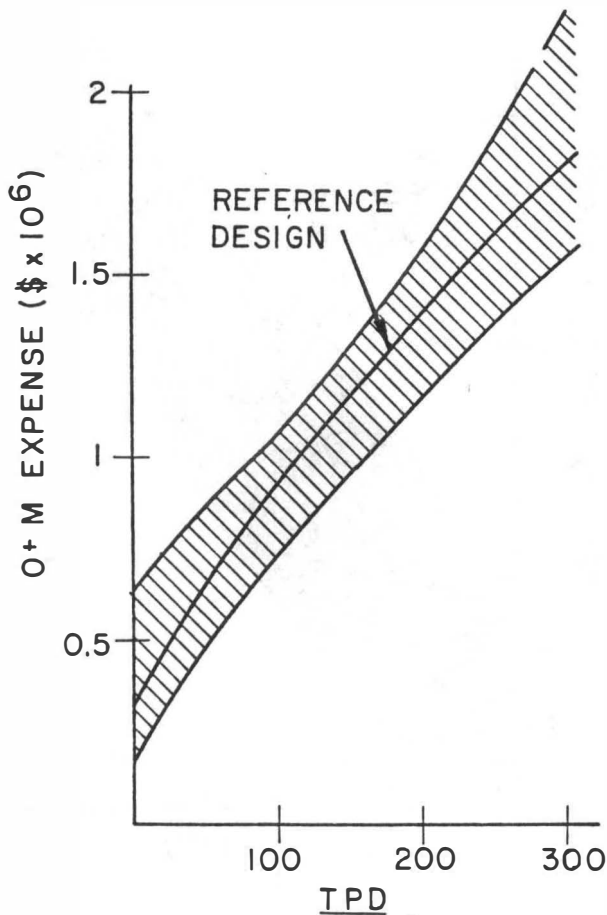


FIG. 6 OPERATION & MAINTENANCE COSTS  
REFERENCE IPC DESIGN  
(Excludes Debt Service on Capital)

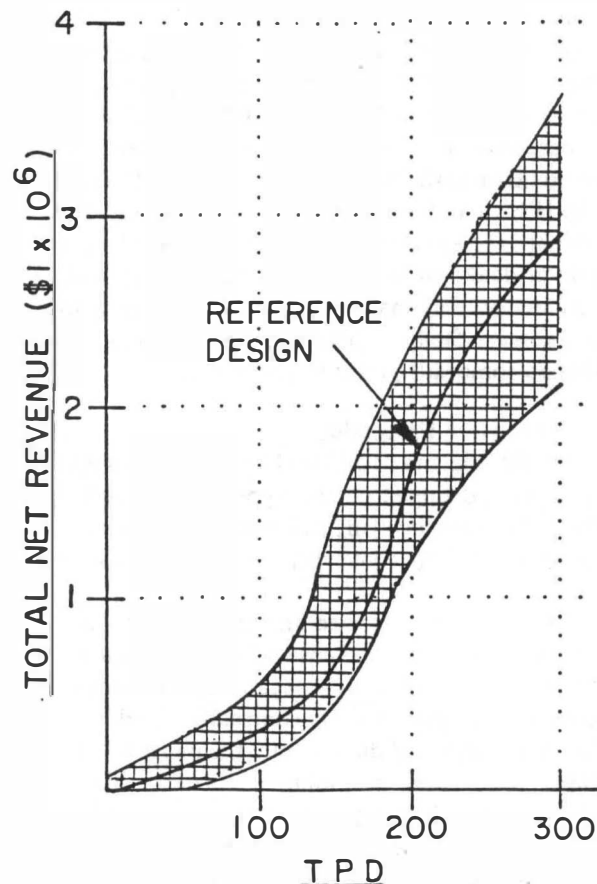


FIG. 7 TOTAL REVENUE NET OF TRANSPORTATION COSTS

or from taxes for recycling programs collected at solid waste disposal facilities.

(h) There is percentage revenue sharing and distribution of risk between the operator and users.

The reference IPC capital construction costs are based on the design criteria provided here, and in general include all the construction costs to complete the facility, including: site work and utilities; pre-engineered metal building and support services; process equipment; land acquisition (assumed \$85,000 per acre); nonunion labor; performance and payment bonds; contractor overhead and profit; design engineering; and project management fees.

Additional costs for payloaders, forklifts, and other rolling stock normally funded through private 5-year loans or municipal lease purchases range from \$25,000 (1/30 IPC) to \$325,000 (150/300 IPC).

Operation and maintenance costs include categories for: employee payroll and benefit; utility consumption;

repair; residue disposal; supplies; equipment renewal and replacement funds; rental; building and site maintenance; contract services; expendable supplies; and management fees.

Revenue projections in Fig. 7 are based on best market prices net costs for transportation of processed materials to end markets. The revenue projection represents a range for bottle bill and nonbottle bill states and includes 100% of all projected revenues. Fig. 8 depicts reference IPC sizing for various population bases, based on handling commingled and wastepaper materials.

#### Future IPCs

In the future, reference IPC designs will change as advancements in processing technologies occur. Head-on sorting will offer higher quality end products as the sorter has more time to view the materials on the belt, and higher production rates (nearly double) with less worker fatigue and injury [3].



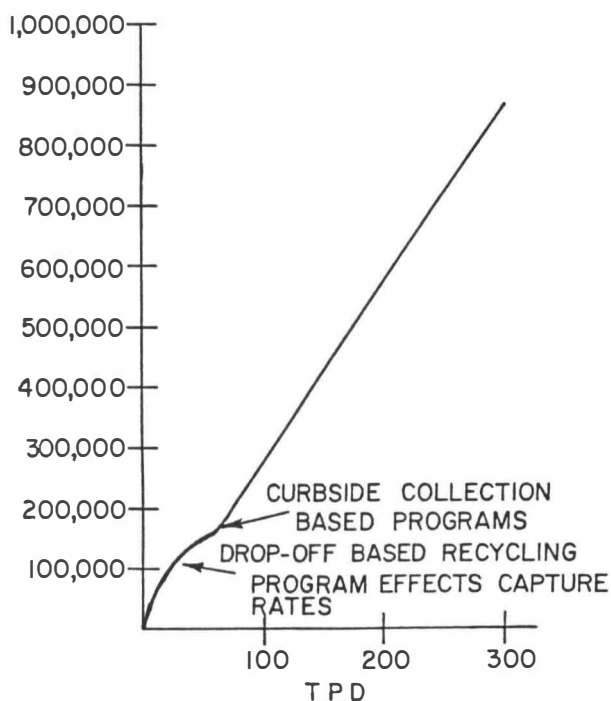


FIG. 8 POPULATION VERSUS MRF CAPACITY

Automatic optical sorting systems will, at some point in time, be available to separate clear, whole containers from mixed colored containers. In the short term, manual sorters will still be required to separate colored and broken containers. Automatic optical sorters may eventually replace the manual picking stations for glass and plastic.

Future IPCs may take material processing one more step. As more and more end markets become inundated with processed recyclables and revenues from end markets dwindle, client communities and IPC operators may look to develop more reliable end markets that they can control. Side by side, plastic extrusion and

paper pulping facilities can feasibly augment existing and planned IPCs. The further development and down scaling of these processing technologies may allow economical alternatives to IPC process designs. For economic reasons, paper pulping, plastic sorting and extrusion, and glass beneficiation processes may be centralized at regional processing facilities funded through contractual agreements between IPC operators and the centralized facilities.

## CONCLUSION

The reference IPC designs described in this paper can serve as a guideline to those who specify, procure, and design source separated recyclables processing systems. A successful process design is contingent upon the input and expertise of knowledgeable professionals. The process design must be based on the composition and quantity of the incoming recyclable feedstock, the required end market product quality specifications, and a thorough knowledge of the processes and equipment involved.

The final design and construction of integrated material process systems, accomplished after careful consideration of all parameters, is only the first step to a successful recycling program. A strong and enduring commitment by all project participants (residents, community leaders, and the IPC operator alike) will ensure that the IPC remains an economical alternative to waste disposal and continues to be functional within a changing environment over its full service life.

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