DISCUSSION by Harvey D. Funk, P.E.,
Assistant Vice President, Henningson,
Durham & Richardson

Mr. Hickman's paper on Storage and Retrieval of Prepared Refuse was reviewed with a great deal of interest. Our work in energy and materials recovery from solid waste continually involves us in storage and retrieval needs in our projects. Our viewpoint of this subject as it relates to Mr. Hickman's paper is as follows:

Resource Recovery feasibility is largely dependent on the energy recovered from the solid waste stream. The energy conversion methods available include:

1. Mass burning of solid waste as a primary fuel,
2. Burning of prepared solid waste as a primary fuel,
3. Burning of prepared solid waste as a supplementary fuel,
4. Pyrolysis,

All of these methods (except the first one) can require interim storage with controlled retrieval.

The energy conversion method will dictate the material specifications (particle size, composition and moisture content) as well as the required feed rates. The feed rate requirements can vary under different operating conditions. The conversion method may also be able to accommodate a wide range in material size, composition and moisture content. So, versatility appears to be the requirement for storage and retrieval systems.

The ideal interim storage and retrieval system would be able to handle a wide range of feed rates, with redundancy and the variable refuse derived fuel (RDF) characteristics.

Our system at Ames utilizes the supplemental fuel conversion method, where three boilers have been modified for burning RDF. Each of the boilers can be fed separately or jointly; each can accept a wide range of feed rates and the two front fired units with traveling grates can accept larger particle sizes.

Particle size can be controlled at the processing plant by grate openings in the shredders. The fuel characteristics can also be varied by adjusting the air classifier. The less drop, the more sand, glass and grit that will fly. Conversely, the more drop, the less combustible fraction going to the boilers.

In other words, there is flexibility on both sides of the interim storage and retrieval system. This flexibility gives the option of adjusting the system to the most efficient operating level. Flexibility is desirable and should be designed into a system because of the unknowns, the present state-of-the-art and the unique characteristics of individual conversion units. The interim storage must be compatible with the flexibility in the other two parts of the system.

The system in use is an 84'-diameter, 550-ton storage bin with four controlled outfeeds. For the first eight months of operation, the system has worked well under a wide range of conditions. The only problem encountered occurred when oversized material was delivered to the bin. The oversized material (nominal 3" with some material 8") was produced when by-passing the second of two stages of shredding because of a bearing failure. Grate openings were partially reduced in the primary shredder but not to the point of achieving the regular 1 ½"
nominal size. The large particle size would not feed through the grizzly bars into the drag conveyors without opening up the spacings.

Life-cycle costs analysis will only be confirmed after longer operating periods. Mr. Hickman pointed out power consumption as an important consideration. We agree, as the capital costs are fixed and certainly both maintenance and energy costs will continue to increase. We have experience at projecting energy costs, but almost no experience at estimating maintenance costs in an 84'-diameter, 550-ton storage and retrieval system. Operating experience will be the only way to get an accurate cost.

In summary, I would like to address two things:

1. Mr. Hickman stressed the importance of precisely identifying your product to be handled so the supplier of a storage and retrieval system can design for a specific material.

In response, I would like to stress the need for versatility, flexibility and redundancy. It is not always possible to determine the exact characteristics of the materials to be handled.

Specific items to consider:
- Feed rates
- Fire control
- Level indicators
- Access to all maintenance points
- Interlocking operating controls
- Housekeeping provisions
- Emergency bin unloading system
- Odors and emissions

2. We have all come a long way in our knowledge and technical abilities in resource recovery during the past few years. The future of resource recovery depends on the interchange of knowledge and technology gained from experience.

We, along with the city of Ames and the equipment suppliers, offer to share and exchange our experiences with you (as many others have done with us) to enhance the future of resource recovery.

DISCUSSION by Gordon L. Sutin, P.E.,
Gordon L. Sutin & Associates Ltd.,
Hamilton, Ontario

The Author of this paper is perhaps more experienced in the storage and retrieval of solid wastes than anyone else in the field. The first major installation for the storage and retrieval of shredded municipal waste without air classification was at the East Hamilton Swaru in Hamilton, Canada, and since that time, many installations have been made, although in most cases for the storage of air classified material.

The general drift of this paper is to place the responsibility for product control on someone else so that the product provided for storage and retrieval should meet the requirements of storage and retrieval system.

In my opinion, the responsibility is wrongly placed.

There is no doubt about the need for the manufacturer of storage and retrieval equipment to be made aware of the kind of material he is to handle. And if this was possible 100 percent of the time, it would be ideal. It must be recognized, however, that there are limitations on equipment which shreds refuse, and without spending large quantities of money on preparation of the shredded refuse before storage, one cannot expect a guaranteed type of material.

Mr. Hickman has clearly outlined the various kinds of problems that can be expected in the storage and retrieval of shredded refuse and has set up ideal conditions to avoid these problems.

For example, he makes a statement that the change in mass characteristics of prepared refuse is highly undesirable and can be avoided. My experience has been that the only way of avoiding these problems is by complex sophisticated preparation of the material before storage. There is no argument about the importance of achieving specified particle size in eliminating large quantities of extremely oversized material. However, bearing in mind that one of the functions of the system which includes storage of shredded refuse is the disposal of refuse, one must recognize that all refuse must be disposed of, whether or not it is stringy.

The paper suggests the essentiality of accurate density values but does not go into the matter of determining the density values. This is perhaps a much bigger problem than is mentioned because refuse varies from month to month, from season to season and indeed from year to year. Thus a system based on particular density ranges must also be able to accomplish its function even with densities outside this range in the future. It is suggested that the angle of repose of shredded refuse must be carefully determined, but this as well depends on the material itself which may vary not only from city to city, but may vary at different times of the year and at different times from now on into the future. Mr. Hickman has suggested that it is important to include equipment operating costs in the total cost evaluation. I must agree with this for this
is becoming more and more an important factor with rising energy costs. It is suggested in the paper that it is essential that preparation equipment produce a material to meet specifications. This is fairly easy to do 95 percent of the time, but the storage and retrieval equipment must be capable of handling the material at all times and therefore, in my opinion, it is the proper function of the retrieval equipment supplier to make certain that his equipment will work even during the 5 percent of the time when material does not match the specifications as set out originally. There are many unknowns, even now, in the shredding of refuse and there is no doubt that over the years improvements will be made not only in the preparation equipment, but as well in the storage and retrieval equipment.

I must agree with the need for a proper maintenance program and must also agree that corrosion in general has not been a problem, at least certainly not in my experience.

The summary in the paper aptly describes the terms which need to be looked at in order to avoid unnecessary problems.

On the other hand, shredded refuse is indeed a difficult material to handle and this paper tends to point towards the shredded refuse storage and retrieval system as the key operation within the entire system. In fact, I consider this to be merely a tool and that the upstream and downstream equipment must be catered to, rather than the storage and retrieval system. In other words, I should like to see more effort being made by the manufacturers to enable us to design plants based on the needs of the upstream and downstream equipment.

The basing of the entire plant design on criteria established for proper operation of the storage system is not a reasonable expectation. The most important factor is satisfactory performance of other plant functions. It behooves the storage equipment manufacturers to ensure that their equipment will meet the requirements of the rest of the plant.

COMMENTS by Robert L. Merle, P.E.—Eastman Kodak Co.

This paper can serve as a check list for engineers and owners in specifying storage equipment. What is the basis of data for Fig. 9—Density variation with pile height? Source of data should be specified so as to avoid misinterpretation. Other items which should be considered include:

1. Access doors for inspection, fire fighting, bridge breaking or clean out.
2. Fire detection—sensors; alarming, automatic suppression systems such as CO₂, foam or water;
stand pipes for connection to a water source and availability of fire hoses.

3. Detection of level and pluggage.

4. Industrial wastes could present some very special problems. They could have a low moisture content (~6 percent) and an angle of repose near 90°. Dryness could present problems of dust explosions and housekeeping.

Should system storage be in one large bin or should two or more smaller units be installed to provide redundancy to insure continuous system operation?

What has been the experience with required maintenance? How much down time can be expected? What is projected annual maintenance cost?

What specifications for material stored in the silo do you require?

**DISCUSSION** by David L. Klumb
Union Electric Company

Author's paper accurately reflects Union Electric's experience with the Atlas solid waste live bottom bin used for the Trash to Kilowatts experimental unit.

There are two considerations that should be added when integrating a surge bin into a milled solid waste utilization system:

1. An intimate design relationship must be established between the bin supplier and the supplier of equipment which feeds the milled waste into the bin. Uniform distribution of material in the bin to provide for uniform distribution to multiple bin outfeeds is a basic requirement.

2. It follows from Item 1 that an intimate design relationship is also necessary between the bin outfeed conveyor and the equipment that transports the milled waste from the bin outfeed conveyor discharge on to the following waste processing point.

Other bin design considerations might include:

1. Access to bin mechanisms for routine maintenance and observation during operation.

2. Provisions for simple metering of bin outfeed(s) considering the variable density of the material in the bin.

3. Spare bin drives.

4. Provisions for maintenance removal of bin mechanisms which are normally buried under the milled waste. A failure of a mechanism during operation could be a problem if the mechanism is buried under a substantial amount of waste material.

5. Provisions for monitoring bin level.


7. Provisions for fire control.

I'm sure the author has thought about the items enumerated above.

**DISCUSSION by Laurie R. Russell, P.E., Russell Engineering, Omaha, Nebraska**

Mr. Hickman's paper focuses our attention on the unusual characteristics of shredded refuse materials that make it one of the most difficult materials to store and handle that we have ever experienced.

In our searches for available equipment to handle shredded refuse derived fuel (RDF), for our energy recovery projects, we traveled thousands of miles and visited dozens of installations. We readily came to appreciate the uniquely difficult characteristics of RDF in conveying, storage and retrieval from storage. We observed basic and major problems in most of the installations visited.

For the Solid Waste Recovery Project at the City of Ames, Iowa, which was designed by Gibbs, Hill, Durham and Richardson, under the direct supervision of the Discusser, we selected in 1973 a conical live bottom storage system as manufactured by Mr. Hickman's firm, Atlas Systems Inc. The equipment has performed exceptionally well and to our knowledge is the most successful RDF storage and retrieval system in the United States. Except for some upset situations which we will discuss later, the equipment has proved to be a reliable and low maintenance system.

However, as Mr. Hickman points out in his paper, the keys to a successful storage and retrieval system begin in the processing plant where the refuse is shredded.

In the first 6 months of operation of the Ames, Iowa Solid Waste Recovery System, there have been a few operational upsets in the processing plant that have given us an opportunity to observe their effects on the performance of the storage facility and to gain an insight into the behavior of RDF shredded to various particle sizes. Descriptions of these incidents follow:

1. Initially, when the plant was started in October, 1975, the spacing of the grate bar grids in the second stage shredder provided a 2" × 3" net opening. This spacing proved to be too small. The specified particle size was 1½" nominal max. whereas the maximum particle size produced was only about ¾". Further, the shredder throughput was less than 50 percent of its specified capacity of 50 tons per hours.
Grate bars with appreciably larger openings were clearly indicated. However, until new grates could be manufactured, which required several weeks, it was decided to cut out alternate grate bars, thereby enlarging the openings and allowed continuing plant operations.

Now the openings became about 3" X 8". These larger openings permitted the occasional passage of material as large as 8 to 12" in one dimension. The larger size materials caused the RDF to bridge over the retrieval slots in the storage tank floor which house the drag conveyors. Also, jaming of the air lock feeders which serve the boiler firing pneumatic conveyors also occurred.

2. In March, 1976, the second stage shredder was forced out of service for 2 weeks to replace a rotor shaft bearing that had failed because of an accidental breakage of a fitting on the bearing's lubricating oil sump.

So that plant operations could continue without the second stage shredder, a bypass system, built as a part of the original plant for just this purpose, was placed into service. The bypass allowed the first stage shredder to operate in single stage service. Some of the grate bar sections were moved from the second stage to the first shredder in an attempt to hold down the particle size produced. However, some materials as large as 12" in one direction were passed and caused troublesome bridging in the retrieval system and stoppages and jamb-ups in the air lock feeder and pneumatic transport systems.

The storage and retrieval system for RDF energy recovery projects is a vital part that justifies careful consideration. We believe that the publication of papers such as Mr. Hickman's paper, is a progressive exchange of information that is necessary to the success of the concept of energy recovery from municipal refuse.

DISCUSSION by Junius Stephenson,
Havens & Emerson

1. Mr. Hickman should include a graph on the pressure (psf) exerted at each level by the shredded refuse.

2. Keene, N. H. is a small community and has unique problems other than those of larger cities. Have you any information on the effect of briquetting on the mechanics of storage and retrieval and economics including capital costs and operating costs of any special shredding requirements as well as the briquetting operation and storage equipment.

3. Tonnage rating on a bin is misleading. They should be rated in cf. capacity and each user's wt./density incorporated.

DISCUSSION by Clarence D. Beatty,
Camp Dresser & McKee Inc.,
Boston, Massachusetts

Mr. Hickman's paper is not highly technical, as he states in the introduction, but he presents some important basic information which should be helpful to those unfamiliar with the characteristics of processed refuse. The paper is of particular value to the systems designer, but it is also of value to others who are inexperienced in refuse processing but are involved in the solid waste processing field.

In discussing "prepared refuse," it is assumed Mr. Hickman refers to municipal solid waste consisting of household refuse and limited amounts of commercial and industrial wastes. If the material he illustrates can be described more precisely he should include a description of the material.

Mention is made that proper consideration must be given to fire protection, but no suggestions are made as to what types of fire protection systems are effective. Reference to alternative systems would be appropriate.

Mr. Hickman correctly states that stringy particles tend to wrap around rotating equipment and that material produced by the processing equipment should be uniform in order to avoid problems with the storage and retrieval equipment. However, since the paper stresses storage and retrieval, it would be helpful if he could suggest methods of handling refuse which is not uniform. It would seem good practice to design the storage and retrieval system to handle materials with a wide range of characteristics, if possible, because the system operating conditions may change from those specified in the design. For example, the operating requirements for a storage bin which receives material from a primary shredder may change if there are changes in the feedstock. It is desirable to design the system to accommodate such a change without modifying the system.

It would be helpful if Mr. Hickman provided additional data on how the density curve in Figure 6, Density Variation With Pile Height was developed. What is the relationship of density to time, and how do the cross-sectional area and the configuration (shape) of the storage bin affect density?