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Project Summary

Considerations in Selecting Conveyors for Solid Waste Applications

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Several types of conveyors used to move processed fractions of municipal solid waste (MSW) were evaluated to provide reliable guidance to design and operating engineers. Properties of materials that affect the conveyability of MSW and its fractions are discussed and criteria for evaluating MSW conveyors are presented.

The report describes and analyzes test results for three types of conveyors belt, vibrating pan, and apron. Procedures are given for assessing and operating belt conveyors with respect to spillage rate. Experimental results are given from a recirculating test rig operated with six waste fractions over a range of belt configurations, velocities, and flow rates. Test results and analyses are also presented for a vibrating pan conveyor with six feed stocks operated over a range of frequencies and stroke lengths. In addition, results are evaluated from experiments with a small apron conveyor.

Screw, drag chain, and bucket conveyors are excluded from this study. Pneumatic conveyors were studied as a basis for developing a pneumatic conveying test rig for MSW fractions. Parameters, design, and cost of a full-scale laboratory rig is investigated. Material characteristics, pneumatic system geometry, and air and solids flows are evaluated and presented. Cost and sizing of the pneumatic test rig is established using the author's evaluations and the manufacturer's quotations. Cost comparisons for purchasing the system for testing materials, versus having them tested at the manufacturer's site for a fee, are examined.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in two separate reports (see Project Report ordering information at back).

Introduction

To select, design, and operate the various types of conveyors for most bulk solids, some knowledge is needed of the relevant properties of the solids. But information on the properties and conveyability of MSW and its processed fractions is not readily available in the literature. This lack has hampered design engineers and equipment vendors in selecting and constructing conveyors for MSW. Proper evaluation and assessment procedures at existing plants have also been compromised by this information void. Waste-processing facilities often experienced conveying problems during startup and full operation. But, extensive efforts to remedy such problems are usually based on treatment of symptoms rather than causes, and however ingenious they are, they contribute little to guide the conveyor design engineer. Problems should be assessed and solved in the design phase by providing a mechanism of tests to expand the basic knowledge of material properties of MSW and its processed fractions.

This program was implemented to investigate engineering design considerations in selecting conveyors for resource recovery facilities. The first phase of the research program included material characterization, establishment of evaluation criteria, and experimental measurements and observations. The second phase consisted of additional tests using densified, refuse-derived fuel (d-RDF) and blends of coal and d-RDF. Discussions were held with representatives from several conveyor equipment manufacturers to assess the needs, approach, and goals of the project. The third phase of the study involved pneumatic conveyor systems, which are used at most waste-processing facilities. Operation and performance problems are more acute with these than with mechanical conveyors. A pneumatc conveying test rig for MSW and its fractions was designed, construction costs were estimated, and a test plan was developed. Considerations, materials, limitations, and rationale for design of the test rig are included in a separately bound portion of the project report.

Procedures

Investigators and conveyor manufacturers agreed that the need for improvement in the design and operation of conveyors for MSW fell into three categories: (1) organized, comprehensive data regarding material properties and handling interactions; (2) known significance of involved parameters; and (3) acceptable criteria and techniques for evaluation and field testing of existing conveyor equipment. Controlling spillage was of extreme importance.

Criteria Considered for Study

The key MSW properties that affect conveyability were studied and their importance was assessed. They are listed as follows:

Measured properties
1. Abrasiveness*
2. Angle of external friction*
3. Angle of internal friction*
4. Angle of maximum inclination (of a belt)
5. Angle of repose
6. Angle of slide
7. Angle of surcharge
8. Bulk density — loose
9. Bulk density — vibrated
10. Cohesiveness*
11. Elevated temperature⁺
12. Flowability — flow function⁺
13. Lumps — size — weight
14. Specific gravity⁺
15. Moisture content
16. Particle hardness*
17. Screen analysis and particle size
18. Presence of sized and unsized material

Assessed properties:
1. Aeration (fluidity)
2. Plasticity or tendency to soften
3. Tendency to build up and harden
4. Corrosiveness
5. Generation of static electricity⁺
6. Degradability (ability to break down in size)
7. Tendency to deteriorate in storage (decomposition)
8. Dustiness
9. Explosiveness
10. Flammability
11. Generation of harmful dust, toxic gas, or fumes
12. Hygroscopic nature⁺
13. Tendency to interlock, mat, and agglomerate
14. Presence of oils or fats⁺
15. Ability to pack under pressure
16. Shape of particles
17. Stickiness (adhesion)
18. Contaminable
19. Weight (lightness and fluffiness; ability to be windswept)

MSW fractions produced and conveyed in resource recovery plants include raw and shredded wastes, light and heavy air-classified fractions, and ferrous metals. The fractions may vary in properties from one plant to another and over time at a single facility. The most frequently found and/or most difficult to handle fractions were chosen for study. Test samples of processed waste fractions were obtained from the Baltimore County Resource Recovery Facility in Cockeyville, Maryland. The samples were representative of individual processed fractions of MSW and were reasonably consistent from test to test.

Acceptable spillage was the main criterion for selecting conveyors for MSW. The most undesirable feature at operating plants with systems to convey MSW fractions is high spillage rate. Here spillage is defined as MSW that falls on the sides of conveyor belts and drops to the floor at transfer points. Spillage causes rotating equipment to malfunction, and it produces odor, sanitation, maintenance, and cleanup problems Designating spillage as the primary concern for conveyor design was the consensus of manufacturers, operators, and the authors.

Other criteria considered were power consumption, reliability, dust emission levels, material transfer, and throughput. Dependence of throughput on belt speed was studied. Power consumption was measured at various operating points. Malfunctions of equipment were noted and documented. Dust levels were recorded and evaluated. Experimental observations during tests can serve as a guide for feeding the belt with a variety of feedstocks.

Test Rig Evaluations

Test rig evaluations were carried out on belt and vibrating pan conveyors to provide information on the most commonly used types of conveyors. Testing of an apron conveyor was limited to batch tests on feedstocks of d-RDF and blends of d-RDF and coal.

A closed-loop test rig configuration with a continuous recirculating flow was assembled (Figure 1). The flow speeds were fixed and a measured quantity of test material was allowed into the system. A constant mass flow was obtained throughout the loop. Six waste fractions were tested on the belt and vibrating pan conveyors. Test variables included inclination, velocity, depth of burden, and mass flow rate.

A pneumatic conveying test rig for MSW was developed (Figure 2) using analytical techniques and evaluation procedures acquired from studies and field tests. Costs of test rigs were determined based on vendor price quotations.

Results and Discussion

Conveyor Tests

Results of most belt conveyor tests showed that the sensitivity of the spill rate to flow rate and/or to inclination was much smaller in the upper ranges of the increases in belt speeds. Higher spill rates occurred at lower belt speeds. When belt speed was increased at a constant mass flow rate, spills were reduced to a minimum. Higher mass flow rates resulted in higher spill rates for a given test material and belt speed.

*Test methods for processed solid waste fractions are yet to be developed.
⁺Considered unrelated to conveyability of solid waste

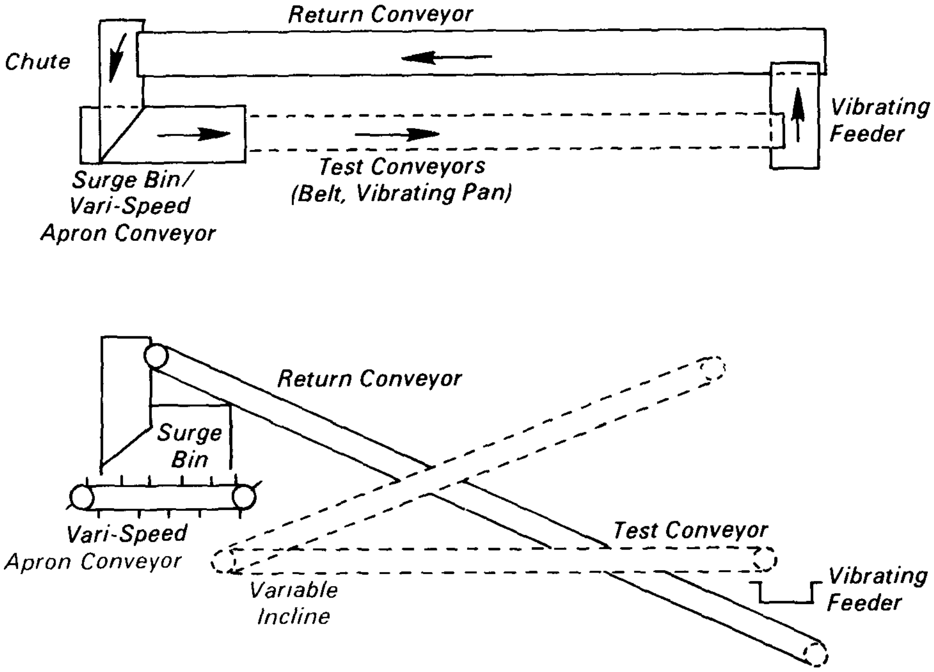

Figure 1. *Schematic of conveyor test rig.*

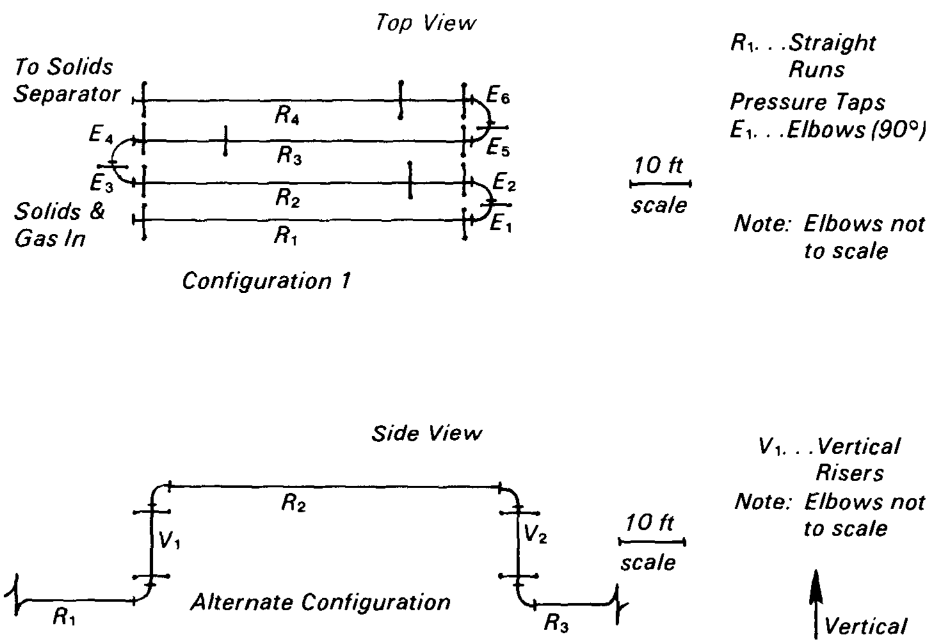

Figure 2. *Schematic view of pneumatic test rig (passive circuit).*

The six solid waste fractions tested showed similar spill-rate patterns, but the rate depended on the individual properties of each fraction. Homogeneous materials generally had lower spill rates than heterogeneous ones. Higher spill rates occurred when the incline of the conveyor was increased from 14° to 18°. Preferred speeds were found for a given mass flow rate and incline. Dense and uniform materials were less prone to slip or roll back on the inclined conveyor.

Belt conveyor data indicated that, except for very low rates of throughput, the movement of MSW and its fractions by conveyor always generated spills. Spills are described in Table 1 by belt section based on the type of fraction, flow rates, and velocities.

Some types of spills encountered were (1) fine, inert particles that became wedged between the belt and skirting and were blown out by material falling on the belt, (2) crumbled fractions that fell over the sides of the conveyor, (3) light materials that were swept off the belt by air currents, and (4) higher-density fractions that bounced off the belt.

The maximum carrying capacity of vibrating conveyors increased with stroke and frequency. Increasing the amplitude from 12.7 to 22.2 mm at 540 rpm resulted in carrying capacity increases ranging from 170% for the heavy fraction to 262% for MSW. The conveying speed increased with higher frequencies at a given mass flow rate. Similar effects occurred with changes in stroke. When a hand-held ampmeter was used to measure the vibrating conveyor motor current, energy consumption was not significantly different with frequency or stroke length in the ranges covered.

Tests results on the apron conveyor showed that carrying capacity increased linearly with increasing conveyor speed. Very little spillage occurred off the sides and most of that took place at an incline of more than 30°. These spills were caused by materials that fell back and off the lower end of the conveyor. Inclines of 0° to 15° had little effect on carrying capacity; but from 15° to 39°, a sharp drop occurred. Only two feedstocks (d-RDF and a blend of d-RDF and coal) were used for these tests.

Determining Bulk Densities of MSW

The six materials evaluated in this study were coded according to the Engineering Conference of Conveyor Equipment Manufacturer's Association (CEMA) 1979 publication concerning belt conveyors for bulk materials. These published standards for determining bulk densities of aggregates and coal are not generally applicable to MSW, however. Users must therefore be aware of their limitations, which results from the heterogeneity and variability of the materials. Development of new, reliable procedures for determining bulk densities of MSW were not within the budget of this investigation.

Distribution of Spills

The nature and mechanism of spillage was studied by isolating sections of the belt conveyor to prevent carryover of materials from one section to another. Thus the nature and mechanisms of spills for each belt section could be observed. The distribution of spills in each section may depend on the fraction, speed, or load, or a combination; or it may have no clear trend (Table 1).

Homogeneity of MSW Versus RDF

During the vibrating conveyor study, an attempt was made to separate the processed waste fractions into their component parts. A technique was used to split the stream of waste at the discharge end into equal top and bottom layers. Particle size distribution was performed on the two layers for three different materials — MSW, RDF, and the heavy fraction. In MSW and the heavy fraction, smaller particles of higher bulk density tended to concentrate in the bottom layer. In RDF, however, the top and bottom layers were quite similar.

Pneumatic Conveying

The materials considered for pneumatic conveying were shredded waste, ferrous fraction, heavy fraction, and RDF. Raw MSW was not included. Studies previously reported concerning particle size distribution of raw MSW indicate that some components are of a sieve size larger than 26 cm. This size would require a duct pipe of 75-cm diameter. The needed fan power would place the pneumatic test rig out of the "small" classification. The literature reports a full-scale pneumatic conveying system for raw waste located in Sweden that requires five turbo-extractors o 100 kw each. But in the U.S. Resourc Recovery Plants, RDF and shredde MSW are the only materials actuall being pneumatically conveyed. RDF ha the first priority in both this modelin effort and in instructions to manufac turers from whom price quotation were solicited.

Conclusions and Recommendations

Determination of the value of information from this work requires application and testing of the findings on a variety of conveyor styles, sizes, and applications in full-scale commercial facilities. Though projected follow-up evaluations using the rationale and experience from this study are not likely to be funded, both the findings and areas pinpointed for additional investigation will benefit interested readers.

Table 1. *Conveyor Spills*

Product and Flow Rate	*Belt Section*	*Spills from Conveyor Sections as Per Cent of Total Conveyor Spills*		
		46 m/s (150 ft/min)	*92 m/s (300 ft/min)*	*137 m/s (450 ft/min)*
RDF at 2.7 Mg/hr (3.0 tons/hr)	*1*	*37.5*	*23.5*	*24.2*
	2	*43.0*	*9.5*	*13.1*
	3	*13.2*	*14.6*	*13.6*
	4	*6.3*	*52.4*	*49.1*
MSW at 2.7 Mg/hr (3.0 tons/hr)	*1*	*41.7*	*30.2*	*29.7*
	2	*39.7*	*16.4*	*14.9*
	3	*11.6*	*10.9*	*13.9*
	4	*7.0*	*42.6*	*42.5*
Heavy fraction at 9.1 Mg/hr (10.0 tons/hr)	*1*	*38.5*	*33.3*	*50.0*
	2	*46.2*	*44.4*	*25.0*
	3	*6.4*	*5.6*	*8.3*
	4	*9.0*	*16.7*	*16.7*
Ferrous fraction at 9.1 Mg/hr (10.0 tons/hr)	*1*	*25.0*	*15.0*	*6.7*
	2	*50.5*	*18.1*	*56.3*
	3	*17.9*	*59.1*	*31.9*
	4	*6.7*	*7.6*	*5.1*
d-RDF/coal blend at 9.1 Mg/hr (10.0 tons/hr)	*1*	*89.1*	*72.8*	*67.0*
	2	*2.9*	*2.5*	*4.8*
	3	*3.0*	*6.8*	*11.7*
	4	*4.9*	*17.8*	*16.4*
d-RDF at 13 .6 Mg/hr (15.0 tons/hr)	*1*	*15.0*	*20.0*	*66.7*
	2	*2.5*	*10.0*	*11.1*
	3	*47.5*	*10.0*	*11.1*
	4	*35.0*	*60.0*	*11.1*

Bulk Density Determinations

CEMA methods used to classify and define bulk materials did not apply to MSW and many of its fractions Users must therefore be aware of their limitations.

Belt Conveyors

Experimental results on belt conveyors indicate that (1) the sensitivity of spill rate to flow rate generally increases in the upper range of belt speeds, and/or (2) the degree of incline is smaller at higher belt speeds. The recommendation is to operate in the "fast and lean" range rather than under "slow and loaded" conditions.

Measurements of discharge trajectories for four fractions at fixed mass flow and varying belt velocities correspond reasonably well to the CEMA theoretical expectations. These calculations could probably be used to predict trajectories of MSW fractions accurately. Negligible change in belt motor current was found for a varied range of velocities, capacities, and materials. This lack of fluctuation in power consumption probably indicates use of a motor that surpasses the required design and capability

In the vibrating conveyor experiments, carrying capacity increased for all fractions with both frequency and stroke. The capacity curve is expected to reach saturation level at a higher undetermined frequency. In this study, the operating frequency was limited to 430 to 545 c/m (cycles per minute) at a 22.2-mm stroke and 390 to 550 c/m for a 12.7-mm stroke because of an unresolved imbalance in the system. No significant difference occurred in energy consumption with frequency or stroke length in the above ranges. Compaction of material as a result of pan vibration was found in all solid waste fractions. MSW and RDF had the highest degrees of compaction.

Apron Conveyors

When the carrying capacity of apron conveyors is plotted versus conveyor speed, the maximum carrying capacity increases linearly with increasing velocity. The speed range evaluated is typical of those used with apron conveyors. The conveying surface is rigid, and the bouncing effect seen with the conveyor belt is absent. Very little spillage occurred over the sides.

Pneumatic Conveyors

Two systems for pneumatic conveying of MSW fractions were investigated. The first used a high-resistance, fixed geometry system, and the other employed a simplified, variable geometry system with restricted capabilities. In selecting conveyors, considerations based on user requirements and the availability of conveyors at the manufacturer's sites for testing the materials to be conveyed should enter into purchasing decisions. A need for regular tests over a period of years would justify ownership of a complex unit. Limited needs could be met by performing tests at the manufacturer's sites or by purchasing a simplified pneumatic conveyor.

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***Carlton C. Wiles** is the EPA Project Officer (see below).*
This Project Summary covers two reports, entitled:
"Considerations in Selecting Conveyors for Solid Waste Applications," (Order No. PB 83-107 482; Cost: $14.50, subject to change)
"A Pneumatic Conveying Test Rig for Municipal Solid Waste Fractions," (Order No. PB 83-107 474; Cost: $10.00, subject to change)
The above reports will be available only from:
National Technical Information Service
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