ABSTRACT

Controlled processing of refuse for resource recovery usually requires a refuse feed rate responsive to the demands of the process system. Even after being reduced in size, prepared refuse exhibits certain characteristics that can create considerable difficulty in retrieving it from storage at a controlled rate.

This paper explores, in general terms, several basic material characteristics as well as other factors which must be carefully considered and evaluated in order to minimize problems in storage and retrieval of prepared refuse.

INTRODUCTION

It should be noted that it is not the intention of the author to present a highly technical treatise on such a complex subject. The purpose of this paper is to identify and discuss, in general terms, those items which, in the author's opinion, create most of the difficulties encountered in storage and retrieval of prepared refuse. This information can then be used by the systems designer to minimize problems in the subject area.

PROBLEMS

Storage and retrieval of prepared refuse can — and does — create several problems which may not be experienced (or may be experienced to a lesser degree) in other types of bulk materials. Problems due to bridging, arching, ratholing, compaction, abrading, erratic retrieval (feed) rates, etc., are certainly not new to the field of materials storage and retrieval. However, prepared refuse is particularly susceptible to these problems, primarily due to the characteristics of the material.

MATERIAL CHARACTERISTICS

The basic characteristics of prepared refuse are of utmost importance to the designer of storage and retrieval equipment since these characteristics are the very basis for his design. (It should be noted that these same characteristics are also quite important to other equipment in the overall process which is not included in this paper.) Therefore, these basic characteristics should first be examined to determine their effect on storage silos (bins) and retrieval equipment.

Material Size:

The physical dimensions of the prepared refuse are of utmost importance in the design and/or selection of storage facilities and retrieval equipment for prepared refuse. To illustrate, let us take a look at a wide range of particle sizes observed at actual installations and briefly discuss the effect of each range of sizes on the design and/or performance of the equipment. It should be particularly noted that all the illustrations are of a material which has a specified size of 2.54 cm (1 inch) nominal with a maximum dimension in any direction of 10.16 cm (4 inches).
Figure 1 illustrates the average material size being produced to the general specifications with very little material exceeding the specified size. With minor exceptions, the material size being generated falls within the specifications and there should be no problem in the proper functioning of a well designed storage and retrieval system.

Figure 2 illustrates very small particles such as dust, lint, sand, ground-up glass, etc. Although the quantity of these small particles is small in comparison to the total material processed, its effect must be taken into account. Dry dust and lint are very combustible and proper considerations must be given to fire protection and house cleaning, as well as other design details. The abrasive nature of some of these very fine particles also requires attention and will be discussed later.

Figure 3 indicates a significant quantity of refuse exceeding the specified particle size. The relative quantity of over-sized particles is of sufficient magnitude to increase the tendency of the material to bridge, arch, rat-hole, and, in general, reduce the efficiency of the retrieval equipment — and probably other process equipment.

Continuing to Figure 4, we see an extreme example of very stringy oversized material in very large quantities. This material, which is composed primarily of cloth, plastics, wire, rope, etc., is now present to such a degree that it can cause massive bridging and arching in the storage structure and can also severely reduce the effectiveness of the retrieval equipment or even render it useless.

By way of analogy, the long fibre particles present have the same effect on the material mass
as reinforcing bars have in concrete. In each case, the tensile strength of the mass is considerably increased, thereby completely changing the nature of the material mass. This change in the mass characteristics of prepared refuse is highly undesirable and should — and can — be avoided.

Another detrimental effect of these stringy particles is their pronounced tendency to wrap around and build up on rotating equipment; hence greatly reducing the efficiency or, in some cases, rendering the retrieval equipment completely ineffective or inoperable.

The importance of achieving the specified particle size and eliminating large quantities of stringy (oversize) material through proper preparation equipment selection, operation and maintenance cannot be over emphasized.

Material Density:

Prepared refuse is a compressible material which can result in a very wide variation in density. As an example, refer to a typical density specification for prepared refuse in storage shown in Figure 5.

If this refuse was stored in a silo to a height of, say, 70 feet, the actual density of the refuse at any location in the pile would look somewhat like the example in Figure 6. Please note that the density at the bottom of the pile can approach 400 kg/M³ (25 pcf) and this must also be taken into account in the design or selection of the storage and retrieval system.

To further complicate matters, the compressible nature of shredded refuse creates internal pressures
FIG. 3 SIGNIFICANT QUANTITY OF EXCESSIVE PARTICLE SIZE
FIG. 4 EXTREME QUANTITY OF OVERRSZE MATERIAL
<table>
<thead>
<tr>
<th>Condition</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>loose</td>
<td>64 kg/m³ (4pcf)</td>
</tr>
<tr>
<td>average, as stored</td>
<td>240 kg/m³ (15pcf)</td>
</tr>
</tbody>
</table>

FIG. 5 SPECIFIED DENSITY FOR VARIOUS CONDITIONS

FIG. 6 DENSITY VARIATION WITH PILE HEIGHT
while in storage. A graphical illustration of the horizontal pressure component would look something like Figure 7(a), and can easily become a contributing factor to a wall-to-wall bridging situation as illustrated in Figure 7(b), as well as contributing to bin structural problems.

In addition to its effect on the silo structural design, the material density can — and does — have a tremendous effect upon the operating speeds, torque requirements, etc., of the retrieval equipment. As the material is retrieved from the stored mass, it usually decompresses to some intermediate density value between the loose density and the maximum density, as stored. For double shredded and air classified municipal solid waste, this intermediate value is generally 160 kg/M³ (10 pcf). In Figure 5 we noted that the loose density was 64 kg/M³ (4 pcf). Obviously then, the retrieval equipment must be capable of performing satisfactorily at any density between these two values. It is therefore essential that accurate density values (under various conditions) be established and specified for each individual application and condition.

Material Angle of Repose:
Prepared refuse, like many other materials, exhibits a wide range of normal angles of repose, ranging from as low as 45° to as high as 70° or more. The actual angle for a given material depends upon many factors such as fiber size, moisture content, density, etc.

A primary concern involving the angle of repose is the effective storage volume of the storage facility. For example, Figure 8(a), illustrates a truncated cone type storage silo receiving shredded refuse, with an assumed angle of repose of 45°, through the top center of the silo and allowed to free fall to the center of the bin. Figure 8(b) portrays the same situation except the angle of repose of the material has been changed to 70°. Note the considerable difference in the effective storage volumes of these two examples.

Available space is frequently a major factor in establishing the size and/or configuration of the storage facility. A material exhibiting a high angle of repose, combined with limited space, presents a very difficult problem to the engineer designing the storage and feeding equipment. For example, assume an available space with the horizontal base dimension “D” and shredded refuse with a specified angle of repose “θ”. The profile of the stored material (with free fall into the bin) would appear as in Figure 9(a). This might not result in adequate storage and, therefore,
some type of distributor must be utilized to increase the storage as in Figure 9(b).

From these comparisons, it is evident that the angle of repose of the shredded refuse must be carefully determined and specified in order to achieve the optimum design of the storage facility. In addition, the space available for the storage facility should be determined with due thought.

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and consideration being given to the effect of the angle of repose of the prepared refuse as well as other factors.

Material Abrasiveness:

There are many abrasive particles present in prepared refuse. Among these are: sand, glass, metals, plastics, rocks, etc., the quantity and size depending upon the particular material (i.e., municipal waste, waste wood, etc.) and the preparation system and equipment being employed.

The abrasive qualities of the refuse require particular attention to design details such as oil and grease seals, sliding contact areas, materials of construction, operating speeds, shielding, etc. Taking this abrasive factor into account during the evaluation and selection of the preparation process and equipment can result in far less abrasion in all downstream equipment.

Moisture Content:

Prepared refuse with a moisture content up to approximately 50 percent does not usually present a mechanical problem (although there can be chemical and/or thermal problems). In the event a higher moisture content is expected, this should be made fully known to the designers of the storage and retrieval equipment.

OTHER FACTORS TO BE CONSIDERED

Although the characteristics of prepared refuse provide the basis for the design of the storage and retrieval equipment, there are other factors that must be considered by the systems designer or consultant. These factors may appear redundant, but occasional omissions or failure to appreciate their significance have, in the past, resulted in some rather unfortunate and, frequently, very costly consequences. They are therefore included as reminders.

Extrapolation of Performance Results:

One of the most common pitfalls is that of extrapolating operating results from a small pilot plant, or model, up to a larger size. Changing the size of the storage and retrieval equipment by extrapolating (either up or down) has proven to be very costly, to say the least.

This particular pitfall can be avoided by evaluating storage and retrieval equipment on a full scale (and "same material") basis. If this is not feasible, you must then rely upon your own evaluation of the recommendations of your prospective vendors, considering their respective technical ability, experience, and integrity.

Power Requirements:

With today's energy situation, it is more important than ever to include the equipment operating costs in the total cost evaluation. Lower operating costs frequently offset higher initial capital cost in a very short period of time.

Selection of Preparation Equipment:

Once the specifications for the prepared refuse are established, it is essential that the preparation equipment (up-stream from the storage silo) produce a material to meet the specifications. Otherwise, performance of the retrieval equipment as well as other equipment (down-stream from the preparation equipment) may be seriously impaired.

Operation:

All equipment should be operated according to the respective manufacturers operating instructions.

Maintenance:

Although a well planned and executed equipment maintenance program is usually assumed, it is essential that the refuse preparation equipment be maintained in such a manner as to insure the specified material particle size (and material content) without any appreciable amount exceeding the specification.

Corrosion:

Although corrosion due to prepared municipal refuse has not been a problem in the past, it is advisable to always consider the possibility and evaluate each application on an individual basis.

Cold Weather Operation:

Cold weather operations do not usually require any special consideration. However, freezing of the material mass could become a problem due to one or more of the following in the presence of prolonged low temperatures:

(a) High material moisture content.
Storage and controlled retrieval of shredded refuse is an integral part of many processes used for resource recovery. It is therefore essential that operational and maintenance problems on the storage and retrieval equipment be minimized. This can be accomplished by a better understanding and appreciation of those factors which can adversely affect the performance of the storage and retrieval equipment.

Since each individual application is different to some degree, it is not practical to make specific engineering recommendations except on an individual basis. However, the following general suggestions should prove helpful in avoiding unnecessary problems associated with prepared refuse storage and retrieval.

1) A realistic material specification should be established based upon the overall process requirements.

2) A very thorough evaluation of all equipment involved in the preparation of the refuse should be made to insure that this equipment can, in fact, produce a material that meets the specifications.

3) As early as practical in the project, discuss your storage and retrieval requirements with qualified designers and builders of such equipment. The items enumerated in this paper can be used as an outline, or guide, for discussion.

4) Make a thorough evaluation of all storage and retrieval equipment, methods or schemes proposed, and make a decision accordingly.

Key Words
Prepared Refuse Storage and Feeding
Refuse Storage and Feeding
Refuse Characteristics
Effect of Prepared Refuse Characteristics on Storage and Feeding
Surge Bins
Storage
Bulk Storage
Silos
Bins
Feeders
Silo Dischargers
Silo Feeders
Live Bottom Bins
Retrieval Systems