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solid waste shredding and shredder selection

a current report on solid waste management

SOLID WASTE SHREDDING
and
SHREDDER SELECTION

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Preface

Within the past several years, one solid waste unit process has seen an outstanding growth pattern. That unit process is solid waste shredding.* In recognition of future potential importance of this process, the Office of Solid Waste Management Programs contracted with the Midwest Research Institute in 1972, to study and report on the state-of-the-art of solid waste shredding and develop an evaluation and comparison procedure for those considering the purchase of shredding equipment. Since the completion of this effort in January 1973, there have been unforeseen developments which already outdate portions of the original final report. The purpose of this document is to update the MRI document to reflect the latest developments in this rapidly emerging field, as well as to compile a comprehensive listing of those objective and subjective factors which should go into the decision-making process for shredder selection.

Portions of the original MRI report have been deleted because new data has tended to make obsolete some of the original material. Also, the original version contained a decision-making algorithm which has been omitted in this version. The decision-making factors from that algorithm, however, have been included and expanded in this document to acquaint the decision maker with the criteria that should impact the shredder selection.

Because the field of shredding continues to evolve in technology and application, OSWMP plans to periodically update this document as the need arises and new data is brought to light. If the reader is aware of significant developments not contained in this document, this office would welcome being informed of such developments.

Since the MRI report has been completed, very little additional documentation concerning solid waste shredding has emerged; consequently, the evolution of this report has been based primarily on actual site observations and discussions with shredder plant operators, consultants, shredder manufacturers and others knowledgable in the area of shredding.

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* Shredding is the term recommended by Waste Equipment Manufacturer Institute (WEMI) for the mechanical process of solid waste size reduction and supersedes such terms as milling and grinding.

Acknowledgment

Sincere appreciation is extended to the many people who reviewed the original Midwest Research Institute's version of this report and provided responsible suggestions for its revision.

Special recognition is warranted for the following groups and individuals for volunteering exceptional effort in helping to make this document as current and factual as possible. The contributors in alphabetical order were: (1) Harvey Alter and Kenneth L. Woodruff of the National Center for Resource Recovery, (2) Gary Boley, City of Madison, Wisconsin, (3) Harvey D. Funk of Henningson, Durham and Richardson, Inc., Omaha, Nebraska, and (4) Shredder Subcommittee of the Waste Equipment Manufacturers Institute of the National Solid Waste Management Association. These members are:

a. Allis Chalmers
b. Carborundum Company
c. Hammermills, Inc.
d. The Heil Company
e. Jeffrey Manufacturing Company
f. Newell Manufacturing Company
g. Saturn Manufacturing Company
h. Williams Patent Crusher

CONCLUSIONS

The following paragraphs present a summary of the major conclusions of this effort:

1. Size Reduction of municipal solid waste is an emerging technology. There is, as yet, no comprehensive assembled body of knowledge on the planning, design and fabrication of facilities and equipment, or on the economics of purchasing and operating a facility, although much work has been done by consultants in this area and knowledge is emerging. Most manufacturers firmly believe that sales of size reduction equipment for application in solid waste systems will significantly increase in the next five years.

2. A major application of size reduction is in land disposal systems. Size reduction is especially suited to land disposal operations because it increases site life, reduces odors, blowing, and strewing, eliminates voids and reduces vermin infestation, and reduces the need for daily soil cover.

3. The future major application of solid waste size reduction is in resource recovery systems. Size reduction produces a manageable range of particle sizes, increases homogeneity, and reduces the bulk of solid waste. All of these factors are necessary for efficient operation of many of the currently proposed resource recovery systems.

4. There are 11 basic types of size reduction equipment and many of them can theoretically be used for shredding of solid waste. However, only three types--the hammermill, the grinder, and the wet pulper--are considered practical.

5. Hammermills and grinders are the principle type of solid waste size reduction machines now being used or considered for future installations in the United States.

6. The wet pulper is not usually considered a primary machine for size reduction of solid waste. Although one installation is in operation in the United States, most wet pulper installations now being studied or proposed also include a shredder ahead of the pulper.

7. Hammermills are either vertical or horizontal shaft type designs. There are distinct differences in their technical performance. Grinders are vertical shaft type designs.

8. Limited technical performance data for shredders used in solid waste size reduction are available. Some equipment manufacturers possess data on the performance of their machines, but consider the data proprietary and confidential.

9. Economic performance data for shredders used in solid waste size reduction are available but unreliable. The data are usually reported in dollars per ton of waste and are not itemized in categories, such as capital investment, amortization, power, labor costs, and maintenance costs. Variations in the data are often due to bookkeeping practices, management practices, and inaccuracies in data collection techniques. EPA is currently publishing a document to aid shredder operators in categorizing and collecting these costs.*

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* Hitte, Steven J. An Accounting System for Solid Waste Shredder. (in press). January 1975.

Chapter I

INTRODUCTION

A. Background

The Solid Waste Disposal Act of 1965 as amended has concentrated considerable interest on the question of what to do with the huge quantities of municipal solid waste generated in the United States each year.* Recent activity has centered on the utilization of this great quantity of material as a national resource. Thus, emphasis in solid waste management has changed in recent years from disposal to recovery, recycling, or reuse. Many systems for the recovery and reuse of solid waste require that the waste components be physically separated from each other and that a reduction in the particle size of the waste precede recovery operations. Even in those geographic areas where disposal will continue to be the only economic solution to the solid waste problem, size reduction may increase the efficiency and life of the disposal system.

Size reduction is an operation that is common to many solid waste management systems--reuse, recovery, or disposal. It is also an operation that can be accomplished with off-the-shelf commercially available equipment. This report presents the results of a study to develop a rational procedure for the comparison and evaluation of size reduction equipment.

B. Objective of the Study

The objective of this report is to provide a state-of-the-art report describing shredder technology. This report is intended for use by administrative personnel (or other equipment purchasers without technical backgrounds) as an aid in the comparison, evaluation, and selection of shredding equipment. A secondary objective is to illustrate a method of organizing data for shredder selection.

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* The Solid Waste Disposal Act; Title II of Public Law 89-272, 89th Cong. S.306, Oct. 20, 1965. Washington, U.S. Government Printing Office, 1966. 5 p.

CHAPTER II

SIZE REDUCTION OF MUNICIPAL SOLID WASTE

A. Introduction

Size reduction is defined as operations or processes which reduce the size of influent materials through division into two or more subunits. For the purpose of this report, only size reduction by the application of mechanical forces is considered. Size reduction of municipal solid wastes (often called shredding, grinding, or pulverizing) is a new concept, and much of the technology has been borrowed from the mining and rock-crushing industry.* Because solid waste is a heterogeneous mixture (unlike rock), much of the technology is not directly transferable; and size reduction of solid waste has not always been efficient; however, as more solid waste systems have been built, the technology of solid waste size reduction has been significantly advanced. (See Appendix 1 for a current state-by-state listing of shredding facilities.)

B. Reasons for Size Reduction in Solid Waste Management

More than 125 million tons of municipal solid waste are produced annually in the United States. Land areas suitable for land disposal near urban areas where the bulk of the solid waste is generated are becoming scarce and expensive. Open burning and open dumping have been outlawed in many areas because of pollution and health hazards. Incineration is becoming increasingly more expensive because of sophisticated pollution control equipment required to meet acceptable air and water quality standards. Current emphasis in solid waste management, therefore, has centered on both disposal of this great quantity of material and its utilization as a national resource. Because the quantities of solid waste produced each year are so great, the relatively high capital costs of mechanical processing equipment can be amortized over large tonnages, and consequently the cost of processes such as shredding have become competitive with other solid waste management options. This in turn has permitted shredding to become an integral part of disposal and resource recovery systems as will be explained in the following sections.

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* Waste Equipment Manufacturers Institute defines shredding equipment as "a mechanical device used to break up solid waste and recoverable materials into smaller pieces." WEMI has designated the term "shredder" to cover all such equipment that fulfills this definition. Shredding and size reduction can be considered synonomous for purpose of this report.

C. Shredding as an Integral Part of a Disposal System

Municipal solid waste generally has a low, but nonuniform bulk density. Size reduction increases the homogeneity and the bulk density. The process of size reduction yields a smaller range of particle sizes and thoroughly mixes the solid waste. The net result is that the waste can be easily compacted to a uniform density, and voids formed by bulky items are eliminated. The amount of reduction in bulk can vary depending on the final processing of the waste; however, landfill measurements have indicated that shredded waste placed in a landfill and compacted in a manner similar to unshredded waste can have the effective density increased 25 to 60 percent over that of unshredded solid waste, depending on whether or not daily cover is required.*+

It is the bulk reduction and mixing of the waste that gives size reduction its most promising potential for immediate application in land disposal technology. Solid waste that has been shredded and compacted has fewer voids than unshredded waste, has no objectionable odor when properly compacted, does not attract vermin, and has been used in landfill without a daily cover of soil.‡ It is because of these advantages that a milled solid waste disposal site tends to be more saleable to the general public than a standard land disposal site

Shredding can also fit into another disposal system variation, and that is, land disposal preceded by incineration. Shredders are sometimes used to reduce bulky wastes so that they may be fed into the incinerator combustion chamber and processed along with the nonshredded waste. Additionally, there are new incinerator combustion chamber designs, such as fluidized beds, spreader stokers, and suspension burners, that require shredded solid waste for certain feed characteristics, as well as, rapid combustion characteristics.

Shredding has also been used in conjunction with solid waste baling as in the San Diego, California, solid waste baling demonstration project funded by EPA. The bales were found to maintain relatively high density, after wire tying, with a relatively low compactive

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*Effective density = Weight refuse/(Volume refuse + volume cover in landfill).

+Reinhard, J. J., and R. K. Ham. Solid waste milling and disposal on land without cover. U.S. Environmental Protection Agency, 1974. 2 v. (Distributed by National Technical Information Service, Springfield, Va., as PB-234 930--PB-234 931.)

‡EPA position on landfill of shredded solid waste can be found in the Appendix II.

effort as compared to a scrap metal type baler using nonprocessed waste and no wire tying.* Should market conditions warrant, fractions of the shredded waste (e.g. light combustibles, ferrous material, etc.) can be separated out prior to baling for disposal.

D. Shredding as an Integral Part of a Resource Recovery System

As was indicated in the preceding paragraph, solid waste disposal and resource recovery are neither mutually exclusive, nor independent. An increasing number of communities are looking to resource recovery to serve not only as a means of conserving resources, but also as a means of reducing the volume of solid waste for disposal. Shredding is a processing step that serves both resource recovery and disposal.

There are basically two forms of resource recovery being instituted in communities today. The first form is recovery of materials such as glass, paper or metals. The other is recovery of energy such as by pyrolysis (heating with limited oxygen to produce chemical by-products with fuel value) or by direct combustion of the light combustible portion of solid waste in power plant boilers along with fossil fuel. Many variations of both forms of resource recovery are facilitated by or directly require shredded solid waste as an input material. The reasons for this are:

1. Ease of handling: Compared to nonprocessed solid waste, shredded solid waste has a smaller range of particle size, is more uniform in density, and is a more homogeneous mixture, thus permitting it to be easily handled and processed by mechanical equipment. The mechanical and chemical processes used by most recovery systems require separation of various components. This separation is easier and more efficient when particle size range is controlled. Sorting operations such as screening, air classification and magnetic separation can be optimized with respect to power requirements and efficiency of separation by shredding waste to designated particle size ranges. Shredding should be considered a "service" component of the system--i.e., it does not determine what the operating parameters of the system are; it simply adjusts the physical characteristics of the solid waste to optimize efficiency of the system.

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* Baling Solid Waste to Conserve Sanitary Landfill Space. San Diego, California. Office of Solid Waste Management Programs, 1974. (Unpublished report, Grant No. G06-EC-00061.)

2. Improved burning characteristics: For energy recovery systems such as the one employed by the Union Electric facility in St. Louis, Missouri, shredding serves a twofold purpose. As stated above, it improves handling and separation characteristics for sorting into a light, fuel fraction and a heavy, chiefly inorganic fraction. The heavy fraction, in turn, can be further separated into ferrous, nonferrous metals, and glass fractions. The light, fuel fraction of shredded material is amenable to pneumatic feeding of the tangentially coal fired boilers employed by Union Electric. Once inside the boiler, the solid waste particles are burned in suspension. Because these particles are relatively small (typically 1.5 inches or smaller), the chances of complete combustion of the waste are enhanced for the relatively short time that the waste is in suspension. Similarly, for some forms of heat recovery incinerators, such as fluidized bed furnaces, or spreader stoker furnaces, small particle sizes can increase the surface area of the solid waste for better heat transfer characteristics. It should be pointed out, however, that for many standard grate incinerators shredded waste is actually detrimental to complete combustion, because too dense a fuel bed is formed to allow for complete combustion and mixing with process air.

E. Particle Size Specification

Output particle size is normally specified in terms of the "nominal" particle size produced by a shredder. The nominal particle size is usually designated as a minimum percentage by weight of waste passing a given screen size, such as 80 or 90 percent passing a three inch square mesh screen.

The single, most important step in designing a solid waste size reduction facility is to determine what functions the facility is expected to perform in the solid waste management system. This involves determining what input the shredder will receive and what output it is expected to deliver. Of the two--input and output--an exact definition of the output requirements is the more critical, for the output requirements determine the performance specifications of the size reduction facility--capacity in tons per hour, output particle size, composition, etc. The output particle size required will depend on what the next step in the solid waste management system is to be. For instance, if land disposal is the next step, a nominal particle size of three or four inches might be specified as the required output of the shredder. For the derivation of solid waste fuel for power plant application, a nominal particle size of 1.5 inches might be specified. For such an application, multi-stage shredding might be warranted, that is, the first stage shredding would produce a nominal particle size of four inches for the purpose of separation into a heavy fraction and a light fuel fraction. This light fuel fraction would in turn go through a second stage shredder with an output nominal particle size of 1.5 inches for feeding into a boiler. This multi-stage shredding would yield an overall shredding power and maintenance savings by not reducing the heavy fraction smaller than necessary. Similarly, other solid waste management systems will define particle size requirements where shredding is to be used. These particle size requirements should be carefully noted to avoid too coarse a shred which could adversely affect the remainder of the system or to avoid too fine of a shred which could adversely affect the system and unnecessarily increase power, maintenance and other operating costs.

CHAPTER III

TYPES OF SHREDDING EQUIPMENT AND POWER REQUIREMENTS

There are 11 basic types of size reduction equipment commercially available--crushers, cage disintegrators, shears, shredders, grinders, cutters and chippers, rasp mills, drum pulverizers, disk mills, wet pulpers, and hammermills. WEMI now designates all of the pieces of equipment under the general term "shredder" with the exception of wet pulpers. To date, hammermills, grinders, and wet pulpers have been used in the United States for the size reduction of municipal solid waste. The other forms of shredders have seen considerably less application for large scale municipal waste shredding and consequently will not be discussed further.*

A. Wet pulpers

A wet pulper is similar in design and operation to a common household blender. In operation, a slurry of about 90 percent water and 10 percent solid waste is placed in the pulper. The interior of the pulper may be lined with protruding hardened impact pins, but often the interior is a smooth surface. A central rotating element (either a disk or a set of blades) spins at high speed (peripheral speed of 5,000 ft/min) forming a vortex or whirlpool in the slurry. Repeated impact of the solids with the rotating element reduces the solid waste to a pulp. Unpulpable items, such as rubber tires are ballistically rejected. Wet pulpers can operate as a batch process or a continuous process. After pulping, the slurry is removed from the pulper; and the majority of the water is removed by squeezing and is reused.

Wet pulping as a means of solid waste reduction has had limited application in the United States. To date, the operating experience in this area has been limited to a plant in Franklin, Ohio, funded partially under an EPA demonstration grant. The Franklin plant is a small pilot plant having a capacity of six tons/hour. Larger plants have been proposed; however, their plans may include the use of a dry shredder ahead of the pulper to increase pulper efficiency as well as reducing wear and damage to the pulper.

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* Midwest Research Institute. Size reduction equipment for municipal solid waste. Environmental Protection Publication SW-53c. U.S. Environmental Protection Agency, 1974. 126 p. (Distributed by National Technical Information Service, Springfield, Va., as PB 226 551.)

The wet pulper and dry shredding system are not generally interchangeable in application. The wet system requires extensive auxiliary equipment for addition and removal of water and this equipment is not needed for the dry system. Additionally, the wet system is usually designated for a specific resource recovery system such as fiber recovery, whereas dry shredders generally have broader application. Because of its presently limited use, the wet pulper will not be discussed further in this document.

B. Hammermills

A hammermill is a common type of equipment currently used for size reduction of solid waste. A hammermill consists of a central rotor or shaft with radial arms (hammers) protruding from the rotor circumference. The rotor is enclosed in a heavy duty housing, which may be lined with abrasion resistant steel members. Some hammermills may also have stationary breaker plates or cutter bars mounted inside the housing. Input material is reduced in size by impact, attrition, and shearing forces induced by the hammers.

There are two basic types of hammermills--the horizontal shaft type and vertical shaft type. The horizontal shaft hammermill is the more common type (Figure 1). As the name implies, the rotor or shaft is horizontal and supported on each end. Input is usually at the top and material flows through the machine assisted by gravity. Force feed at the side of the hammermill has also been used for solid waste shredding. Most horizontal hammermills have a grate placed across the output opening. Input material cannot pass through this grate until it has been sufficiently reduced in size in at least two dimensions. Output particle size is controlled primarily by the size of openings in the grate. Some manufacturers also offer reversible rotor horizontal hammermills.

The vertical shaft hammermills have the rotor placed in a vertical position. The input material moves parallel to the shaft axis and flow is assisted by gravity. The lower shaft bearing must be a thrust bearing; that is, a bearing capable of supporting the weight of the rotor. The machines may have a decreasing clearance between the hammer tips and the stationary housing from top to bottom, thus effecting progressively finer size reduction as the material moves through the machine.

There are two basic variations of both the vertical or horizontal shaft hammermills--the swing hammer type and the rigid hammer type. The swing hammer type is the most common in solid waste processing and has hammers mounted on pins and free to pivot (Figure 2). The swing hammer concept reduces damage to the machine when it encounters

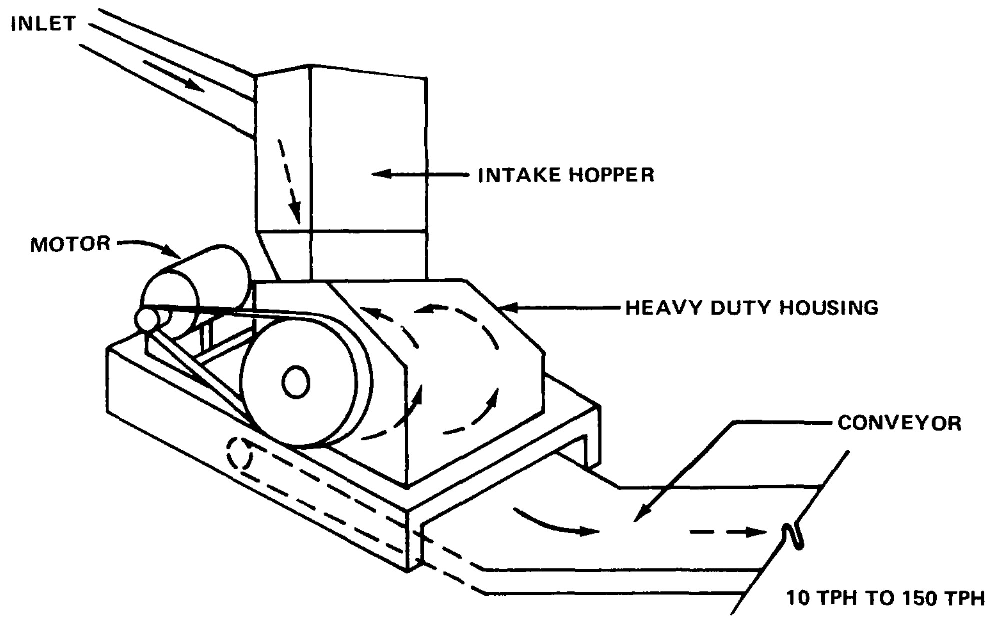
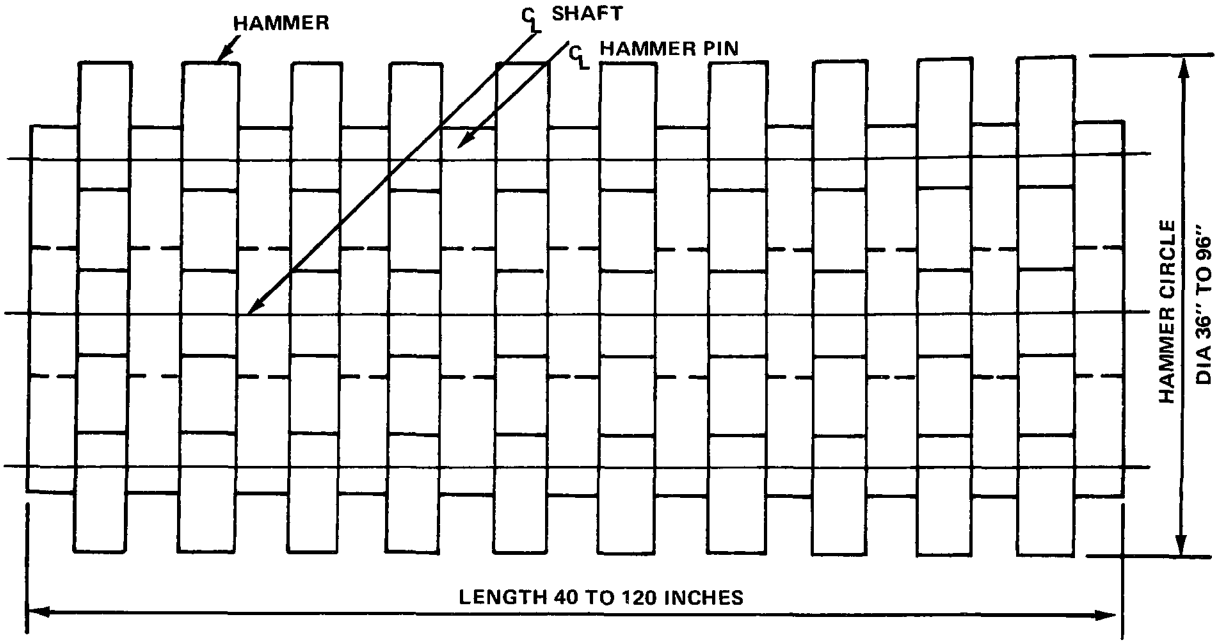
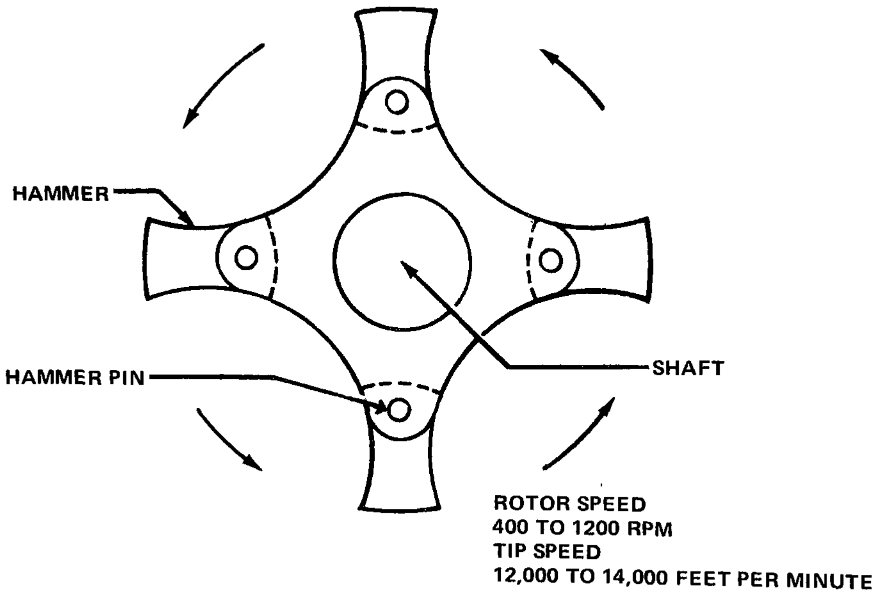


Figure 1. Diagram of a horizontal hammermill identifying the various components. Source: Funk, H. D. Henningston, Durham, and Richardson, Inc. Unpublished data, 1974.



TOP VIEW – HORIZONTAL ROTOR



END VIEW – HORIZONTAL ROTOR

Figure 2. Cross sectional views of the swing hammer type rotor showing its dimensions and rotation speeds. Source: Funk, H. D. Henningson, Durham, and Richardson, Inc. Unpublished data, 1974.

a very hard piece of input material. However, the hammers can create a severe imbalance problem if they become entangled with the input material and are not allowed to swing freely. The rigid hammer type is more typical of smaller sized machines not specifically designed for solid waste. For both the fixed- and rigid-hammer types, hammer shapes vary from sharp choppers to blunt rectangular beaters. (Figure 3). The latter are often used in machines for processing solid waste materials.

C. Grinders

Another common type of equipment currently used for size reduction of solid waste is the vertical shaft grinder. This machine uses rolling star wheels, which look much like heavy gears or cog wheels, protruding from the rotor circumference, which grind the refuse by rolling it between the wheels and the housing side walls. The material flows through the machine assisted by gravity.

D. Methods of Controlling Ouput Particle Size

As was mentioned in the preceding chapter, output particle size is quite important to the effectiveness of the next step of the solid waste management system, whether it be resource recovery or disposal or a combination of the two. Once the particle size requirements have been determined, the shredding system must be capable of producing an output particle size to meet those requirements. Each of the shredders described above have particle size control provisions which will be briefly described.

1. Horizontal shaft hammermill: This type of shredder has a system of grates on the bottom or output side of the shredder housing (Figure 4). The grate openings are usually rectangular in shape, and by varying the size of these openings, the nominal particle size may be controlled. Material cannot pass through the grates until it is small enough in at least two dimensions to pass through the grate openings. Minor changes in particle size occur with changes of material feed rate, moisture content, and composition.

2. Vertical shaft hammermill: This shredder has control over particle size within the configuration of the shredder itself, where the hammer tip distance to the housing wall is decreased from the top to the bottom of the shredder. Average output particle size has been found to change as the feed rate or material composition changes

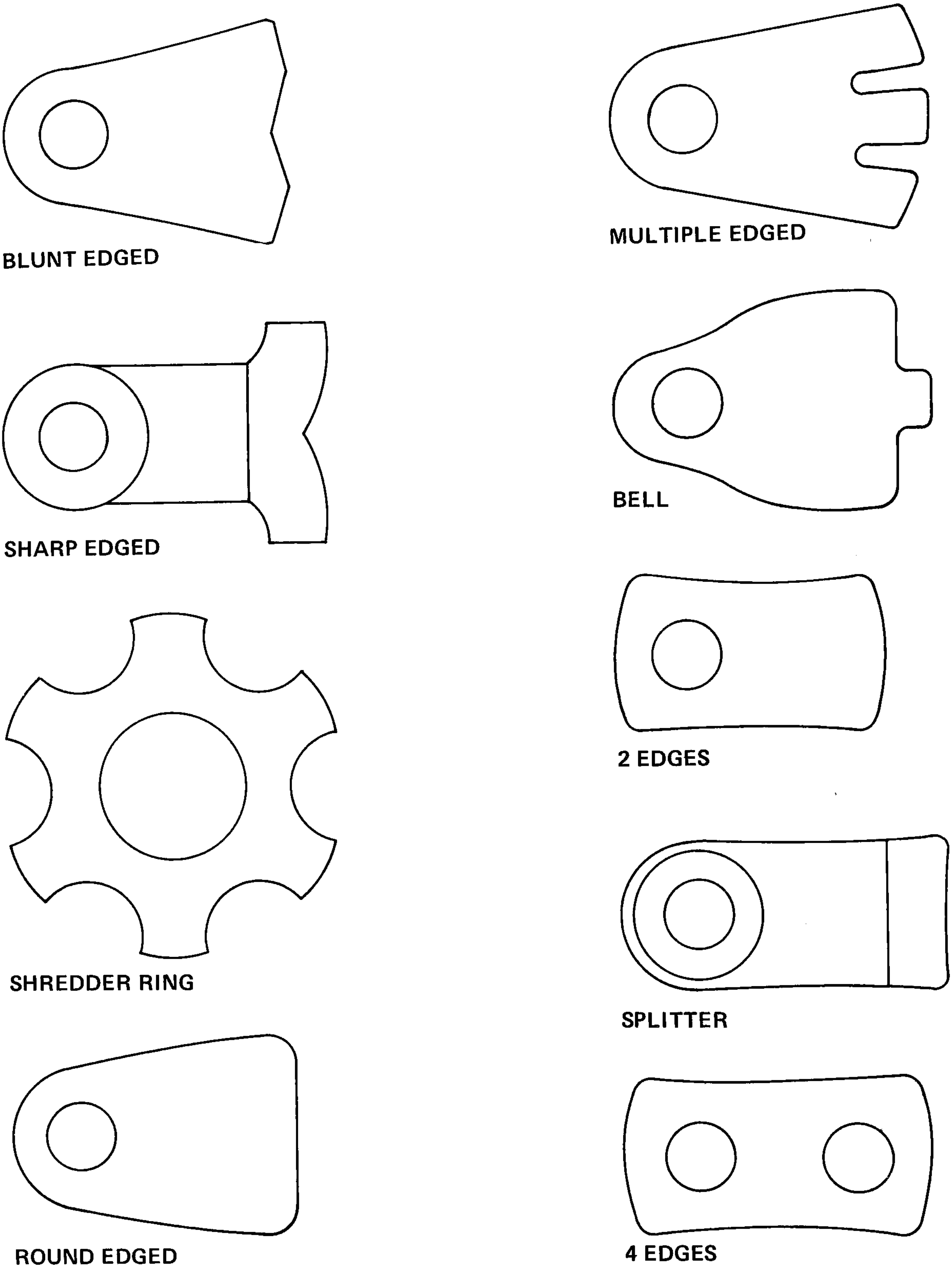
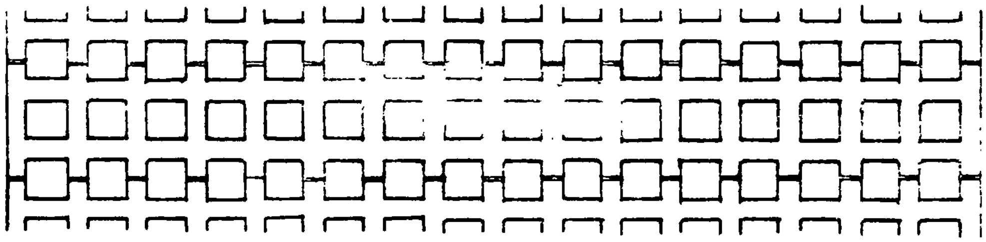
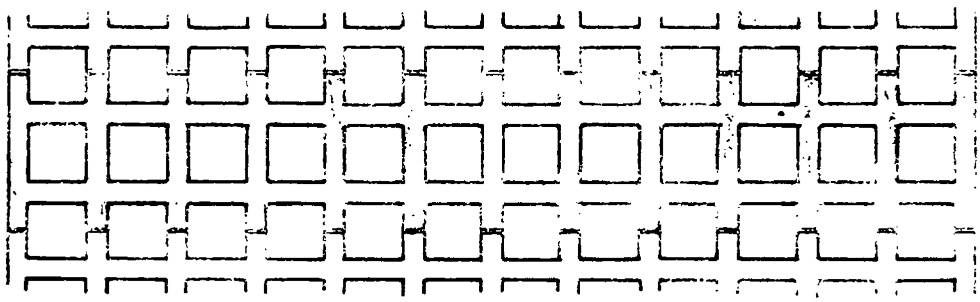


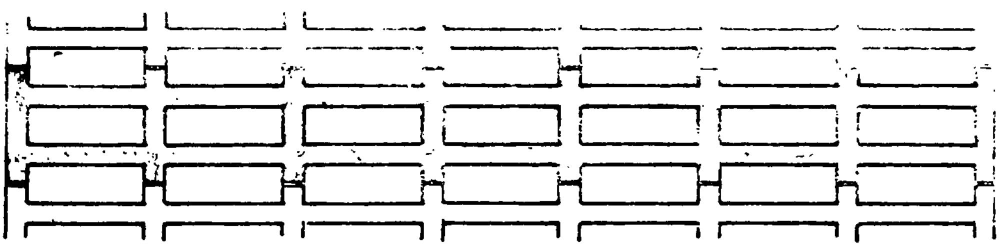
Figure 3. Types of hammers used on hammermills depicting their shapes. The weight may vary from 15 to 500 pounds each. Source: Funk, H. D. Henningston, Durham, and Richardson, Inc. Unpublished data, 1974.



2 X 2 PANEL GRATE



14 X 14 PANEL GRATE



RECTANGULAR PANEL GRATE

Figure 4. Sizes and shapes of grate bars located on the bottom of the horizontal shaft hammermill. Source: Funk, H. D. Henningson, Durham and Richardson, Inc. Unpublished data, 1974.

and as the hammers and housing plates wear. Although this factor would appear at first to be a disadvantage, for systems that do not require accurate particle size control, it may be of minor importance.

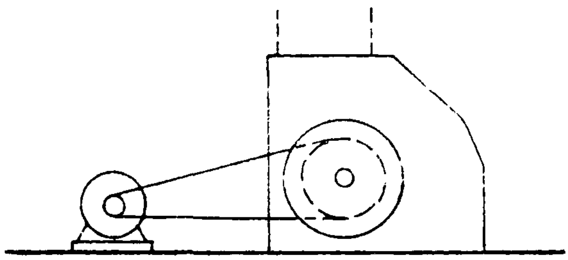
3. Vertical shaft grinder: This shredder uses an adjustable choke ring plus internal arrangements to vary shredding clearances and thus effect particle size control.

Besides the above provisions for particle size control, other factors can effect the nominal output particle size. These factors include wear of components within the shredder, moisture content of solid waste, number of hammers used within the shredder, and solid waste composition and feed rate.

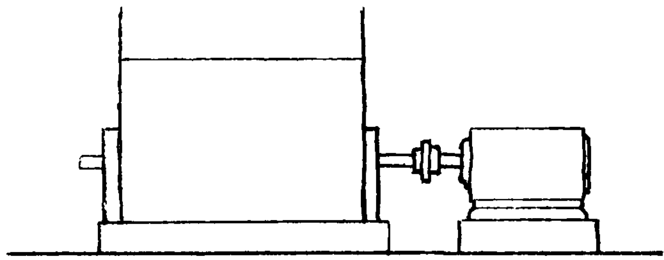
E. Drive Motors (Figure 5)

Most size reduction equipment designed for shredding municipal solid waste requires a main drive motor in the range of 200 to 1,500 hp. The electric motor, such as the squirrel cage or wound rotor motor, is the most common type of motor selected, although diesel drives and steam turbines have been proposed and used for some installations. Factors to consider in choosing a motor type include (1) type of power available, (2) location of the facility; if remote, diesel power units may be more cost effective than having high capital cost of providing adequate electrical service, (3) maintenance and dependability characteristics of motor, (4) ability to handle surge requirements, and (5) the overall operating cost efficiency of the motor which relates to the above factors.

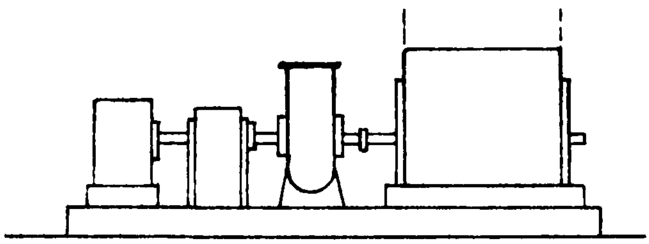
One procedure for connecting the drive motor to the shredder is direct drive, i.e., the motor shaft is coupled directly to the shredder rotor shaft. This procedure is generally the most simple and least expensive connection method. Almost all manufacturers of horizontal shaft hammermills recommend direct drive. However, one manufacturer does use a belt drive from the motor shaft to the rotor with a large flywheel mounted on the other end of the rotor. There does not appear to be any significant problems with the belt drive system, although it is slightly more complex than the direct drive. The belt drive does allow some flexibility in motor locations, and may be advantageous in locations where space is at a premium.



BELT DRIVE



DIRECT DRIVE



STEAM TURBINE

Figure 5. Common types of drive motor systems varying from 200 to 1,500 hp. The prime moves may be gas, steam, or electric. Source: Funk, H. D. Henningson, Durham, and Richardson, Inc. Unpublished data, 1974.

The vertical shaft hammermills and grinders generally use a gear or belt drive system. Direct coupling of the motor shaft to the vertical rotor is not practical. Thus, for most vertical shaft hammermills and grinders, the motor is located along side the unit and a gear drive unit is utilized. One manufacturer uses the gear box as an integral part of the shredder structure. Gear units, depending on specific designs, will require additional support equipment (such as lubricant pumps and temperature control devices), that are not required for direct or belt drives. They may also increase the maintenance requirement of the shredder facility.

F. Motor Size Requirements

The machine size and the power required for a solid waste shredder are determined by the size and nature of the input material, the processing rate (in tons per hour) desired, and the output particle size required. The output particle size determines the degree of size reduction and the minimum theoretical energy required. The size and nature of the input material determines the minimum horsepower required to attain a level of performance without frequent jams or damage to the machine. The processing rate determines the physical size of the machine and the total horsepower required.

The following paragraphs present general guidelines for the selection of machine size and horsepower. The data presented in these paragraphs were developed from analysis of existing solid waste size reduction installations, contacts with shredder manufacturers and users, and a review of the technical literature. The guidelines necessarily represent averages and are therefore believed to be conservative, i.e., use of the guidelines will yield specifications for a shredder that are more than adequate for the desired performance. (For listing of ongoing shredder installations see Appendix I.)

1. Input material: Determining the amount, size, and nature of the input material is the first step in selecting a properly sized shredder and motor.

a. Categories of solid waste: A characteristic of solid waste is that it is of a mixture varying from automobiles at one extreme to paper at the other. To simplify discussion of the problem, three categories of solid waste have evolved from common usage and are in general used throughout the industry. The categories are shown in Table 1.

b. Municipal solid waste: Current per capita solid waste production in the United States is about one ton/year. Approximately 80% of this waste is medium waste and about 20% is bulky waste. (Heavy waste has been excluded because it represents a form of waste that is generally not collected and processed by government agencies and is not considered as a part of municipal solid waste in the accepted understanding of the phrase.) This 80% -- 20% mixture can be expected to "show up" at the receiving area of a solid waste size reduction operation that processes all municipal solid waste. This mixture will be referred to as combined municipal solid waste. It is important to realize that a size reduction facility may have to handle a significant variation from this, "combined municipal solid waste mix," depending on location and seasonal fluctuations.

TABLE 1

SOLID WASTE CATEGORIES FOR SHREDDING*

Solid waste category	Composition
Medium	Packer truck wastes, such as--paper, cardboard, bottles, cans, garbage, lawn trimmings, small crating, small appliances, small furniture, bicycles, tree trimmings, and occasional auto tires.
Bulky	Oversize and bulky items of the above plus--stoves, refrigerators, washers, dryers, doors, large furniture, springs, mattresses, tree limbs, and truck tires.
Heavy	Large and dense materials, all of the above plus items such as--demolition rubble, logs, stumps, and automobile parts.

* Midwest Research Institute. Size reduction equipment for municipal solid waste. Environmental Protection Publication SW-53c. U.S. EPA, 1974 p. 24. (Distributed by National Technical Information Services, Springfield, Va., as PB 226 551.) Modified because shredder manufacturers often desire that waste throughput be specified only in terms of "normal" packer truck waste and oversize bulky waste. Automobiles are usually handled separately.

c. Minimum horsepower requirements: Experience has indicated that there is a minimum horsepower that is required to reliably and efficiently process municipal solid waste within a reasonable time and with a minimum of trouble and delay. Of course, this should be accomplished at a minimum net operating cost, including capital cost, energy consumption, throughput at required particle size and maintenance. The data shown in Table 2 represent the suggested minimum shredder horsepower for each waste category. These data are based on analysis of existing shredding operations. It should be noted that 10 hp per ton/hour is often considered to be a minimum power requirement. Some existing installations approach this figure.

TABLE 2

SUGGESTED MINIMUM SHREDDING HORSEPOWER*+

Category of waste	Minimum horsepower‡
Medium	200
Bulky	500
Heavy	1,000
Automobiles	1,500

* Source: Personal communication. Waste Equipment Manufacturers Institute, NSWMA shredder subgroup, to H. W. Rogers, Office of Solid Waste Management Programs, October 1974.

\+ This table shown is a function of throughput, motor type, particle size requirements etc. and should not be considered as a rigid table. Shredder manufacturers can more accurately determine the power needs for their equipment based on particular user requirements.

‡ Six inch nominal particle size.

2. Particle size: Very limited data are available on the effects of particle size on power requirements. Some actual installation power - particle size - throughput relationships are given in Table 3. Generally, the nominal particle size of the output material directly affects the power requirements of the shredder. The smaller the particle size, the larger the motor that is required for a given capacity or stated in other words, the capacity decreases for a given motor size as particle size requirements become smaller in size.

One other consideration must be made when considering the power requirements for size reduction. The data indicate that power requirements increase exponentially as particle size decreases. Thus, for any given category of waste, there will be a particle size below which it becomes more economical to use two stage size reduction (i.e., a primary and secondary shredder operated in series) than to use one large machine. Current practice in the industry indicates that for the combined bulky and medium waste, the minimum particle size economically feasible in single stage reduction is in the range of two to four inches. However, there is almost no available technical data (except manufacturers proprietary design data) on this subject and no standard procedures have been developed. Each installation must be examined individually, evaluating such factors as power costs, wear, maintenance, labor costs, and capital investment.

3. Total throughput (tons per day and tons per hour): In addition to the category of waste, the particle size, and the power requirements, the total anticipated throughput must be known before the shredder can be sized. In many instances, this is a trivial question since the plant may be originally conceived and designed for a certain capacity in tons per day. This capacity is usually based upon some input parameter (i.e., the tons per day is known by previous collection data) or upon some output parameter (i.e., the size reduction plant is to supply shredded waste for a process that requires a given tonnage per day).

TABLE 3

ACTUAL SIZE REDUCTION INSTALLATIONS*

City	Tons per hour	Horse power	Rotor speed	Discharge opening	Hammer weight	No. of hammers	Nominal size of output	No. of shredder units
A	35-75	1250	900	2¼ x 3¼	200 lbs.	30	1½"	1
B	40-50	500	900	6¼ x 11	100 lbs.		3 "	1
C	20-25	500	850	box-type	96 lbs.	22	5 "	1
D	8-17		1250	155 mm.	16 lbs.		3 "	1
E	15-25	200	1350	10 x 18	14 lbs.		3 "	1
F	22	200	1350		14 lbs.		3 "	1
G	100	900	900	6 x 72	120 lbs.	33	4 "	4+
H	40-50	1000	369		64 lbs.‡	60+	3 "	1

* Courtesy of the National Center for Resource Recovery.
\+ 4 units represent two lines of two stage shredding.
‡ Ring grinders.

It is also necessary to establish the required capacity of the machine in terms of tons per hour. This requires an analysis of such factors as number of operating days per week, number of shifts per day and number of hours per shift, as well as, the working schedules of the collection crews. There are several points that must be considered when calculating capacity requirements of a shredder: (1) twenty-four hours per day operation is not practical because of maintenance and downtime provisions which are both necessary and unavoidable for shredding equipment, (2) there is a time lag between the collection of waste and its delivery to the size reduction facility. In order to provide multi-shift operation of the shredders, increased storage provisions may be necessary, and (3) there are practical limits on the capacity of a single processing line or facility. These factors will be discussed in more detail in the chapter entitled, "Operating Considerations."

4. Total horsepower: After considerations on waste categories, particle size, power requirements, and machine capacity have been determined, total machine horsepower is simply the product of capacity in tons per hour and unit power required in horsepower hours per ton. For example, a 50 ton/hour machine processing waste with a unit power requirement of 20 hp hour/ton would need a 1,000 hp motor.

CHAPTER IV

ANCILLARY PROVISIONS AND EQUIPMENT

Thus far, the discussion of shredding equipment has centered around the shredder and its accompanying motor. After sizing these items, it is necessary to provide ancillary or support facilities of compatible capacity to complete the size reduction facility. These ancillary provisions can be grouped into two classifications: 1) those provisions that serve to store and handle the solid waste and 2) those provisions that serve to make the shredding operation more economically efficient, operationally efficient, safe, and environmentally acceptable. The first classification will be discussed in this chapter and the second will be incorporated into the following chapter on operating considerations.

The functions of a typical facility are indicated in the block diagram flow chart of Figure 6 and a facility layout is shown in Figure 7. The installation includes the following basic operations:

1. Receiving and holding--receiving input waste, prêmixing, sorting, separation of bulky items, temporary storage for processing;

2. Input conveying--material transfer, inspection, sorting, separation;

3. Feed control--material flow rate control;

4. Size reduction--shredding of the solid waste; (Chap. III)

5. Discharge conveying--material transfer, separation of unwanted and marketable components; and further processing

6. Removal, storage or, disposition of shredded waste.

A. Receiving and Holding

The receiving and holding area of the size reduction facility serves the function of accepting the input solid waste from the collection system (usually packer trucks), and storing the material prior to processing by the shredder. This function is necessary because the input is usually in batches (i.e., individual packer trucks) with varying quantities of waste at different times. Maximum efficiency of the shredder usually requires continuous feeding at a uniform rate. Thus, a buffer or temporary

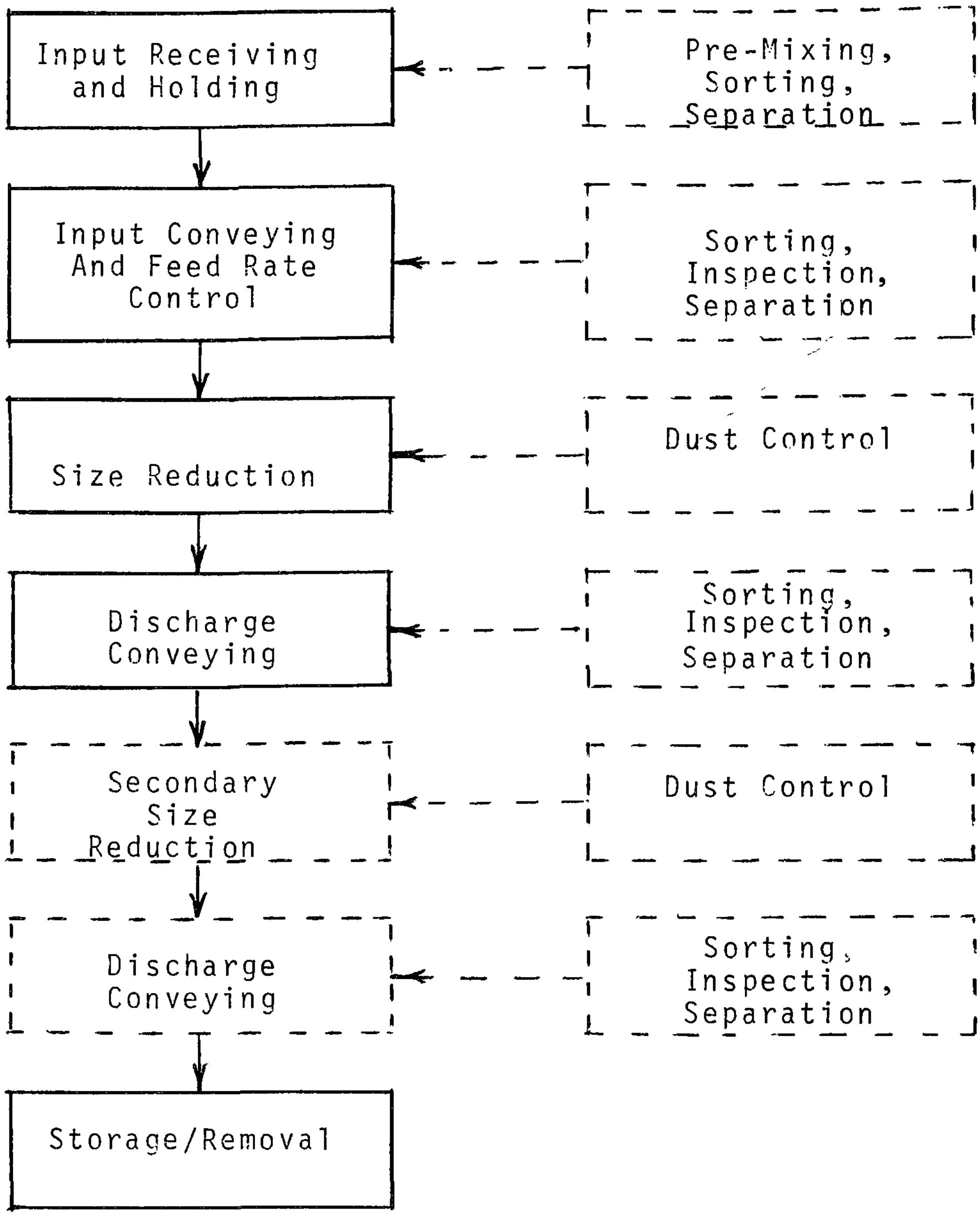


Figure 6. Block diagram flow chart of a size reduction facility. The dashed lines indicate optional unit operation.

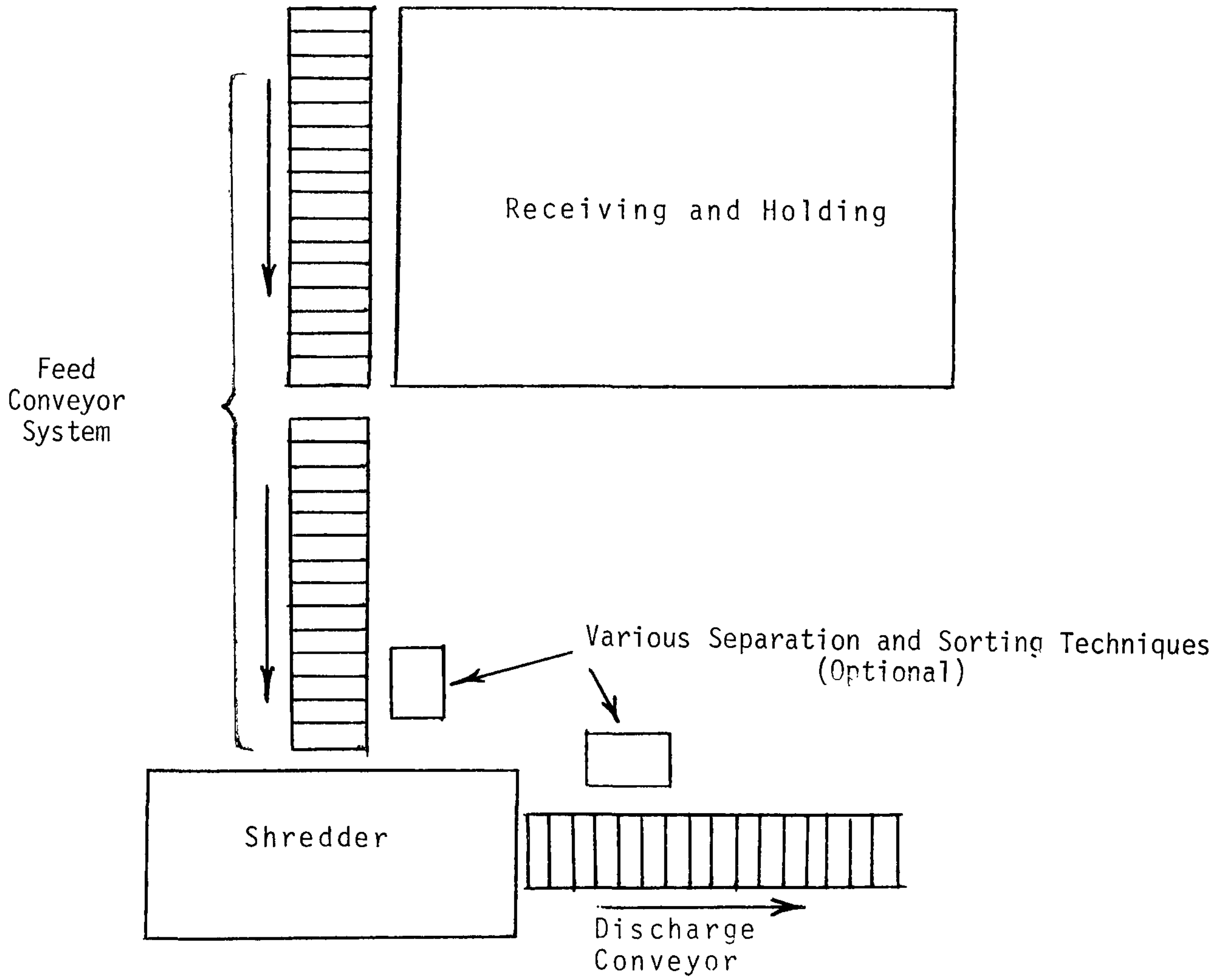


Figure 7. Example of a size reduction facility layout identifying each operation.

storage is needed between the waste collection and the shredding operations. The number of shifts of operation will affect the sizing of the receiving and holding area. It is quite important that this portion of the facility be designed so that material can be moved as needed into the input conveyor while at the same time allowing collection vehicles to maneuver and unload with a minimum of delay or confusion.

One procedure developed for receiving, holding, and handling the solid waste material has been the open receiving pad. The pad is simply an open, level and paved area adjacent to the waste shredder. In some installations, the pad is enclosed so that operations are not affected by inclement weather, and so that site aesthetics can be maintained. Packer trucks deposit the waste on the pad at the direction of an operator. The pad operator uses a bucket-equipped hi-loader, or a typical front end loader, to pile and mix the waste, and to place the waste on the input conveyor. The operator partially controls the feed rate to the shredder by the amount of waste he places on the conveyor. He can also increase the efficiency of the shredder by distributing bulky and difficult-to-process items throughout the waste. In some cases, the white goods (stoves, washers, etc.) are not mixed but are processed together to effect a more efficient magnetic separation where appropriate.

The open receiving pad has been proven to be a workable input system because it provides an easy and economical means of presorting and mixing the input waste. Although municipal solid waste is generally considered to be a heterogeneous material, it is not a thorough mixture as received, and it will contain occasional bulky items, such as appliances or pieces of furniture. Also contained are difficult-to-shred items such as tires, rolled-up rugs, tree trunks, heavy metal pieces, etc. With an open receiving pad, the operator can normally remove some of the items that he does not want to enter the machine, distribute the remainder of the bulky items, and mix the solid waste before feeding it to the shredder.

Other input receiving systems have also been used. One frequently used procedure has been to have the packer trucks discharge the waste directly into a feed hopper or storage bin. These systems should be designed and operated to minimize bridging, or jams and to assure uniform feeding from the storage pile. Another common system is to discharge the waste from the packer trucks directly onto the shredder input conveyor. This system subjects the input conveyor to considerable abuse and causes uneven feeding of the shredder--sometimes resulting in motor overloads, machine jamming, and shutdowns. The "push-pit" system has also been used as a method of shredder system feeding.

In this system, the waste is discharged into a pit containing one or more hydraulic rams which "push" the waste onto the incline conveyor. Another receiving and handling method is the storage pit and crane system where the waste is discharged into a large receiving pit and loaded via crane onto the input or feed conveyor system. This system can take advantage of existing storage and handling provisions at incinerators that are being converted into shredding facilities; however, this method of feeding can tend to result in surge loadings.

B. Input Conveying

Input conveying consists of those components within the facility which transfer the solid waste from the receiving and holding area to the shredder. The conveying operations control material flow rate will frequently consist of two or more conveyors--a horizontal conveyor sometimes located in a pit that handles material directly from the receiving pad, and an incline conveyor that transports the material up and into the shredder.

1. Horizontal feed conveyors: Heavy duty metal pan-type and piano hinge conveyors have proven to be a reliable type of input conveyor. The horizontal conveyors receive considerable abuse, mainly due to dropping and dumping of the solid waste onto the conveyor. Operating life of flexible belt conveyors has, in general, not been adequate in this application. Other conveyors such as vibratory conveyors have also served in this capacity. The typical arrangement places the conveyor in a horizontal position at the bottom of a feed trench. The trench is often about five feet deep and has vertical or diverging skirt boards reaching from the conveyor surface up to the receiving pad. The solid waste is simply pushed from the receiving pad onto the horizontal conveyors.

The horizontal conveyor often operates at a fixed speed, and the waste feed rate to the shredder is adjusted by the depth of waste the operator places in the trench. Several installations have installed variable speed conveyors for additional feed control. The horizontal conveyor should be electrically interlocked to the incline conveyor; and they both should be electrically interlocked to the shredder motor. These interlocks will stop the conveyors if the shredder motor overloads. This gives the shredder an opportunity to clear itself before receiving additional input that could cause a jam.

2. Incline conveyors: Flow into a shredder is generally assisted by gravity. Therefore, it is necessary to raise the waste to the feed opening of the shredder unless the shredder is located in a pit rather than above grade. The incline conveyor may be a flexible or rubber belt conveyor since this conveyor is not subject to the same abuse that the horizontal conveyor receives, except where significant amounts of oversized bulky waste is processed or the belt would otherwise be subject to high impact or shock loading. A common problem with some belt conveyors is the tendency of the waste to slide back down the conveyor. This problem can be minimized by using a shallow slope or a belt with a textured surface or with cleats Another problem with rubber belt conveyors are that they cannot take the abuse from the ricocheting waste if extended into the shredder housing.

3. Sorting and separating: Some separation of the waste can be done at the feed conveyor system. Separation at this point is usually a protective measure designd to prevent undesirable materials from entering the shredder. Due to the depth of material on the conveyors, the presence of numerous closed bags and boxes, and the tangled nature of the material before shredding, a thorough separation is not practical. A metal detecting system can be used to detect large pieces in the waste stream. However, the generally accepted procedure is to visually monitor the feed conveyor and manually remove any undesirable material.

C. Feed Control Techniques

Control of feed rate is probably the most important aspect of daily operation of a size reduction facility. Feed control is of major importance because it has a great affect upon the efficiency and life of the shredder. It is also difficult to control the feed rate accurately and reliably. Several techniques have been tried with varying degrees of success. Some of the more common techniques are discussed in the following paragraphs.

1. Oscillating and vibratory feeders: The vibratory feeder has long been used in the ore and rockcrushing industry to feed aggregate material of variable composition. It will agitate the input and tend to distribute it evenly over the feeder surface. It thus tends to "smooth out" variations in flow rate. A diagram of a typical installation is shown in Figure 8. The vibratory feeder is installed in the bottom of a trench with sloping sides. The feeder is shorter than a normal input conveyor and can be fed from three sides. The waste material is simply pushed off the pad and onto the feeder which then feeds the inclined belt that raises the solid waste to the shredder. Structural problems from the vibrations can occur with this type of installation if there is inadequate base support.

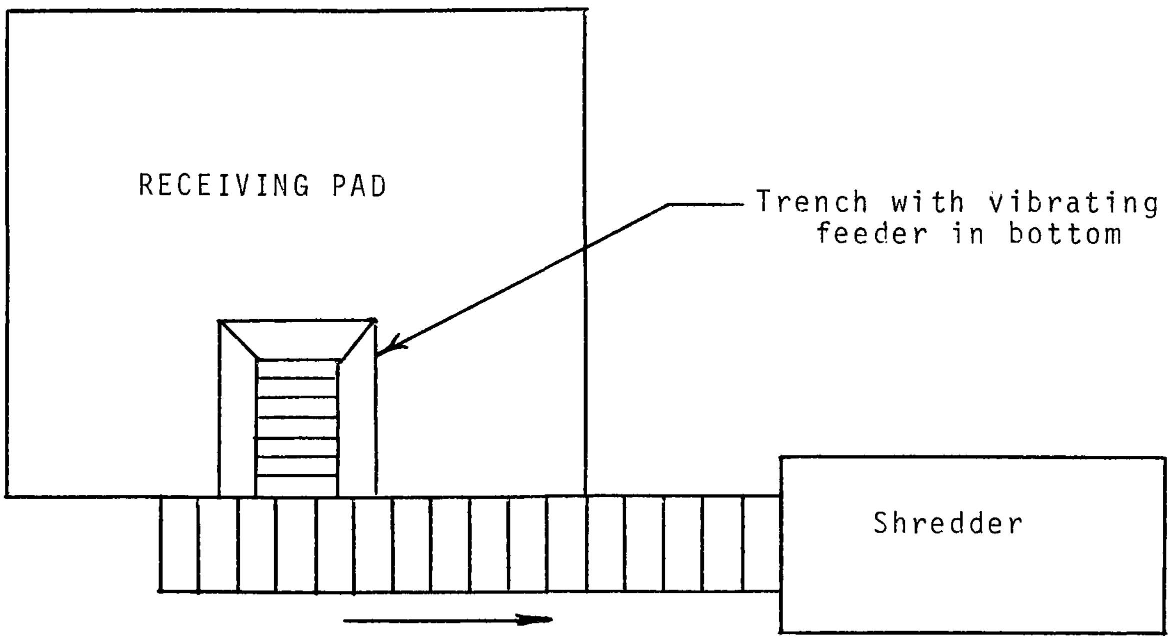


Figure 8. Layout of a solid waste size reduction facility utilizing a vibratory feeder.

2. Leveling bars: Leveling bars, or "doctor" blades, have been used with the feed conveyor system to control the depth of waste on the conveyor. Often, these devices have not been successful because of the tendency of the waste to jam, bridge, and hang up on items caught on the bar or blade. One successful application has a direct feed from the input conveyor to a shredder mounted in a pit. A hydraulically operated blade is located over the input conveyor just ahead of the shredder. An operator continuously monitors the input and controls feed rate to the shredder by adjusting the height of the blade. Minor jams at the blade are frequent, but they are easily controlled by operator action.

3. Compression feeders: This device can be a crawler belt or roller that compresses the input waste and literally "force feeds" it into the machine. It usually has a hydraulic power drive with a variable speed control. This device serves three functions:

a. It controls the rate of feed;

b. It physically holds the waste and slowly releases it into the shredder thus minimizing severe surges and overloads to the shredder. The waste is "nipped" off a little at a time as it is being fed to the shredder.

c. It obstructs the input opening and reduces "backfire" or ejection of material out the input opening.

D. Discharge Conveying

The discharge conveying elements of the shredding installation serve the function of removing the processed waste from the shredder and conveying it to a further processing or disposal area. There are normally two elements to the discharge area; the discharge chute or collector and the discharge conveyor.

1. Discharge chute: The material being discharged from the shredder typically possesses considerable energy and moves at high velocities. For horizontal shaft hammermills with bottom discharge, a simple chute or deflection plate may be placed directly under the discharge to absorb most of the energy from the waste. The waste then slides down the chute or plate onto the discharge conveyor. However, the waste can "stick" to the chute and cause a jam. To avoid this potential problem, the chute or deflector plate can be replaced by a vibrator conveyor. The vibratory conveyor can take the abuse and impacts from the discharged waste and still provide a positive method of transporting the waste away from the shredder. Steel apron and belt conveyors can also be used in this capacity.

2. Discharge conveyor: The discharge conveyor transports the waste from the discharge chute to further processing or disposal operations. This conveyor is typically a flexible belt that moves at a much faster speed than the input conveyor. A flexible belt conveyor can be used in this application because the shredded waste is relatively homogeneous and contains no bulky objects to subject the conveyor to abnormal physical abuse. The conveyor moves at a faster speed to assure that the discharge of the shredder is always clear. The speed may cause displacement of the waste so conveyor sides and covers are frequently used.

3. Further processing for resource recovery: If separation or recovery of certain waste components is to be performed, it is usually done at some location in the discharge conveyor system. At this point, the waste has been shredded, has a narrow range of particle size, should not be very deep on the conveyor, and has not been compacted or compressed. A wide variety of separation devices including magnetic, pneumatic, and vibratory may be employed. A discussion of separation techniques is beyond the scope of this report.

E. Removal, Storage, and Disposal

The final operation of the size reduction facility is removal--i.e., disposition or disposal of the shredded waste. Several removal systems are now in use at various size reduction facilities in the United States. The waste may be:

a. Directly conveyed (mechanically) to the next operation in the solid waste management system; i.e. land disposal;

b. Loaded into transfer vehicles, either directly or via stationary compactor, for bulk transport to the next operation; or

c. Placed in intermediate storage to await transfer to the next operation.

Direct mechanical conveyance of the shredded waste to the next operation is not frequently used. In fact, it is generally only used when the next operation is landfill and the size reduction facility is located at the landfill site. Even then, it is not common because of the capital investment required for long conveyor runs, and the fact that the waste will still have to be spread at the conveyor end.

Loading the shredded waste into transfer vehicles for bulk transport to the next operation is a typical procedure, especially in landfill systems. This procedure offers a direct cost savings when the landfill is at a remote location. The size reduction facility may be placed at a convenient location within the collection system and serve as a shredding plant and a transfer station.

Placing the shredded waste in temporary storage prior to transfer to the next operation is a common technique. The simple reason for this is the difficulty of synchronizing operations at the size reduction facility with the next operation in the system. Thus, a storage or buffer zone is needed. However, problems can occur in feeding the shredded waste out of the storage facility. The waste is easily compacted, does not readily flow, bridges across openings and is, in general, difficult to handle in bulk.

Provisions used for removing stored shredded waste including live bottom bins, open pad storage, and bins with an arm installed in the bottom, which "sweeps" material to a discharge opening.

CHAPTER V

OPERATING CONSIDERATIONS

Once the shredder and motor have been selected and installed along with complementary materials handling equipment the plant would be, for all practical purposes, ready to operate. There are, however, a number of additional considerations to make in designing the plant to assure minimal downtime, employee safety, efficient plant layout, good sanitation and so forth. This chapter discusses some of these considerations.

A. Shredder Installation

Three concepts for physical location of the shredder are in general use. They are: (1) below ground (in a pit); (2) at or above ground level; and (3) on the side of a hill. All three concepts have been used successfully and neither has a distinct advantage over the others. Often, the choice of installation is determined by site restrictions or topography rather than by technical or performance factors.

Installation of the shredder at ground level is the simplest and the most common type of installation. The shredder is usually mounted on a concrete base and has easy access from all sides. A drawback with this type of installation is that it requires an inclined feed conveyor to lift the waste to the shredder input. An approach to this problem is to put the input receiving pad on the roof. The inclined conveyor would thus be eliminated and the shredder feed would be directly from the input feed conveyor. This approach has an obvious appeal for facilities located in congested urban areas where space for a receiving pad is at a premium.

Installation of the shredder below ground level or in a pit is a concept that has been used at several installations in order to shorten input conveyor runs. Some reasons behind this choice has been that noise is confined and plant personnel may be protected from fires or explosions that may occur due to flammable materials in the waste and also from flying debris from the shredder. There is also the consideration that the inclined conveyor is moved from the input to the output (to lift the waste out of the pit), thus resulting in a minor cost savings because of the less complicated equipment required for conveying the shredded waste. However, access to the shredder for maintenance becomes limited. This can be accomplished with an overhead crane or a yard crane.

If the plant site has a hill or a pronounced slope, it may be wise to install the unit on the side of the hill. The input pad is then located at the top of the hill, and the discharge area is located at the bottom. The incline conveyors are eliminated and this concept has an obvious appeal in simplicity and equipment cost savings; structural costs may be increased if the plant is to be enclosed.

B. Power Assist Devices

Most manufacturers of shredders offer items that can aid in the operation of the shredder. Any shredder that has a pressurized bearing lubrication system can take advantage of the pressure producing equipment to operate hydraulic power assist devices. Some manufacturers recommend a separate hydraulic power pac for these devices. These devices include:

1. Hydraulically operated access doors: These items are especially helpful on horizontal shaft hammermills where manufacturers include these door openers as standard equipment for quick access to the rotor and hammers.

2. Hammer pin extractors: These devices are used to pull the hammer pivot pins from their mounting so that worn hammers may be replaced. These devices are helpful as it is sometimes difficult to manually remove hammer pins after extensive use of the shredder.

3. External breaker and grate bar adjustments: Several shredders have stationary breaker bars or cutter bars whose clearance with the hammers can be adjusted from outside the shredder. Manual adjusters are standard equipment, however, hydraulic adjusters are available and have been well received by operators who have used them.

C. Motor Controls

In addition to the necessary motor switch gear, installation of indicating and recording power meters, input and discharge conveyor interlocks, as well as bearing and motor temperature interlocks are typically included.

Indicating ammeters are a standard item at most shredder installations since observations of motor current draw is the easiest way to determine overloads. The operator can watch the ammeter and adjust the feed rate to obtain maximum efficiency of the shredder. Many installations have warning devices connected to the ammeter to signal the operator when overloads occur. Several installations have recording amp or watt meters. These are not considered necessary and are only used when continuous records of power consumption are desired. Such records can be quite useful in determining long-term motor power requirements and efficiencies.

Shredder motor interlocks to the input conveyor are becoming the standard device for protecting the shredder and drive motor from overloads. These devices stop the input conveyor when the shredder drive motor overloads. This prevents further feeding of material into the shredder, reduces the load, and gives the shredder an opportunity to "clean out" a potential jam before it occurs. Typical design is to have an automatic cutoff which stops the input conveyor, with restart being manual or automatic, thereby requiring operator attention to the cause of the stoppage. Many operators of size reduction facilities consider the shredder motor conveyor interlock the single, most important automatic control in the entire facility. Even those installations not originally including the interlock have now installed them because damage to the shredder and motor has resulted from overfeeding.

The shredder bearing temperature sensor is another protective device gaining wide acceptance. At most installations, it is designed to issue a warning if the shredder bearing overheats, and will continue to give the warning until the temperature returns to the safe range. The warning alerts the operator to stop the feed conveyor thus reducing the load on the shredder (and bearings) until the temperature drops. Some installations have included a bearing temperature interlock that will shut off the shredder and feed system if the bearings continue to overheat or exceed a critical temperature.

D. Fire Control Systems

Due to the high percentage of flammable materials in municipal solid wastes, fires in the shredder can occur. Normally, a fire can be "snuffed out" by continued feeding of the shredder; however, fires associated with jams or stoppages must be extinguished. Manually activated carbon dioxide or water extinguisher systems are available. Additionally, heat sensitive, or infrared detectors can be installed at the beginning of the output conveyors. When a fire is visually detected in the input conveyor, the shredder and the output conveyor can be immediately stopped to keep from spreading the fire to other portions of the facility.

E. Dust Control Systems

Dust and small particle debris are a constant problem around a solid waste shredder. Two techniques are used to control and minimize the problem. The simplest is to use a continuous water spray inside the shredder. Water reduces the amount of dust generated and causes most debris to exit the shredder with the discharge. However, water can accelerate leachate potentials for landfills and decrease the apparent B.T.U. value of the combustibles.

Pneumatic dust collectors are the other form of dust control technique used. Typically, they are used in systems where the shredded waste is being used in an incinerator or boiler where additional water content is undesirable. The devices usually consist of cyclones placed downstream of the shredder and are more efficient than water sprays.

Litter control devices to minimize spillage of shredded material consist of some form of cover, such as a wire mesh placed over the output conveyors.

F. Explosion Provisions

It is almost inevitable in a shredder installation that some potentially explosive materials will enter the facility. The majority of these, such as aerosol cans, nearly empty gas cans and so forth, may explode within the shredder with little or no consequence. There are, however, some materials which may cause extensive damage to the facility and more importantly cause danger to the workers. Provisions such as separate, outdoor shredder placement, special pressure relief devices and so forth, should be explored to minimize explosion potentials. The manufacturers of shredding equipment should be consulted for further information concerning these provisions. Attempts should be made to screen input material, where possible, to keep potentially explosive materials from entering the shredder.

G. Other Operating Problems and Provisions

1. Shredding of difficult items: Because the horizontal and vertical shaft hammermills have a restricted opening, they may be subject to damage from difficult to process items. The shredder will "try" to reduce the item to the output size or to "extrude" it through the opening. Items such as heavy steel, rolled-up rugs, large tree limbs, etc., which require power inputs beyond the capabilities of the machine, can cause jams. Thus, for these machines, presorting of input material and separation of undesirable items is recommended. Some mills have the capability of collecting unmillable material so as not to damage the mill.

2. Wear rates: Some manufacturers of horizontal and vertical hammermills offer reversible action for the hammer rotors. After the hammers are well worn on one side, the rotor is operated in the reverse direction so that the hammers wear on the other side; purportedly reducing the frequency for manually reversing the hammers.

Most shredder operations provide routine maintenance for all surfaces within the shredder subject to high wear rates. For instance, some operations provide daily retipping of hammers and welding of other wear surfaces. There are many alloys to choose from for hard surfacing, and the decision must be made as to the correct balance between the cost of weld material (expense increases as wear resistance increases) and the cost of welding (labor), and downtime.

3. Scheduling of Operations: There is a time lag between the collection of waste and its delivery to the size reduction facility. The packer trucks start each day empty, as they do not normally store waste overnight. It is not uncommon, therefore, for the first packer truck to arrive at the size reduction facility with a load of waste two to three hours after the start of working hours. The last packer trucks may also arrive well before the close of normal working hours to allow time for return to their headquarters. Thus, all deliveries of waste to the size reduction facility would be made in a five to six hour period. It is common to schedule shredder operations beyond collection hours to completely process all of the day's input. However, due to health and safety hazards, unshredded waste is not usually left overnight for processing the next morning. Common practice has been to schedule the shredder to six to eight hours of operation a day, five days a week. However, most of these operations have been small plants processing 150 to 500 tons/day and, consequently, have smaller capital investments. As bigger and more expensive plants are designed and built (1,000 to 1,500 tons/day), the trend seems to be to a two-shift operation with 12 to 14 hour work periods each day.

General experience indicates that there is a practical limit to the capacity of a single size reduction operation. A capacity of 40 to 60 tons/hour has been the current operating limit for reasonable conveying and feeding systems. The volume of material represented by 40 to 60 tons/hour begins to present logistical problems that may require subdividing the operation into two or more units if larger capacities are desired. There have been, however, recent specifications requiring 75 to 100 tons/hour to be processed through a single line. Experience will determine the feasibility of material handling of this high tonnage.

Another consideration in the scheduling of operations concerns the degree of redundancy or backup equipment desired to handle downtime situations. The degree of redundancy needed should be carefully analyzed to balance the cost of providing standby equipment versus the cost of downtime. For some situations, the best solution might be to have no backup processing lines, but rather to have a good inventory of parts available for repairing the existing processing lines. It should be remembered that for any solid waste management system, even with resource recovery, a sanitary landfill must be available for nonprocessed material, residuals after resource recovery and for standby when processing facilities are down. It may be more cost effective to occasionally use the sanitary landfill for all the waste than to have one or more additional shredding lines. For resource recovery situations where the output must be supplied on a minimum tonnage per day basis, extra processing equipment might be required.

4. General Maintenance Provisions: In addition to the options heretofore mentioned concerning shredder maintenance, the overall facility itself must be designed for ease of maintenance. A fundamental principle to observe is to allow plenty of clearance for any repair or replacement situation that is likely to arise. This would include operations such as lifting out rotors, replacing motors or pulling shafts used with conveyors. Provisions should be made for an overhead crane, portable crane, or lifting device where necessary, such as above the shredders.

In addition to providing adequate clearance for maintenance and repair, the facility should be designed for good housekeeping and sanitation. Surfaces, such as the receiving pad or storage pit should be readily cleanable. The storage pit or conveyor pits should have drains or sumps to remove liquids which might accumulate, as well as water used in cleaning these areas. Routine cleanup should be provided in areas of material spillage.

CHAPTER VI

SHREDDER SELECTION EVALUATION CRITERIA

A. Introduction

This chapter explores some of the more salient factors or criteria that should be addressed when specifying and/or selecting shredding equipment. These factors are grouped into objective and subjective categories depending on the degree of judgment used in their evaluation. Objective considerations include such factors as price, horsepower and rated throughput. Subjective factors include criteria that do not have such distinct answers, for example, actual or dependable capacity, and the degree of complexity of the system. Subjective criteria should be judged in light of actual field experience.

B. Objective Factors

Most of the data needed to evaluate objective factors can be collected from shredder manufacturers. It will be up to the decision-maker to determine the relative importance of each factor for his particular situation.

1. Machine weight. This factor could affect construction requirements (and therefore costs) with respect to the foundation and its bearing capacity. Some believe that machine weight is a good indicator of structural strength and performance, although OSWMP staff has seen no compilation of data to either support or refute this contention.

2. Rotor weight and Rotor inertia. This information can provide a measure of shredder's ability to handle surge loads.

3. Machine size. This factor will have direct influence on building structure size and cost. It could also affect siting of the shredder and associated material handling equipment within existing installations, such as an incinerator, in accordance with existing clearances and constraints.

4. Rate in tons/hour, a basic indicator of equipment capacity as expressed by the manufacturer.

5. Rate in tons/shift. This measure of capacity allows for routine maintenance, startup, etc., and is a better indicator of what can actually be processed over a shift.

6. Input and output locations. These can affect building design and conveyor configuration.

7. Unique design features, as specified by manufacturer.

8. Horsepower, as specified by manufacturer. This will affect operating and capital costs.

9. Availability of service policy.

10. Availability of field service.

11. Availability of spare parts. This factor can markedly affect overall operating costs, effectiveness, and dependability of operation.

12. Special installation requirements, as specified by manufacturer.

13. Output particle size. This has direct bearing on power requirements and possibly plant configuration where multistage shredding is considered. Particle size must also be considered in relation to the next process, e.g., air classification.

14. Number of surfaces and configuration of the shredded particles. This may affect resource recovery processes.

15. Control systems, which may have features to protect against jams, motor overloads, etc.

16. Shipping and installation costs.

17. Total system cost, including conveyors.

18. Installation schedule.

19. Type of motor.

20. Performance bond.

21. Performance guarantee safety features.

22. Availability of fire/explosion control systems.

23. Availability of noise, smoke, or odor control systems.

24. Availability of power assist devices.

25. Total enclosed space required, including that needed for all support equipment and waste storage.

Much of the basis for evaluating the subjective factors should come from actual equipment "track records", contacting users of the equipment for data input, and site visits should be made if possible. Since experience with certain aspects of solid waste shredding technology is not yet extensive, unforeseen problems may be brought to light by the users of various shredders. In such instances, the manufacturer should be contacted to see if any provisions have been made recently to overcome these problems. As with the objective criteria, the subjective factors should be ranked in importance according to local considerations.

1. Actual capacity (tons/hour, tons/shift, tons/day). This figure would take into account storage capacities, daily average and peak loads, input and output conveyor capacities, and projected solid waste growth patterns. For resource recovery systems (fuel fraction separation, ferrous metal recovery, etc.) it is desirable, if not necessary, to know how much material will be processed dependably. When determining actual capacity, the nominal particle size must accompany the data because of its significant effect on throughput. Nominal particle size should be specified in terms of minimum percent of material that will pass a certain screen size. (e.g., 90 percent passing a 3-inch square opening.)

2. Unit power (horsepower--hours/ton). This indicates requirement for power and motor size. Once again, this should be considered in relation to nominal particle size, as power requirements generally increase as particle size decreases.

3. Maximum output particle size. This can affect the next processing step such as air classification.

4. Maximum size of input material. This factor is a determinant of what is excluded from the shredding process. Manual pre-shred separation would be based partly on this criterion. Before selecting a shredder, the decision-maker should determine maximum input particle size that he feels would be desirable to process, and the approximate fraction of the total waste load to be processed.

5. Frequency and duration of breakdowns (tons/repair). The nature of the material processed may markedly affect this parameter.

6. Backfire (ejection from the input). If this appears to be a problem, provisions must be made to ensure employee safety.

7. Labor costs. Not only total labor costs but also the separate figures for routine labor and for repairs should be considered.

8. Types of repair required. Machanical, electrical, and welding skills may be required on a routine or as-needed basis to assure maximum productivity of the system.

9. Effectiveness of power assist devices. The maintenance needs and dependability of these devices must be considered with respect to the benefits derived.

10. Access for maintenance. Not only is easy access to all shredder system components desirable, but adequate clearance should also be provided for quick removal and replacement of parts, such as a rotor shaft. There should also be ready access to the parts of all support equipment, such as conveyor systems, to assure minimum downtime.

11. Effectiveness of noise, smoke, odor, and dust control.

12. Effectiveness of explosion and fire control provisions. In addition to provisions within the system, it would be prudent to have control over material entering the plant in order to avoid having potentially explosive or hazardous material going into the shredder. Industrial waste generators might be required to certify that they are not hazardous wastes.

13. Effectiveness of other safety features.

14. Effect of moisture in waste on power consumption, particle size distribution, and wear rates.

15. Strength and efficiency of motor-shredder interface--belt drive, direct coupling gears, etc.

16. Effectiveness of mechanism for rejecting nonprocessibles to guard against jamming. Also evaluate the method of emptying the reject mechanism.

17. Peak and average power consumption fo shredder/conveyor system.

18. Power cost. This depends on tonnage throughput, type of material processed, particle size, and local unit rates.

19. Number of personnel required. Should include supportive personnel required on a regular basis.

20. Effectiveness of lubrication systems.

21. Complexity of the system and its parts. Undue complexity might mean more frequent breakdowns and higher operating costs.

22. Operating "headaches" found by users. The manufacturer should be asked whether there are new developments that might correct these problems.

23. Manufacturers' reputation. Users should be asked about the cooperativeness of the manufacturer in "debugging" the system. Particular care should be given to defining responsibility for the various components. If a manufacturer supplies only the shredder, he is not responsible for overall system designs.

24. Predicted and actual life of equipment, moving parts.

25. Water requirements.

26. Adequacy of field service.

27. Wear rates (for hammers, liner plates, etc.). Cost of alloys used for hard surfacing will have to be weighed against increased productivity of shredder and less frequent servicing.

28. Time required in startup to reach operating conditions.

29. Effectiveness of litter control provisions.

30. Adequacy of storage for shredded material. This factor should be judged in relation to capacity requirements and provisions for unloading or handling stored material.

31. Location of control room.

32. Housekeeping requirements.

It is likely that not all installations contacted or visited will be able to supply data for each of the above subjective factors, and this is why several facilities should be contacted if possible. Additionally, multiple data sources will help to eliminate or "average out" some of the inevitable biases.

D. Use of Data Accumulated

If a thorough job has been done in gathering the objective and subjective data listed above, plus any data deemed desirable for the specific installation under consideration, then some method of comparing this data in a logical fashion is warranted.

Perhaps the easiest way to organize the data would be to set up a form on which the characteristics of the various shredders being considered can be noted and compared (Figure 9).

The next level of sophistication in decision-making would be to quantify each shredder's rating with respect to each selection criteria on a predetermined scale, such as 0 to 10 points, with 10 points being the most superior rating for any one criteria. Points could be tallied for all criteria for each shredder with the shredder most likely to be selected having the most points.

To go a step further, one could rank the criteria in levels of importance for their situation, and assign a multiplier value to this criteria. For instance, the criteria might be broken into five levels of importance with the least important criteria receiving multiplier values of 1 and the most important criteria receiving multiplier values of 5. These multiplier values would then be used to multiply the numerical rating attained in the above paragraph for each criteria with respect to each piece of equipment. The new ratings for each piece of equipment could then be tallied to arrive at a score. This approach of ranking criteria assures that relatively unimportant criteria do not carry the same weight as a factor of great signficance.

The important point is to consider all criteria with respect to each alternative. These decision aids do not make decisions, but merely organize and clarify the decision-making process.

	Selection Criteria								
	Objective factors				Subjective factors				
Shredder Type	Machine Weight	Rotor Weight	Machine Size	Rate in tons/hr.	etc.	Actual Capacity (ton/hr.)	Unit Power (hp-hr/ton)	Maximum Output Particle Size	etc.
Type 1									
Type 2									
Type 3									
etc.									

Figure 9. A form, such as the one shown here, can be used to help organize the data on the shredders being evaluated.

Appendix I

MUNICIPAL SOLID WASTE SHREDDER LOCATIONS*

STATE	LOCATION	START UP DATE	STATUS	SHREDDER TYPE	CAPACITY (tons per hour)	WASTE TYPES	USE
California	Los Angeles	1975		one vertical	10	municipal	landfill after materials recovery
	San Diego	1970	not in operation	one horizontal	40	municipal	bale and landfill
	Mountain View	1975		one vertical	15	municipal,commercial	landfill after materials recovery
	San Francisco	1973		one horizontal	75	municipal	landfill after ferrous recovery
Colorado	Alamosa	June 1972	installed	one vertical	15	municipal	landfill
	Boulder	1973		one vertical	15	municipal	composting
	Chaffe County	June 1974		one vertical	15	municipal	landfill
	Pueblo	Jan. 1975		two vertical	20,20	municipal,commercial	landfill after ferrous separation
Connecticut	Milford	April 1972	not in operation	two vertical	40,40	municipal,commercial, oversized	landfill
Delaware	New Castle Cnty.	1972	installed	four horizontal	25,25,25,25	municipal	landfill
Florida	Brevard County	1975		two horizontal	60,60	municipal,commercial, oversized	landfill
	Gainesville	1966	not in operation	two horizontal	25,25	municipal	composting
	Pompano Beach	Oct. 1972	installed	one vertical	20	municipal	landfill after paper and ferrous recovery
Georgia	DeKalb County	April 1973	installed	two vertical	40,40	municipal,commercial, oversized	landfill
		June 1973	installed	three vertical	15,15,15	municipal	landfill
	Atlanta	1975		one horizontal	75	municipal,commercial, oversized	bale and landfill
Illinois	Chicago	1975		one horizontal	75	municipal,oversized	supplemental fuel
				one vertical	60	already shredded waste	supplemental fuel
Iowa	Ames	late 1974		two horizontal	50,50	municipal,oversized (wood)	landfill after incineration
Kansas	Cass County	1975		one vertical	20	municipal,commercial, industrial	landfill after materials recovery
Massachusetts	East Bridgewater	1973		three horizontal+	75,10,10	municipal	supplemental fuel
	Marlboro	Nov. 1973		one horizontal	30	municipal	landfill after incineration
	McPherson	1975		one vertical	15	municipal,commercial industrial	landfill
Maryland	Baltimore	early 1975		two horizontal	50,50	municipal,industrial, oversized	pyrolysis
Missouri	St. Louis	1972	installed	one horizontal	45	municipal	supplemental fuel
Montana	Great Falls	Aug. 1973	installed	two vertical	15,20	municipal,commercial	landfill after ferrous separation
Nebraska	Omaha	Summer 1975		one horizontal	50	municipal	landfill after materials recovery
New Jersey	Monmouth County	Nov. 1974		one vertical	50	municipal,commercial, oversized	landfill
New York	Chemung County	1973		two horizontal	40,40	municipal,commercial, oversized	landfill
	Onondaga County	1973	installed	three vertical	40,40,40	municipal,commercial, oversized	landfill
	North Hempstead	1975		one horizontal	75	municipal,commercial, oversized	bale and landfill
North Carolina	Guilford County	Jan. 1974	installed	one vertical	50	municipal,commercial oversized	landfill
Ohio	Columbus	1975		three horizontal	60,60,60	municipal,commercial, oversized	landfill
	Willoughby	Aug. 1973	installed	two vertical	25,25	municipal	landfill
Oregon	Portland	1973	installed	one horizontal	20	municipal	landfill
Rhode Island	Providence	Aug. 1972	not in operation	one vertical	50	municipal,industrial	landfill
South Carolina	Beaufort County	1974		one vertical	20	municipal,commercial	landfill
	Charleston	1974		three vertical	20,20,50	municipal,commercial, oversized	landfill
Texas	Galveston	Sept. 1973	installed	one vertical	25	municipal,industrial	landfill
	Houston	1967	installed	one horizontal	40	municipal	originally compost; landfill after materials recovery, supplemental fuel
	Odessa	Oct. 1974		one horizontal	50	municipal,commercial	landtill (discing with soil)
Washington	Cowlitz County	early 1975		one horizontal	50	municipal	power generation
West Virginia	Charleston	1975		one vertical	15	municipal	resource recovery
Wisconsin	Appleton	June 1974		two horizontal	25,25	municipal	landfill after materials recovery
	Madison	1967	installed	one horizontal	25	municipal	landfill after ferrous separation
		1969	installed	one vertical	15	municipal	landfill
Canada	Edmonton, Alberta	Sept. 1970	installed	one vertical	25	municipal	landfill
	Regina, Saskatchewan	1974	installed	one horizontal	40	municipal	landfill
	Toronto, Ontario	1975		one horizontal	40	municipal	landfill after ferrous separation

* Source: May/June 1974 Waste Age and the National Solid Wastes Management Association December Technical Bulletin.

\+ One primary shredder (75 tph), two secondary shredders (10,10 tph).

Appendix I con't.

INDUSTRIAL AND OVERSIZED BULKY WASTE SHREDDER LOCATIONS*						
STATE	LOCATION	START UP DATE	SHREDDER TYPE	CAPACITY (tons per hour)	WASTE TYPES	USE
Alabama	Decatur	November 1969	one horizontal	40	industrial	materials recovery
Connecticut	Ansonia	May 1974	one horizontal	30	oversized bulky	incineration after materials recovery
District of Columbia	Washington	1973	one horizontal	10	oversized bulky	landfill after incineration
Florida	Ft. Lauderdale	1973	two horizontal	50,50	oversized bulky	landfill after incineration
	Tampa	June 1967	one horizontal	6-8	oversized bulky	landfill after incineration
Georgia	Atlanta	February 1975	one horizontal	75	oversized bulky	landfill; bale, railhaul
	DeKalb County	January 1963	one horizontal	6-8	oversized wood	landfill after incineration
Illinois	Chicago	1970	one horizontal	30	oversized bulky	landfill
		1971	one horizontal	30	oversized bulkv	landfill
Indiana	East Chicago	1975	one horizontal	25	oversized bulky	---
	Indianapolis	1971	one horizontal	50	industrial	landfill
		August 1971	one horizontal	25-35	oversized wood	landfill after incineration
	Ft. Wayne	February 1971	one horizontal	35-50	oversized wood	landfill after incineration
Kentucky	Louisville	April 1962	one horizontal	20	oversized bulky	landfill after incineration
		February 1968+	one horizontal	32	industrial	landfill
		July 1969+	one horizontal	40	industrial	landfill after materials recovery
Maine	Romford	October 1972	one horizontal	40	industrial	heat recovery
Massachusetts	E. Bridgewater	1973	one horizontal	75	oversized bulky	materials recovery
	Holliston	January 1974	one horizontal	40	industrial	materials recovery
	Marlboro	November 1973	one horizontal	30	oversized bulky	landfill after incineration
	Saugas	1974	one horizontal	20-25	oversized bulky	heat recovery
Michigan	Dearborn	August 1970	one horizontal	40	industrial	landfill after materials recovery
	Detroit	June 1967	one horizontal	20	industrial	landfill
		1972	one horizontal	50-60	industrial,oversized bulky	landfill after paper recovery
Missouri	St. Louis	1971	one horizontal	10-15	oversized bulky	landfill after incineration
		June 1969	one horizontal	30	oversized bulky	landfill after incineration
New York	Berlin	August 1972	one horizontal	10	industrial	heat recovery
	Buffalo	1970	one horizontal	240 cu.yd/hr.	oversized bulky	landfill after incineration
	Elmira	1973	two horizontal	40,40	oversized bulky	landfill
	New York City	1973+	one horizontal	7	oversized bulky	landfill after incineration
	Rochester	April 1968+	one horizontal	10	industrial	materials recovery
Ohio	Bellevue	July 1968	one horizontal	5-7	industrial (wood)	---
	Columbus	1974	three horizontal	60	oversized bulky	landfill
	Dayton	1969	one horizontal	10	bulky lumber, wood	incineration
	Newark	1969	one horizontal	10	industrial	landfill
Pennsylvania	Harrisburg	December 1972	one horizontal	20-25	oversized bulky	landfill after incineration
	LeHigh County	September 1974	two vertical	20,20	industrial	landfill
South Carolina	Georgetown Cnty.	April 1974	one vertical	20	industrial	landfill
	Williamsburg County	September 1973	one vertical	20	industrial	landfill
Virginia	Norfolk	1974	one horizontal	30	oversized bulky	landfill after incineration
	Roanoke	July 1968	one horizontal	40	industrial	landfill
	Richmond	June 1974	one vertical	20	industrial	landfill after ferrous-separation
Vermont	Hancock	October 1971	one horizontal	25	industrial	heat recovery
Washington	Camus	1965	one horizontal	5	commercial (paper, cardboard)	---
	Longview	1970	one horizontal	20	industrial polyethylene	incineration
		1971	one horizontal	50	industrial	incineration
	Tacoma	1971	one horizontal	40	oversized bulky	landfill
	Vancouver	1972	one vertical	40	oversized bulky	landfill
Wisconsin	Racine	May 1958+	one horizontal	24	oversized bulky	landfill
Canada	Vancouver, B.C.	July 1971	one vertical	50	industrial	landfill
	Windsor, Ontario	July 1965	one horizontal	30	oversized bulky	materials recovery

* Source: Shredder Subcommittee of the Waste Equipment Manufacturers Institute of the National Solid Waste Manufacturers Institute.

\+ No longer in operation or project discontinued.

POSITION ON LANDFILLING OF MILLED SOLID WASTE*

A. BACKGROUND

The landfilling of milled solid waste without daily soil cover began in Europe with claims that it was an environmentally acceptable and economic method of final disposal. In June of 1966, a solid waste demonstration grant was awarded to Madison, Wisconsin to evaluate the European experience and to determine the feasibility of landfilling milled solid waste without daily cover in this country.

In January 1971, the Madison project personnel met with OSWMP personnel, a consulting engineer, and entomologists from the Bureau of Community Environmental Management (USDHEW), to review the progress and findings to date from the Madison project. OSWMP concluded that the policy governing soil cover for milled solid wastes should be as stated in Sanitary Landfill Facts:

> "The compacted solid wastes must be covered at the conclusion of each day, or more frequently if necessary, with a minimum of six inches of compacted earth."

It was also concluded that further investigation at Madison and in other geographic and climatic areas was needed to fully resolve the policy issue. In a February 2, 1971 memorandum, Mr. Richard Vaughan expressed these findings to OSWMP Senior Staff and Regional Representatives. A copy of this memorandum is attached as Appendix 1.

Additionally, environmental evaluations of landfilling milled solid waste made at the Madison demonstration site have been augmented by information from site visits to other facilities. An increased interest in the procedure is evidenced by the knowledge of six new sites being planned, ten new sites under construction, and five sites operational.

Some of these sites are constructed and operated with provisional approvals, some are operated in opposition to local regulations but in all cases the operations do not adhere to the position stated by the OSWMP on February 2, 1971.

Recent articles, based on European experience, findings from the Madison project, and other new sites within the United States, have appeared in engineering and public works journals. This information, combined with equipment promotional activities has generated an increased interest in the process particularly where problems exist in achieving satisfactory sanitary landfill operations or where milling may compliment resource recovery.

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* Office of Solid Waste Management Programs. Position statement on landfilling of milled solid waste. Unpublished data, Apr. 9, 1973.

B. CURRENT POSITION

Landfilling milled solid wastes can be an environmentally acceptable method of final disposal. The same sound engineering principles involved in sanitary landfill sites, including a properly located, designed, financed, and operated milling facility must be provided to insure successful operations and to minimize adverse environmental impacts. Since environmental, economical, and operational conditions vary from existing sites, the need for cautious planning to meet local conditions and to determine the feasibility of each new site must be emphasized.

It must be recognized that this position is based on detailed investigations at the Madison site augmented by general knowledge from a few additional sites. The ability to mill, grind, or shred wastes such that it is environmentally acceptable to landfill them without daily cover is dependent on the process, its operation, and local conditions such as the environment and the waste content. It is, therefore, recommended that conditional approvals be given by regulatory agencies contingent upon verification that the quality of operation necessary to minimize environmental hazards is maintained. Such verification should be supported by operational controls and monitoring.

Except as modified below, the position statement on sanitary landfill applies to milled solid waste disposal operation. Comments relating milled solid waste to sanitary landfill requirements are listed below in the order presented in the pending "Guidelines for the Land Disposal of Solid Wastes."

1. As an alternative to sanitary landfill, landfilling milled solid waste without daily soil cover can result in increased surface water infiltration and accelerated decomposition which in turn can result in earlier leachate production and temporarily increased pollutional concentrations. Under the usual situation of landfill construction over a period of years, peak leachate production and concentrations occur only in a small part of the fill at any one time. In areas where rainfall infiltration exceeds evaportranspiration and field capacity is reached, the total production of leachate constituents has been shown to be equivalent to a sanitary landfill which reaches field capacity and produces leachate. Therefore, in accordance with the sanitary landfill position, it is necessary to prevent leachate from entering surface or underground sources of water supply. This can be accomplished by preventing leachate production and/or by collecting and treating leachate should it occur.

2. As with sanitary landfill operations, design and operation must conform to applicable air quality standards; specifically, open burning of solid waste must be prohibited.

3. As with sanitary landfill cover, compacted, milled, uncovered landfill surfaces must be left undistrubed to prevent odor. This does not preclude vehicular traffic but precludes excavation of a finished surface.

4. Although milling solid waste reduces the tendency for paper to blow during placement, satisfactory control requires that the waste be spread to a smooth contour and compacted promptly after placement.

5. A milled, uncovered solid waste landfill is much less obnoxious than an open dump and to many observers is no more obnoxious than bare earth.

6. Free venting or loss of gases from milled solid waste, experienced in test cells, indicates that milled solid waste without cover is less likely to trap gases in pockets or cause horizontal gas migration. However, the addition of cover or possible migration through fissures or broken pipe lines, etc. requires the same attention to gas control as a sanitary landfill.

7. European experience, verified by tests at Madison, Wisconsin and Purdue University indicates that:

> Rats cannot extract sufficient food to sustain life from properly milled combined residential, commercial solid waste (7-1/2% organics wet weight in test) nor are they attracted more readily to an uncovered milled solid waste landfill than to a sanitary landfill (baiting studies); the milling process kills nearly 100% of the maggots present in incoming solid waste virtually eliminating fly emergence (sampling studies); and flies are not attracted more readily to an uncovered milled solid waste landfill (Scudder Grill Study).

8. Undetected hazardous materials in incoming wastes have been known to explode or ignite during the milling process. Protection against explosions such as blow-off stacks and personnel shields must be provided. Equipment to extinguish fires which may exist in incoming solid waste or which may be ignited during the milling process, during transport or on the landfill must be provided. No operation should be located where birds might be a hazard to aircraft flight operations.

9. Site selection on an engineering basis is similar to that for a sanitary landfill operation except the availability of daily cover material is not required. The availability of emergency cover is required (see operational plan requirements below). Final cover and final use criteria should be the same as for a standard sanitary landfill.

10. Only properly milled residential and commercial solid wastes should be accepted in an uncovered milled solid waste landfill. Items not accepted in a conventional sanitary landfill and volatile, flammable, explosive or sludge wastes accepted in small quantities at a conventional sanitary landfill, should not be accepted for milling. Final disposal of all wastes not suitable for milling must be in accordance with pending "Guidelines for the Land Disposal of Solid Wastes."

11. All operations and aspects including lighting, dust control, and noise levels must meet the requirements of the Occupational Safety and Health Act of 1970. All solid waste storage areas must be maintained and cleaned at the end of each day's operations, or during continuous operation, as necessary, to prevent fly, rodent, or other vector problems. All equipment must be maintained to control spillage and to achieve a milled product quality necessary to prevent environmental hazard.

12. All operational personnel must be specially trained and instructed on the proper operation, maintenance, and safety aspects of the facilities and equipment.

13. The operational plan must include provision for removal and proper disposal of wastes within 24 hours should the mill facility cease to meet the above conditions because of either a temporary equipment breakdown or a loss of quality operation. The operational plan must include provision of a stock pile of emergency soil cover material and provision to convert the operation to a sanitary landfill.

Preliminary project planning must include a detailed cost analysis including means of establishing a sound financing and revenue system, in order to guarantee that the quality of operation necessary for environmental acceptability can be sustained. Milling and landfilling residential and commercial solid wastes is usually not cost competitive with conventional sanitary landfill disposal. Cost comparisions to justify milling as an alternative to more extensive disposal systems including transfer stations or cover material transport must be evaluated on a local basis. Each community or private operator must make their own thorough economic evaluation of the alternative disposal systems. Milling costs including labor, amortization, utilities, maintenance, and supplies recorded at and relevant only to the Madison project were as high as $7.07/ton for a single 9 ton/hr. Gondard mill operating 5 to 6 hours a day. Costs for a single 15 ton/hr. Tollemache mill operating about 5 hours a day have been recorded at $5.10/ton while costs for a similar operation with "hard to mill" wastes ran as high as $6.44/ton. Transportation to the adjacent landfill averaged about $0.40/ton additional. Spreading and compacting costs averaged an additional $0.50/ton. Cost projections for the combined operation of one Gondard mill at 9 ton/hr. and one Tollemache mill at 15 ton/hr., milling 280 tons/day or a two shift operation is approximately $3.50/ton excluding transport and disposal. These costs reflect local labor rates, union contracts, construction costs, and electrical costs, etc.

C. REFERENCES

1. Ham, R. K., and Porter, W. K., and Reinhardt, J. J.; Refuse Milling for Landfill Disposal. In. The Symposium on Solid Waste Demonstration Projects, Cincinnati, Ohio, May 4-6, 1971. 75 p.

2. Solid Waste Reduction/Salvage Plant. An Interim Report. Demonstration Project; June 14 - December 31, 1967. Grant No. D01-UI-00004. U. S. Public Health Service. 1968. 25 p.

3. Sanitary Landfill Guidelines. U. S. Environmental Protection Agency, Unpublished Report; April 1972. 21 p.

4. Brunner, D. R., and D. J. Keller. Sanitary Landfill Design and Operation. U. S. Environmental Protection Agency Publication (SW-65 ts). Washington, D. C. U. S. Government Printing Office, 1972. 59 p.

5. Stirrup, F. L. Public Cleansing: Refuse disposal. Pergamon Press, Ltd. Great Britain, 1965. 144 p.

6. Department of the Environment. Refuse Disposal. Report of the Working Party on Refuse Disposal. London. Her Majesty's Stationary Office, 1971. 199 p.

7. Department of the Environment. Report of the Working Party on Refuse Disposal. Circular 26/71; April 1971. 7 p.

Appendix III

EXAMPLE

SPECIFICATION

HAMMERMILL, MOTOR AND AUXILIARY EQUIPMENT

1. SCOPE:

This Contract includes the furnishing, for installation by others, of a heavy duty swing hammer horizontal type hammermill, complete with feed and discharge hoppers, the drive motor, coupling, and all accessories, together with their motors and drives as specified herein. The Contractor shall furnish all anchor bolts and other items requiring embedment in the concrete foundation for installation by others, for all equipment furnished under this Contract. The Contractor also shall provide the services of a qualified service representative, to supervise the installation of the equipment, and to properly instruct City personnel in the operation and maintenance of the equipment, for periods totaling not less than 10 days, at the expense of the equipment manufacturer.

The relationship of the hammermill to other parts of the project, and the configuration of the feed and discharge hoppers, are shown on the accompanying general arrangement drawing. The hammermill manufacturer will be required to coordinate his design with the manufacturers of the mill feed and discharge conveyors, to ensure proper clearances and function.

The manufacturer of the hammermill and its auxiliary equipment shall be regularly engaged in the manufacture of equipment similar in design, function, and capacity to that specified. Prior to the date set for receiving bids, a list of installations in which counterparts of the respective items of equipment have been applied satisfactorily shall be supplied to the President, who shall be the sole judge of the acceptability of the proposed equipment. The hammermill shall be similar or equal to those manufactured by the Williams Patent Crusher and Pulverizer Company, or the Gruendler Crusher and Pulverizer Company.

2. FUNCTION AND CAPACITY:

The hammermill shall be designed to mill raw mixed municipal refuse, as collected from domestic and small commercial establishments by packer-type trucks. The mixed municipal refuse is expected to be a heterogeneous mixture of materials of a wide variety of shapes and sizes. Although the refuse will be collected principally from domestic sources, it is possible that occasional heavy or oversize objects, such as discarded yard furniture, bicycle frames, etc., may be fed to the hammermill, which shall be capable of handling such objects without overloading the hammermill or its motor.

The hammermill shall reduce the material fed to it to particle sizes which shall be nominally less than one and one-half inches in size. No more than 5 per cent by weight of the particles produced by the hammermill shall be greater than one and one-half inches, and no particles shall be greater than 5 inches in one dimension after the hammermill has operated at at least 90 per cent of its rated capacity for 40 hours without retipping or replacement of hammers. Occasional pieces of stringy, flexible materials greater than 5 inches in one dimension may be acceptable, as long as such materials do not interfere with the operation of rotary air-lock feeders for pneumatic conveying.

The initial capacity of the hammermill, operating as a single-stage mill, shall be at least 45 tons of raw mixed municipal refuse per hour. Should the capacity of the hammermill be less than 45 tons per hour, or should the nominal particle sizes be greater than those specified, the manufacturer will be required to make such modifications as necessary to provide the required capacity and particle size. Such modifications, if required, shall be made at no

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* Sample of specifications shown in Appendix III were used in St. Louis, Missouri, in conjunction with EPA demonstration project and should not be considered as universally applicable. These are for illustration only.

additional cost to the City, and shall be initiated within five days of the date of notification by the President to the manufacturer that such inadequacies exist. Correction of the inadequacies shall proceed in the most expeditious manner. The President shall be the sole judge of such inadequacies.

The hammermill, with minimum modification of grate bars and/or hammers, shall be capable of future use as a primary mill in a two-stage milling operation, with a nominal average capacity of 70 tons per hour when achieving nominal particle sizes of 4 to 6 inches for raw municipal refuse as collected by packer-type trucks. If so modified at a later date, the hammermill shall be capable of handling such objects as discarded refrigerators.

3. GENERAL DESIGN OF HAMMERMILL AND AUXILIARIES:

a. Housing. The hammermill shall be of heavy duty horizontal design of the swing-hammer type. The frame and housing shall be constructed of heavy rolled steel plates and structural shapes, solidly welded into an integral unit. The main frame shall have bearing support platforms of heavy steel plates welded integrally to the sides. The feed opening shall be approximately 60 inches perpendicular to the rotor, by 80 inches parallel to the rotor.

The hammermill shall be designed to provide quick access to the rotor, breaker plates, grate bars and other internal parts. The design shall provide for the removal of the rotor without disturbing the feed hopper or feeding equipment. The housing shall be opened hydraulically, as hereinafter specified, to permit inspection, maintenance, retipping of hammers in place, and replacement of parts.

The hammermill shall be fitted with manganese steel shear type breaker plates not less than 2 inches thick. Replaceable carbon manganese steel liner plates shall be provided on the sides and top of the crusher chamber. The liners and breaker plates shall be made in sections, bolted to the housing by means of heavy bolts with locknuts. All parts subject to wear shall be easily replaceable.

b. Rotor. The swing hammer rotor shall have a hammer circle of approximately 60 inches and a length of approximately 80 inches inside the housing, and shall have 4 rows of chisel-edged hammers of sufficient number, size, and weight to provide the specified production rate and particle size. The hammers shall be made of alloy steel having high resistance to shock and abrasion, hard-surfaced on the working ends to 500 to 570 Brinell hardness. Hammers shall be staggered so that they cover the full width of the crusher chamber, with those in one row traveling in the spaces between the leading and following rows. The hammer suspension shafts shall be made of no less than 4-inch diameter high tensile alloy steel, surface-hardened to minimize wear.

The rotor shaft shall be not less than 14 inches in diameter in the crushing chamber, turned from a heat-treated, alloy steel forging. The disc plates shall be of cloverleaf design, made of high tensile alloy steel, having high resistance to shock and erosion. The discs and their spacers shall be securely keyed to the shaft and positioned by threaded collars. In order to prevent shock loading and excessive wear on the discs, the discs shall not extend into the crushing area of the hammer system and there shall be a minimum clearance of 9-1/2 inches between the disc circle and the grate bars. The rotor assembly shall be designed to provide an internal balanced flywheel system with sufficient inertia to minimize shock loadings. The rotor shall be balanced statically and dynamically, and shall not exceed 5 mils dynamic vibration, measured peak-to-peak, at operating speed. The WK^2 of the rotor shall be no less than 46,500 lb-ft^2.

The hammermill rotor shall be direct-connected to no less than a 1,250 horsepower, 900 rpm electric motor, as hereinafter specified, by means of a heavy duty, flexible coupling, Falk or equal.

c. Bearings. The rotor shall be carried in double-row, self-aligning, spherical roller bearings having a taper bore approximately 11 inches in diameter. The bearings shall be housed in heavy-duty steel pillow blocks, sealed against dust and moisture, pinned and secured by high tensile steel bolts with heavy nuts and jam nuts, and taper wedge blocks. The shafts shall be drilled and arranged for hydraulic seating and removal of bearings.

d. Lubrication System. The bearings shall be oil-lubricated, and the manufacturer shall furnish an oil circulating and cooling system to supply lubrication to the bearings, including a pump, filter, heat exchanger, valves, temperature and pressure gauges, with appropriate safeguards and alarms to be actuated should oil pressure fail or over-temperature occur.

e. Grate Bars. The grate bars shall be of manganese steel, consisting either of deep section members having spacers, which may be changed in the field to alter the size of the discharge openings, or of sectional grids which could be replaced all or in part with grids having different openings. The grate bars or grids shall be secured by wedges or other means to facilitate quick removal and replacement.

f. Hydraulic Opening System. The manufacturer shall furnish oil hydraulic cylinders to lift and hold in an open position the top hinged cover section of the hammermill to facilitate inspection and maintenance. Provisions shall be made for locking the cover securely when it is in the closed position. The manufacturer also shall furnish the oil hydraulic equipment components, consisting of a motor, pump and oil reservoir, together with control valves and oil for the system. The hydraulic system shall be designed to open the top hinged cover section of the hammermill housing in one minute or less. When in an open position, the cover shall not interfere with hammer retipping.

g. Feed Hopper. A steel feed hopper shall be provided to mate with the hammermill to permit the unobstructed feeding of the intended materials and objects. The shape of the feed hopper shall be substantially as shown on the general arrangement drawing. The feed hopper shall be supported by the feed opening of the hammermill. It shall be fabricated of steel plate not less than 3/4-inch thick, reinforced with structural members and welded together to form an integral unit. Additional external reinforcing shall be provided on the sides receiving direct impact from missiles thrown by the rotor. The inlet of the feed hopper shall be equipped with two rows of reinforced rubber belting, with the strips staggered, to serve as barriers to prevent missiles from being thrown out of the hammermill through the feed opening. An opening in the top of the hopper shall be provided for the installation of a dust removal duct, as shown on the Drawing. Provision shall be made for the installation of manually controlled water sprays into the crusher chamber. Provisions also shall be made for the installation of rubber skirting between the feed hopper and the mill feed conveyor as shown on the Drawing.

h. Discharge Hopper. A steel discharge hopper shall be provided supported from the discharge opening of the hammermill. The discharge hopper shall be fabricated of steel plates not less than 1/2 inch in thickness, reinforced with structural members and welded together to form an integral unit. The inside dimensions of the top of the discharge hopper shall be the same as those of the discharge opening of the crusher. The discharge hopper shall be shaped to conform to the configuration of the discharge conveyer under the hammermill, and shall be fitted to prevent the escape of dust and refuse particles. Skirting shall be provided between the discharge hopper and the mill discharge conveyor, as shown on the Drawing.

4. HAMMERMILL DRIVE MOTOR:

a. General. The motor described herein shall conform to all applicable standards and recommendations of ANSI, NEMA, IEEE, NBFU, UL, NEC, and the electrical and building codes of the City of St. Louis, where applicable.

The hammermill drive motor shall be adequate to start and to drive continuously the hammermill as described herein at the production rates and conditions as specified. The motor and its parts shall be designed for hammermill duty, and shall be designed to withstand, on a continuous basis, 125 per cent maximum pull-out torque. The heterogeneous nature of the materials fed to the hammermill may be expected to impose occasional heavy loads in the motor. Sharply rising stator currents can be expected, which may last on the order of 10 seconds, and which may approach levels of 200 per cent FLA (full load amperes). Occasional current levels of 400 to 500 per cent FLA, of approximately one second duration, must be anticipated in the motor design, to accommodate the impact characteristics of the loads imposed on the hammermill.

b. Motor Design. The motor shall be a squirrel cage induction motor, with the frame size, shaft size and other details coordinated with the requirements of the hammermill and the connecting coupling. The motor shall be at least 1,250 horsepower, designed for 900 rpm. It shall be designed for 3 phase, 60 cps, 4,160 vac, 3-wire service, with a service factor of 1.15. Slip at full load shall be limited to 2.5 per cent maximum. Breakdown torque shall be at least 225 per cent of full load torque with the rated voltage on the motor. The motor design shall correspond to NEMA Design B (normal starting torque, low starting current).

The design temperature rise shall be 90 degrees C. above a 40-degree C. ambient, with winding temperature measured by the resistance method at stabilization, when the motor has been operated continuously at the 1.15 service factor. The insulation system shall be Class F for 155 degrees C. service, and shall incorporate materials and processes approved in AIEE No. 1. The insulation materials shall consist of high temperature polyester enamel, fiberglass, mica, polyester asbestos and aromatic polyamide (nylon) paper.

The normal starting current will be limited by a reduced voltage nonreversing motor starter through application of 65 per cent of rated line voltage, plus or minus 10 per cent through reactors. Starting voltage may be varied to suit conditions by changing taps in the reactor in the motor starter. The starting time shall not exceed 120 seconds with an unloaded hammermill. The hammermill will not be started unless it is unloaded.

The motor shall be suitable for continuous year-around, outdoor operations in a dirt-laden environment and the motor housing shall be equivalent to NEMA II of the totally-enclosed, completely weather-protected type. The housing shall be provided with replaceable glass-fibre filters contained in protective frames and shielded by rustproof hardware cloth. The housing shall be rustproofed, primed and painted with two coats of machine enamel, inside and outside. Cooling air shall be drawn into the motor through the filters by means of a cast impeller fan secured to the rotor shaft within the motor housing. Air shall be drawn in at one end, forced through longitudinal cooling ducts in the stator, and axially along the air gap over a smooth rotor core. Cooling air inlet and exhaust openings shall be so placed that short-circuiting of air flow will not occur. The fan shall be designed with inclined blades to produce low shock to the entering air, and to deliver the air at relatively low velocity into smooth channels to minimize windage losses and noise. The exhaust openings shall be equipped with motorized sealing louvers to prevent dust from entering the motor when it is de-energized.

The motor will be direct connected to the hammermill by a flexible coupling, Falk or equal, suitable for the service intended.

Efficiency of the motor shall be not less than 92 per cent at full load and rated voltage. The power factor shall be not less than 85 per cent at full load and rated voltage.

c. Motor Construction. Both the stator and rotor magnetic structures shall be constructed of stacked laminations of varnished, heat-treated, high silicon electrical grade sheet steel chosen for low loss. Stator laminations shall be stacked and bolted, and keyed and bolted to a rolled and welded steel frame. The rotor side of the stator shall be smooth to prevent vibration and noise due to irregular air flow. Smooth bore air ducts shall pass through the stator for cooling. The rotor laminations shall be assembled in the rotor shaft as single piece steel punchings, stacked and keyed directly to the shaft. A bolted clamping support for the rotor laminations shall secure the rotor laminations to the shaft, with the clamping support welded to the shaft. The rotor surface shall be smooth for noise-free passage of cooling air.

Electrical insulation shall be constructed of a fiberglass reinforced Class F system, which shall be vacuum impregnated after a thorough bake-out procedure. The insulation system shall thoroughly encase coils, connections and leads. The stator coils shall be restrained, and the coil ends shall be braced and supported to prevent movement of the windings, even under short-circuit conditions, and the bracing shall not impose any mechanical strain on the winding, or permit coil vibration or distortion.

Rotor cage electrical bar conductors shall be of oxygen-free electrical conductor grade copper, which shall be brazed or silver-soldered to the end rings to guarantee torque characteristics. The rotor cage structural design shall be such that thermal expansion and contraction shall be kept well within the elastic limits of the copper. Rotor stiffness shall be ensured by welding the rotor core support structure directly to the shaft. The rotor shall be dynamically balanced after fabrication to ensure smooth operations.

The motor shall be run-up in speed under no-load conditions and with rated voltage applied, to cause the rotor to assume an axial equilibrium position relative to the rotating magnetic field produced by exciting the stator. At equilibrium position of the rotor, while turning at full speed, a diamond scribe shall be used to scribe a circumferential mark on the rotating shaft at the coupling end motor bearing housing. With this reference mark, a shaft button shall be assembled into the opposite end of the shaft. The projections of this button and the shaft shoulder shall between them determine 1/2-inch shaft end float, and locate the scribe mark midway between the extremes of the end float. It is intended that the scribe mark appears exactly at the coupling and motor bearing housing when the coupled system is rotating at rated speed. The motor shaft button and the shaft shoulder should act as limit stops at either end of the shaft end float.

d. Bearings. Bearings shells shall be cast of an approved bearing babbitt metal by a method designed to guarantee freedom from blowholes. Bearings shall be of the split-sleeve type, contained in split housings permanently aligned and doweled to the motor frame to permit bearing shell replacement without disturbing alignment of the motor. One bearing pedestal and its fasteners shall be electrically isolated from the motor frame to prevent an eddy current path from encircling the rotor, the bearings and the motor frame.

The bearings shall be oil-lubricated by slinger rings from oil pockets in the bearing pedestals. Each oil pocket shall be equipped with a fill plug, a drain plug and a window-type fill-level gauge. The bearings shall be oil and dust-tight. The bearing design shall be such that the ratio of diameter to length shall be one to one in the journal. The proportioning of the bearing dimensions shall provide a surface velocity and a unit seating pressure to ensure a low temperature rise when the bearing is lubricated by the slinger ring. The shaft journal shall be provided with a ground finish at the bearings of 5 to 10 microinches, rms.

e. Frame. The motor frame shall be of steel and shall provide high impact strength and rigidity without excessive weight, and shall be fabricated with smooth contours. The frame shall be fitted with heavy duty steel bar feet, and with lifting lugs to permit handling by crane. The frame shall be degreased, mill scale removed, rustproofed, primed and painted with two coats of light gray machine enamel, ASA 61. All hardware and fasteners shall be corrosion-resistant.

The motor manufacturer shall supply a suitable bed plate for embedment in a concrete foundation. The bed plate shall provide positive means for both lateral and longitudinal adjustment of the motor.

f. Temperature Detectors and Alarms. Two resistance temperature detectors shall be wound into each phase of the stator windings during construction. Two additional temperature detectors of the spring-loaded type shall be provided, one for each bearing housing, with the springs forcing the detectors into good thermal contact with the bearing housing. All detectors used with the motor shall be connected to a weathertight terminal box, with the wires drawn through rigid conduit attached to the motor frame. The terminal box shall allow a one point pickup of conduit for transmitting the temperature detector signals to an indicating and alarm unit compatible with the detectors. The locations of the indicating and alarm unit will be in the electrical control room, with remote indications at the control station near the operating floor.

The indicating and alarm unit, which shall be furnished under this Contract, shall be of the Wheatstone bridge type in which the resistance temperature detector is located in one arm. The temperature trip point of the Wheatstone bridge shall be detected by a null balance relay. The trip-temperature value shall be adjusted by a potentiometer in the Wheatstone bridge circuit. The assembly of eight Wheatstone bridge circuits, the associated setting potentiometers, the array of channel indicator pushbuttons, switches and the test trip pushbuttons, along with the indicator, shall be appropriately housed in the alarm circuit manufacturer's cabinet, which shall be located in the electrical control room. The purpose of the temperature detectors is to protect the motor by tripping it from the mains when any temperature detecting point exceeds the preset temperature for that point. When such tripping occurs, the temperature channel initiating the signal shall have associated with it a pilot light which remains on until the circuit is reset.

g. Motor Heaters. Corrosion-resistant steel-sheathed magnesium oxide, nichrome wire electric strip heaters shall be provided in the motor enclosure. These shall be energized when the motor is de-energized. They shall have sufficient capacity to heat the air in the motor enclosure and cause its circulation by convection through and about the motor electric parts to prevent the condensation of moisture.

h. Connection Box. A code gauge electric connection box, made of galvanized steel, attached to the motor, shall be provided. It shall accommodate conduit with high voltage service leads to power the motor, as well as a ground cable. A three-phase surge capacitor of appropriate rating in voltage and capacitance shall be provided in the connection box with the common side connected to ground. Lightning arrestors of adequate rating and of a grade suitable to this service shall be provided. The capacitor and the lightning arrestors shall be connected to each phase of the incoming line and to the motor service terminals. The common ground connections of the capacitor and the lightning arrestors shall be through their bases to the grounded frame of the connection box in which they are mounted.

i. Motor Tests and Data. After the motor has been assembled and inspected, it shall be given the following commercial tests and the test data recorded. Five certified copies of the data shall be submitted to the City.

1. Locked rotor current at rated voltage and at 65 per cent of rated voltage.

2. No-load current at rated voltage.

3. Winding resistance at ambient temperature.

4. Insulation tests, including resistance to ground measured with 500 vdc excitation of stator, isolated bearing and rotor, and high potential tests as prescribed by NEMA for motors of this voltage rating and horsepower.

A thorough mechanical and electrical inspection of the motor shall be made to ensure compliance with the Specifications.

Motor performance tests to obtain the data specified in the following shall be conducted either on this motor, or data shall be supplied as obtained from such tests of a similar motor.

1. Rotor moment of inertia.

2. Efficiency and power factor at full load, three-quarter load, half load and one-quarter load (100 per cent voltage).

3. Full load percentage slip (100 per cent voltage).

4. Breakdown torque.

5. Starting torque.

Five sets of curves of motor current, power factor, slip, torque and efficiency shall be provided, along with five complete sets of mechanical drawings and details of motor construction, and five sets of recommended installation, operation and maintenance procedures, together with lists of recommended spare parts.

5. SHOP PAINTING:

All external steel surfaces of the equipment furnished under this Contract, except as otherwise noted, shall be thoroughly cleaned of grease, oil and mill scale, and shall receive one shop coat of Koppers Rustinhibitive Primer No. 612 (phenolic), or approved equal, applied to achieve a minimum dry thickness of 1.5 mils. Shafting and exposed machined surfaces shall be protected with a suitable coating of a soluble slushing compound to prevent corrosion during transit, storage and installation. Motors and reducers shall receive the manufacturer's standard painting system. Finish painting will be done by others.

6. PAYMENT:

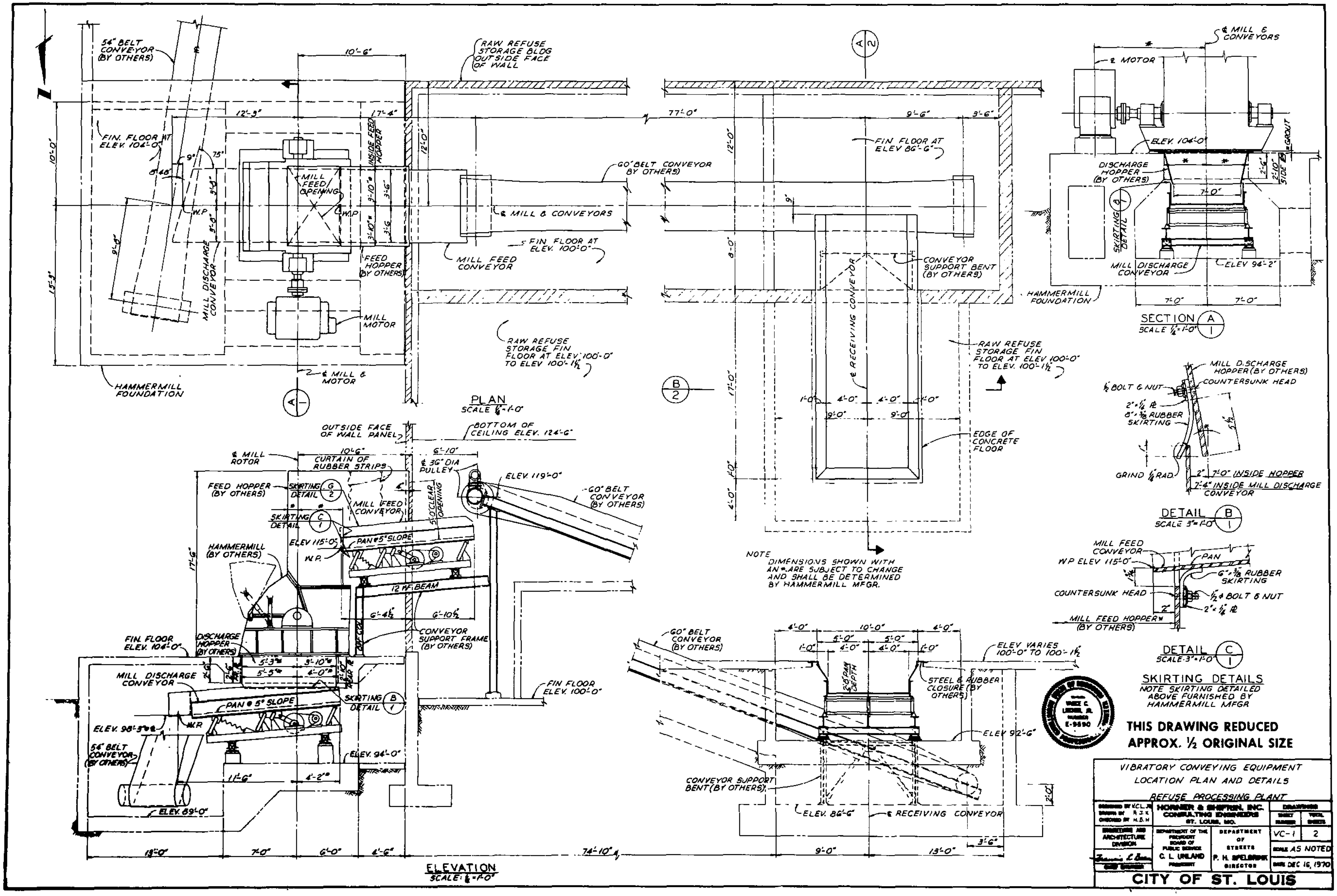
Payment for the equipment included in this Specification, together with the associated equipment, shall be on the basis of the individual lump-sum prices stated in the Proposal, and on the terms stated in the Instructions for Bidders, as follows:

a. Hammermill with Auxiliaries . . . . One Item

b. Hammermill Feed Hopper . . . . One Item

c. Hammermill Discharge Hopper . . . . One Item

d. Hammermill Drive Motor . . . . One Item


54" BELT CONVEYOR (BY OTHERS)
RAW REFUSE STORAGE BLDG OUTSIDE FACE OF WALL
FIN. FLOOR AT ELEV. 104'-0"
MILL FEED OPENING
INSIDE FEED HOPPER
60" BELT CONVEYOR (BY OTHERS)
℄ MILL & CONVEYORS
FIN FLOOR AT ELEV. 100'-0"
MILL FEED CONVEYOR
FEED HOPPER (BY OTHERS)
MILL DISCHARGE CONVEYOR
MILL MOTOR
RAW REFUSE STORAGE FIN FLOOR AT ELEV 100'-0" TO ELEV 100'-1½"
℄ MILL & MOTOR
HAMMERMILL FOUNDATION
PLAN
SCALE ⅛"=1'-0"
FIN FLOOR AT ELEV 86'-6"
CONVEYOR SUPPORT BENT (BY OTHERS)
℄ RECEIVING CONVEYOR
EDGE OF CONCRETE FLOOR
NOTE
DIMENSIONS SHOWN WITH AN * ARE SUBJECT TO CHANGE AND SHALL BE DETERMINED BY HAMMERMILL MFGR.
℄ MILL & CONVEYORS
℄ MOTOR
ELEV. 104'-0"
DISCHARGE HOPPER (BY OTHERS)
SKIRTING DETAIL
MILL DISCHARGE CONVEYOR
ELEV 94'-2"
HAMMERMILL FOUNDATION
SECTION A/1
SCALE ¼"=1'-0"
MILL DISCHARGE HOPPER (BY OTHERS)
½" BOLT & NUT
COUNTERSUNK HEAD
2"×¼" ℞
6"×⅜ RUBBER SKIRTING
GRIND ¼" RAD.
7'-0" INSIDE HOPPER
7'-4" INSIDE MILL DISCHARGE CONVEYOR
DETAIL B/1
SCALE 3"=1'-0"
MILL FEED CONVEYOR
W.P ELEV 115'-0"
PAN
6"×⅜ RUBBER SKIRTING
COUNTERSUNK HEAD
½"⌀ BOLT & NUT
MILL FEED HOPPER* (BY OTHERS)
DETAIL C/1
SCALE 3"=1'-0"
SKIRTING DETAILS
NOTE SKIRTING DETAILED ABOVE FURNISHED BY HAMMERMILL MFGR
OUTSIDE FACE OF WALL PANEL
BOTTOM OF CEILING ELEV. 124'-6"
℄ MILL ROTOR
CURTAIN OF RUBBER STRIPS
℄ 36" DIA PULLEY
ELEV. 119'-0"
60" BELT CONVEYOR (BY OTHERS)
FEED HOPPER (BY OTHERS)
MILL FEED CONVEYOR
ELEV 115'-0"
PAN @ 5° SLOPE
HAMMERMILL (BY OTHERS)
12 W.F. BEAM
CONVEYOR SUPPORT FRAME (BY OTHERS)
FIN. FLOOR ELEV. 104'-0"
DISCHARGE HOPPER (BY OTHERS)
MILL DISCHARGE CONVEYOR
PAN @ 5° SLOPE
FIN FLOOR ELEV. 100'-0"
ELEV. 98'-3"
54" BELT CONVEYOR (BY OTHERS)
ELEV. 94'-0"
ELEV. 89'-0"
ELEVATION
SCALE ⅛"=1'-0"
60" BELT CONVEYOR (BY OTHERS)
ELEV VARIES 100'-0" TO 100'-1½"
STEEL & RUBBER CLOSURE (BY OTHERS)
2'-9" PAN DEPTH
ELEV 92'-6"
CONVEYOR SUPPORT BENT (BY OTHERS)
ELEV. 86'-6"
℄ RECEIVING CONVEYOR
THIS DRAWING REDUCED APPROX. ½ ORIGINAL SIZE
VIBRATORY CONVEYING EQUIPMENT
LOCATION PLAN AND DETAILS
REFUSE PROCESSING PLANT
HORNER & SHIFRIN, INC.
CONSULTING ENGINEERS
ST. LOUIS, MO.
C. L. UNLAND
P. H. SPELBRINK
VC-1
2
AS NOTED
DEC 16, 1970
CITY OF ST. LOUIS

SPECIFICATIONS

VIBRATORY CONVEYORS

1. SCOPE:

This Contract includes the furnishing, for installation by others, of three vibratory conveyors, comprised of one receiving conveyor, one mill feed conveyor and one mill discharge conveyor, complete with drives, motors, belt guards and accessories as specified herein. The Contractor shall furnish all anchor bolts and other items requiring embedment in concrete foundations, for installation by others, for all equipment furnished under this Contract. The Contractor also shall furnish the services of a qualified service representative for a sufficient period of time to supervise the installation of the equipment by others, and to properly instruct City personnel in the operation and maintenance of the equipment. These services will be required for periods to be scheduled with the Contractor installing the equipment, totaling not less than two working days during the installation of the equipment and two working days during the start-up period, at the expense of the equipment manufacturer.

The relationship of the vibratory conveyors furnished under this Contract to the other equipment and structures of the project is shown on the accompanying drawing.

The vibrating medium for each conveyor shall consist of a resonant natural frequency spring and mass system, comprised of low stress, heavy duty alloy steel coil springs, shot-peened and magnaflux inspected, or of other materials subject to approval by the City. All conveyors shall be dynamically counter-balanced and isolated by systems of lower natural frequency than those at which the conveyors operate.

All conveyors shall have positive eccentric shaft drives, with connecting arms driven through V-belts by electric motors. The drives shall be designed to accommodate extraordinary out-of-phase forces which may occur during start-up and shut-down. Stability of the equipment shall be assured by elimination of large gyrations through isolation springs and cushioned limit stops during start-up and shut-down. The drives shall be designed to provide acceleration and deceleration to quickly pass through the natural frequencies of the isolation systems so as to prevent build-up of large gyrations.

All three conveyors shall be designed to accommodate nominal feed rates of 45 tons per hour, with surges of up to 60 tons per hour, when handling the material specified hereinafter. The conveyors shall be capable of modification for future duty to convey nominal rates of 70 tons per hour each, with peak rates up to 100 tons per hour.

All conveyors shall be of heavy duty construction. All bearings shall be dust-tight sealed cartridges. Provisions shall be made for lubrication from convenient and accessible points. Parts for the three conveyors shall be interchangeable, wherever feasible. All moving and vibrating parts shall be easily accessible for adjustment and replacement.

The manufacturer of the vibratory conveyors shall be regularly engaged in the manufacture of conveying equipment of similar design, function and capacity to that specified. Prior to the date set for receiving bids, a list of installations in which counterparts of the respective items of equipment have been applied satisfactorily shall be supplied to the President, who shall be sole judge of the acceptability of the proposed equipment. The vibratory conveyors shall be similar or equal to those manufactured by the Stephens-Adamson Company, or the Carrier Division of the Rex Chainbelt Company.

Minor modifications in dimensions of the equipment specified herein may be necessary to reconcile differences with the equipment furnished by other manufacturers. The manufacturer of the vibratory conveyors will be required to cooperate with the City and its other Contractors in reconciling such modifications.

The manufacturer shall provide full information relating to static and dynamic loadings and forces, and shall guarantee the accuracy of such information.

2. RECEIVING CONVEYOR:

Mixed municipal refuse, as collected from domestic establishments in packer-type trucks, will be dumped from the trucks on a concrete floor. Front-end loaders will push the raw refuse from the floor into the pan of the receiving conveyor. The receiving conveyor, which shall have an electrically controlled means of varying the conveying velocity and rate of discharge, will be required to discharge the raw refuse at a reasonably constant but variable rate to an inclined belt conveyor, as shown on the accompanying drawings.

The mixed municipal refuse is expected to be a heterogeneous mixture of materials of a wide variety of shapes and sizes, with its bulk density ranging between 100 and 350 pounds per cubic yard. Occasional heavy objects, weighing on the order of 50 to 100 pounds and more, may be expected to be included in the refuse.

The receiving conveyor will be installed by others in a concrete pit, below the operating floor, with its isolation mountings supported by a concrete slab and steel beams, as shown on the Drawings.

The receiving conveyor shall have a steel pan, at least 3/8 inch thick, and 33 inches deep, 8 feet wide at its bottom, and approximately 24 feet, 3 inches long at its centerline. The conveyor will discharge to a 60-inch wide belt conveyor. A 1/2-inch thick replaceable liner, about 16 feet long, shall be provided for the bottom of the pan, held in place with countersunk flat-head bolts. There shall be no protuberance inside the pan to interfere with the discharge of the materials handled. The pan of the conveyor shall be set in a horizontal plane, and shall be suitably reinforced to prevent deformation from the impact of heavy objects.

The conveyor shall be provided with a positive eccentric shaft drive, which shall provide a variable discharge rate, and which will permit a stroke of at least one inch. The variable discharge characteristic shall be such that the rate of discharge of the conveyor may be varied from about 30 tons per hour to about 60 tons per hour. The variable rate of discharge shall be controlled by a remote control unit which will permit the desired range of discharge. The remote control unit shall be furnished with a dial for controlling the discharge rate. The remote control shall be accomplished electrically, subject to approval by the City.

The motor and drive shall be mounted on the conveyor frame, with the motor set on an adjustable sliding base. The motor shall be at least equivalent to a 25 horsepower, squirrel cage induction, 480 volt, 3 phase, 60 cycle, totally enclosed fan-cooled motor, NEMA Design "B". The motor shall be designed to permit at least 10 starts per hour without overheating.

3. MILL FEED CONVEYOR:

The mill feed conveyor will receive raw mixed municipal refuse from a belt conveyor and discharge the refuse into the feed hopper of a hammermill, as shown on the accompanying drawing. The mixed municipal refuse is expected to be a heterogeneous mixture of materials of a wide variety of shapes and sizes, with its bulk density ranging between 100 and 350 pounds per cubic yard. Occasional heavy objects, weighing from 50 to 100 pounds and more, may be included in the refuse.

The mill feed conveyor will be installed by others, on a steel supporting framework, also provided by others.

The pan of the mill feed conveyor shall be fabricated of steel plate no less than 3/8 inch thick, and not less than 24 inches deep, 7 feet wide and 13 feet, 3 inches long, as shown on the Drawings. It shall be sloped downward toward its discharge end at an angle of about 5 degrees from horizontal. The discharge end shall extend inside the feed hopper of the hammermill, and shall be suitably reinforced to withstand the impact of missiles from within the hammermill. Provisions shall be made for the installation of heavy rubber strips along the sides of the conveyor to prevent the discharge of missiles and debris from the mill, as shown on the Drawings.

The mill feed conveyor shall be driven by an electric motor through a positive eccentric shaft drive, with a stroke of at least 1 inch. The motor shall be no less than a 20 horsepower, squirrel cage induction, 480 volt, 3 phase, 60 cycle totally enclosed fan-cooled motor, NEMA Design "B," driving the eccentric drive through V-belts. The motor shall be designed to permit at least 10 starts per hour without overheating. The motor and drive shall be mounted on the conveyor frame, with the motor set on an adjustable sliding base.

4. MILL DISCHARGE CONVEYOR:

The mill discharge conveyor will receive milled municipal refuse from the discharge of the hammermill and transfer the milled material to a belt conveyor, as shown on the accompanying drawing. The milled refuse will consist of particles nominally 1-1/2 inches in size, with essentially no particles greater than 5 inches. The loose bulk density of the milled material is expected to be between 4 and 15 pounds per cubic foot.

The conveyor will be installed by others in a concrete pit beneath the hammermill, with its isolation mountings supported by a concrete structure.

The pan of the mill discharge conveyor shall be fabricated of steel plate no less than 3/8-inch thick, and with a variable depth of 30 inches maximum, 7 feet, 4 inches width and 15 feet, 8 inches length at its centerline. The discharge end shall be mitered to permit uniform discharge to a belt conveyor, as shown on the Drawings. The pan shall be sloped downward toward its discharge end, on an angle of about 5 degrees from horizontal. The conveyor pan shall be suitably reinforced to withstand the impact of missiles from the hammermill.

The mill discharge conveyor shall be driven by an electric motor through a positive eccentric shaft drive, with a stroke of at least one inch. The motor shall be no less than a 20 horsepower, squirrel cage induction, 480 volt, 3 phase, 60 cycle, totally enclosed fan-cooled motor, driving the eccentric drive through V-belts. The motor and drive shall be mounted on the conveyor frame, with the motor set on an adjustable sliding base.

5. DIMENSIONS:

Minor dimensional changes of the conveyors may be necessary to accommodate equipment furnished by other manufacturers. The lump-sum bid prices shall allow for such minor changes.

6. SHOP PAINTING:

All exposed surfaces of ferrous metal parts of the conveyors shall have all rust, mill scale, dust, dirt, grease, oil, and all other foreign substances removed by means of wire brushes, chisels, hammers or by washing with water or benzine, as is necessary. Immediately after cleaning, the surfaces shall be given one shop coat of Koppers Rustinhibitive Primer No. 612 (Phenolic) or approved equal, applied to achieve a minimum dry thickness of 1.5 mils.

7. PERFORMANCE:

Should the equipment specified herein not provide the conveying rates of the respective quantities called for, within the limits of the bulk densities and conditions herein described, the manufacturer will be required to make such modifications as necessary to provide the required conveying rates. Such modifications, if required, shall be made with the cooperation of the Contractor installing the equipment, and shall be made at no additional cost to the City, and shall be initiated within five days of the date of notification by the President to the manufacturer that the equipment is not performing as specified. Correction of any such inadequacies shall proceed in the most expeditious manner. The President shall be the sole judge of such inadequacies.

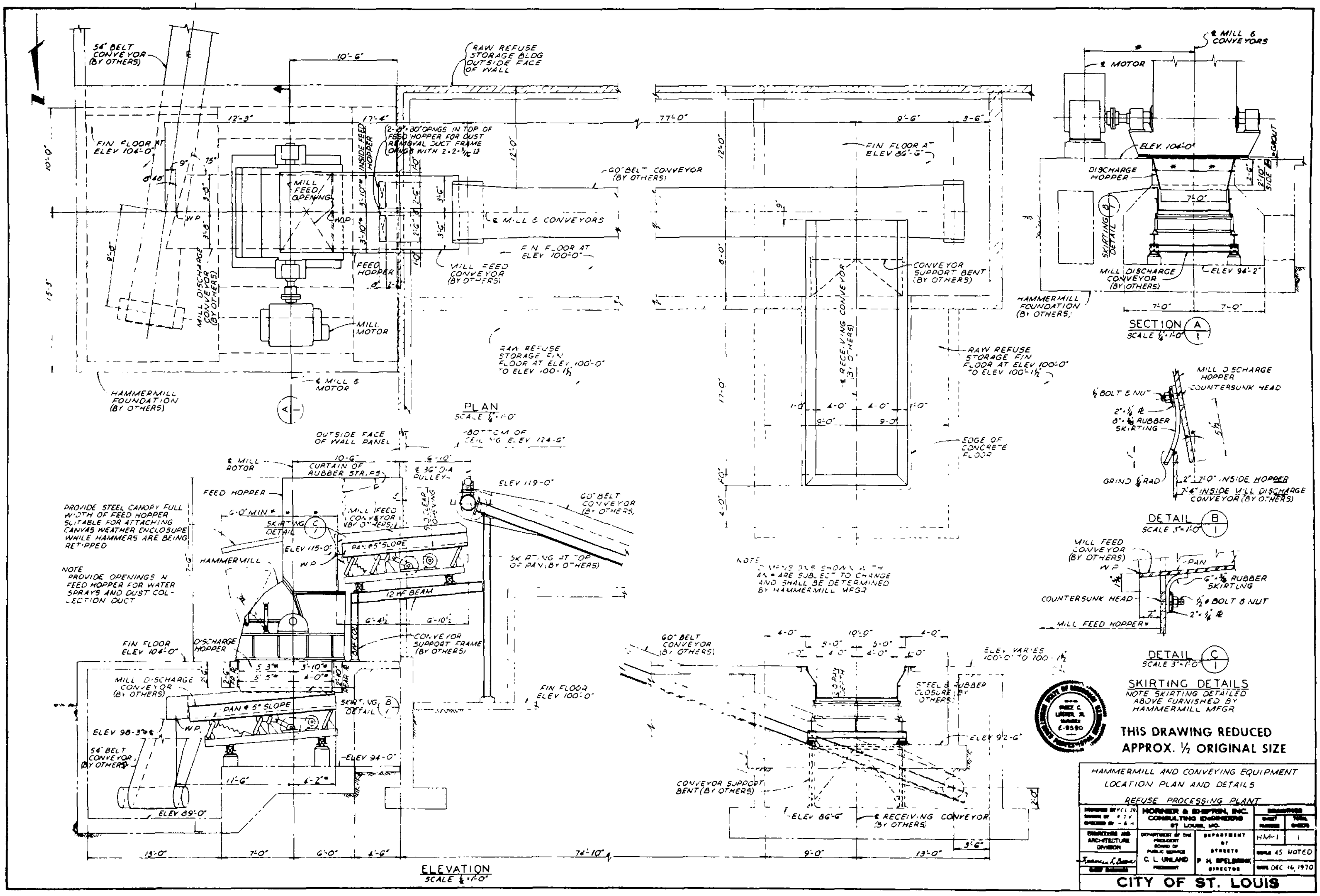
8. PAYMENT:

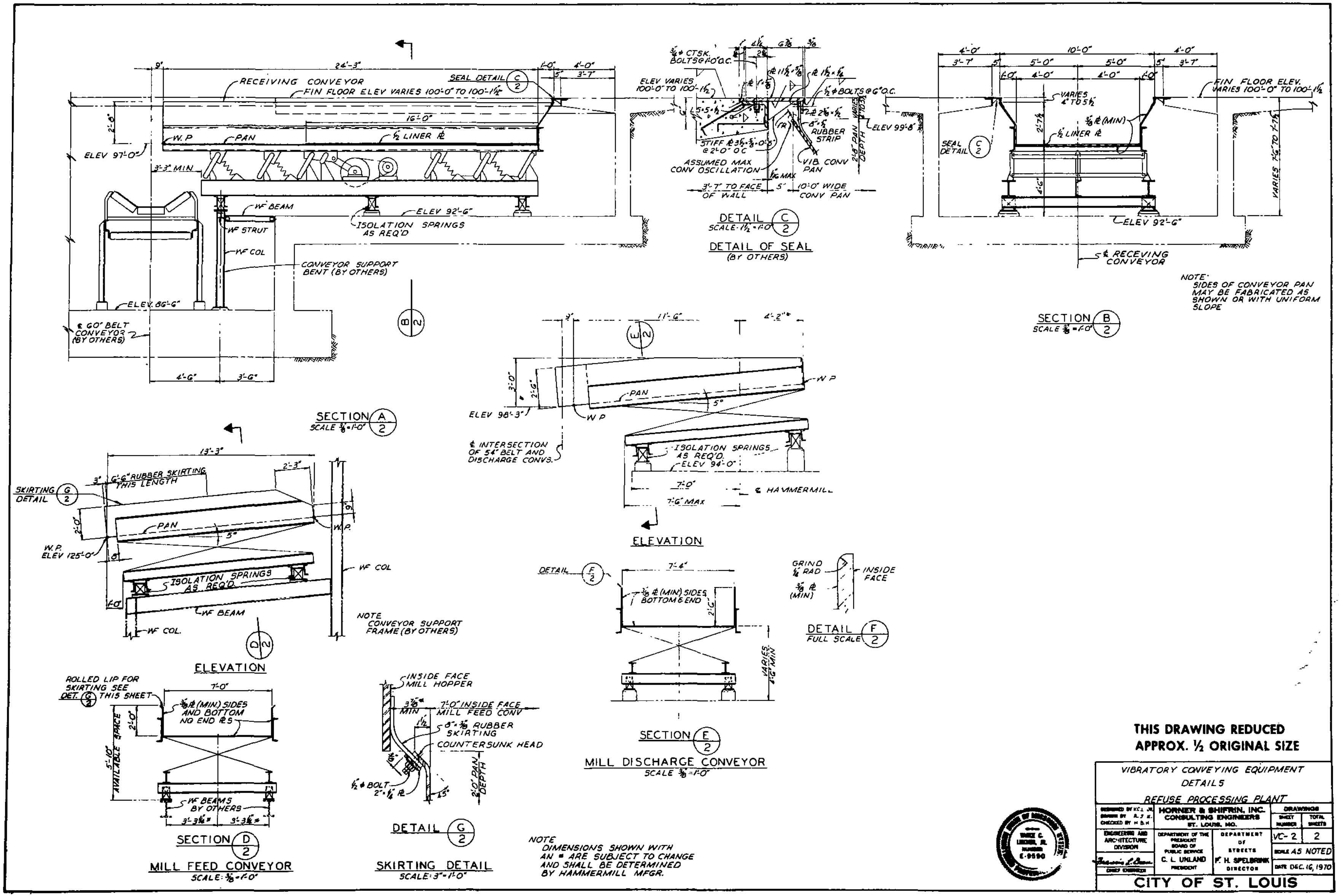
Payment for the furnishing of the vibratory conveyors, including shop painting, described herein shall be on the basis of the lump-sum prices stated in the Proposal for each of the following:

Receiving Conveyor . . . . One Item

Mill Feed . . . . One Item

Mill Discharge Conveyor . . . . One Item


HAMMERMILL AND CONVEYING EQUIPMENT
LOCATION PLAN AND DETAILS
REFUSE PROCESSING PLANT
HORNER & SHIFRIN, INC.
CONSULTING ENGINEERS
ST. LOUIS, MO.
CITY OF ST. LOUIS
C. L. UHLAND
P. H. SPELBRINK
HM-1
SCALE AS NOTED
DATE DEC 14, 1970
THIS DRAWING REDUCED
APPROX. ½ ORIGINAL SIZE
PLAN
SCALE ⅛"=1'-0"
ELEVATION
SCALE ⅛"=1'-0"
SECTION A
SCALE ⅛"=1'-0"
DETAIL B
SCALE 3"=1'-0"
DETAIL C
SCALE 3"=1'-0"
SKIRTING DETAILS
NOTE: SKIRTING DETAILED ABOVE FURNISHED BY HAMMERMILL MFGR
54" BELT CONVEYOR (BY OTHERS)
RAW REFUSE STORAGE BLDG OUTSIDE FACE OF WALL
60" BELT CONVEYOR (BY OTHERS)
℄ MILL & CONVEYORS
MILL MOTOR
HAMMERMILL FOUNDATION (BY OTHERS)
MILL DISCHARGE CONVEYOR (BY OTHERS)
MILL FEED CONVEYOR (BY OTHERS)
FIN FLOOR AT ELEV 104'-0"
FIN FLOOR AT ELEV 100'-0"
FIN FLOOR AT ELEV 86'-6"
CONVEYOR SUPPORT BENT (BY OTHERS)
RAW REFUSE STORAGE FIN FLOOR AT ELEV 100'-0" TO ELEV 100'-1½"
EDGE OF CONCRETE FLOOR
PROVIDE STEEL CANOPY FULL WIDTH OF FEED HOPPER SUITABLE FOR ATTACHING CANVAS WEATHER ENCLOSURE WHILE HAMMERS ARE BEING RETIPPED
NOTE: PROVIDE OPENINGS IN FEED HOPPER FOR WATER SPRAYS AND DUST COLLECTION DUCT
NOTE: DIMENSIONS SHOWN WITH AN * ARE SUBJECT TO CHANGE AND SHALL BE DETERMINED BY HAMMERMILL MFGR
FEED HOPPER
HAMMERMILL
DISCHARGE HOPPER
ELEV 119'-0"
ELEV 115'-0"
ELEV 98'-3"
ELEV 94'-0"
ELEV 89'-0"
ELEV 86'-6"
12 WF BEAM
CONVEYOR SUPPORT FRAME (BY OTHERS)
℄ RECEIVING CONVEYOR (BY OTHERS)
STEEL & RUBBER CLOSURE BY OTHERS



RECEIVING CONVEYOR
FIN FLOOR ELEV VARIES 100'-0" TO 100'-1½"
SEAL DETAIL C/2
W.P.
PAN
½ LINER PL
ELEV 97'-0"
3'-3" MIN
WF BEAM
WF STRUT
WF COL
ISOLATION SPRINGS AS REQ'D
ELEV 92'-6"
CONVEYOR SUPPORT BENT (BY OTHERS)
ELEV 86'-6"
℄ 60" BELT CONVEYOR (BY OTHERS)
SECTION A/2
SCALE ⅜"=1'-0"
¾"φ CTSK. BOLTS @ 1'-0" O.C.
ELEV VARIES 100'-0" TO 100'-1½"
RUBBER STRIP
STIFF PL 3½·⅜·0'-5" @ 2'-0" O.C.
ASSUMED MAX CONV OSCILLATION
VIB. CONV PAN
ELEV 99'-8"
3'-7" TO FACE OF WALL
10'-0" WIDE CONV PAN
DETAIL C/2
SCALE 1½"=1'-0"
DETAIL OF SEAL
(BY OTHERS)
FIN FLOOR ELEV. VARIES 100'-0" TO 100'-1½"
VARIES 4" TO 5½"
⅜ PL (MIN)
½ LINER PL
SEAL DETAIL C/2
ELEV 92'-6"
℄ RECEVING CONVEYOR
NOTE: SIDES OF CONVEYOR PAN MAY BE FABRICATED AS SHOWN OR WITH UNIFORM SLOPE
SECTION B/2
SCALE ⅜"=1'-0"
ELEV 98'-3"
PAN
W.P.
℄ INTERSECTION OF 54" BELT AND DISCHARGE CONVS.
ISOLATION SPRINGS AS REQ'D.
ELEV 94'-0"
℄ HAMMERMILL
7'-6" MAX
ELEVATION
SKIRTING DETAIL G/2
6'-6" RUBBER SKIRTING THIS LENGTH
PAN
W.P. ELEV 125'-0"
ISOLATION SPRINGS AS REQ'D
WF BEAM
WF COL.
WF COL
NOTE CONVEYOR SUPPORT FRAME (BY OTHERS)
ELEVATION
DETAIL F/2
⅜ PL (MIN) SIDES BOTTOM & END
VARIES 4'-6" MIN
SECTION E/2
MILL DISCHARGE CONVEYOR
SCALE ⅜"=1'-0"
GRIND ⅛ RAD
INSIDE FACE
⅜ PL (MIN)
DETAIL F/2
FULL SCALE
ROLLED LIP FOR SKIRTING SEE DET. G/2 THIS SHEET
⅜ PL (MIN) SIDES AND BOTTOM NO END PLS
5'-10" AVAILABLE SPACE
WF BEAMS BY OTHERS
SECTION D/2
MILL FEED CONVEYOR
SCALE: ⅜"=1'-0"
INSIDE FACE MILL HOPPER
7'-0" INSIDE FACE MILL FEED CONV
6"×⅜ RUBBER SKIRTING
COUNTERSUNK HEAD
½"φ BOLT
2"×¼ PL
2'-0" PAN DEPTH
DETAIL G/2
SKIRTING DETAIL
SCALE: 3"=1'-0"
NOTE DIMENSIONS SHOWN WITH AN * ARE SUBJECT TO CHANGE AND SHALL BE DETERMINED BY HAMMERMILL MFGR.
THIS DRAWING REDUCED APPROX. ½ ORIGINAL SIZE
VIBRATORY CONVEYING EQUIPMENT DETAILS
REFUSE PROCESSING PLANT
HORNER & SHIFRIN, INC. CONSULTING ENGINEERS ST. LOUIS, MO.
DEPARTMENT OF THE PRESIDENT BOARD OF PUBLIC SERVICE
C. L. UNLAND PRESIDENT
DEPARTMENT OF STREETS
F. H. SPELBRINK DIRECTOR
VC-2
2
SCALE AS NOTED
DATE DEC. 16, 1970
CITY OF ST. LOUIS

SPECIFICATION

STORAGE BIN AND UNLOADER
AND
PIT UNLOADER FOR MILLED REFUSE

1. SCOPE:

This Contract includes the furnishing, for installation by others, of a storage bin and unloader, and a pit unloader for milled municipal refuse, complete with all motors, drives and accessories, as specified herein. The Contractor also shall provide the services of a qualified service representative for sufficient time to supervise the installation of the equipment, and to properly instruct City personnel in its operation and maintenance. These services will be required for periods to be scheduled with the Contractor for the installation of the equipment, totaling not less than ten working days, at the expense of the equipment manufacturer.

The manufacturers of the storage bin and the unloaders and their auxiliary equipment shall be regularly engaged in the manufacture of equipment similar in design and capacity to that specified. The storage bin and the unloaders shall be similar to those manufactured by Miller Hofft, Inc., or approved equal.

The manufacturer of the storage bin and the unloaders and their auxiliary equipment shall furnish all anchor bolts and other items requiring embedment in the concrete foundation for installation by others, for all equipment furnished under this Contract.

2. FUNCTION:

The material to be handled by the equipment furnished under this Contract will be milled municipal refuse, processed through a hammermill so that the particles to be handled will be nominally 1-1/2 inches in size and smaller, with essentially no particles greater than 5 inches. The loose bulk density of the milled material is expected to be between 10 and 15 pounds per cubic foot. The density of the material at the bottom of the storage bin, above the unloaders, may be as great as 30 pounds per cubic foot.

The storage bin will be filled from the top by means of a belt conveyor system. The bin unloaders will discharge to a belt conveyor, which, together with the loading conveyors, will be furnished and installed by others.

The pit unloader will be installed in a pit, with a receiving hopper furnished and installed by others. The milled refuse will be discharged into the receiving hopper from self-unloading truck-trailers. The pit unloader will discharge to a belt conveyor, to be furnished and installed by others.

3. STORAGE BIN, UNLOADER AND DRIVES:

The storage bin shall be of the size and configuration as shown on the accompanying drawings. The bin shall have a gross internal volume of about 33,000 cubic feet. Its inside dimensions shall be 19 feet wide by 60 feet long at the screw unloader level and 33 feet high from the floor of the bin. The end walls shall be vertical, and the side walls sloped at an angle of about 5 degrees from vertical toward the center of the bin.

The walls of the bin shall be fabricated as flanged panels bolted together in the field. The panels shall be supported by a structural steel system similar to that shown on the accompanying drawings. The loads imposed by the supporting structural system shall be carried down to reinforced concrete supports, also as shown on the drawings. The concrete supports and the bottom slab of the bin will be constructed by others.

The bin shall be designed to accommodate the loads imposed by the distributing shuttle conveyor, the magnetic separator, the chute for magnetic metal, and the superstructure together with the platform and walkways over the top of the bin, and the roof shelter and walkway on the discharge side of the bin. All of these latter items of equipment, including the superstructure and the roof shelter will be furnished and installed by others.

The Contractor shall design the bin and its supporting structure to safely support the superimposed gravity and wind loads. The superimposed loads are tabulated and shown on the drawings at the defined loading points. The storage bin shall be designed to withstand wind loads of 20 pounds per square foot. Allowable stresses in bin supporting members may be increased 33 per cent for cases in which wind loads are combined with gravity loads.

The bottom of the 60-foot sides of the bin shall be fitted with flexible rubber belting extending down as far as feasible into the slot through which the screw unloaders travel, to confine the material in the bin to the greatest reasonable degree.

The bin unloading mechanism shall be similar or equal to Miller Hofft Type H design. It shall consist of a twin screw traversing unloader, with a 60-foot traverse, over the full length of the bin. The unloading screws shall have an 18-inch flight diameter and shall be fabricated of heavy steel plate. The flights shall be securely welded to a heavy steel tube 8 inches in diameter, with a minimum wall thickness of 1-1/2 inches. The flights shall be designed with variable pitch and outside diameter of the flighting carefully proportioned over their length to discharge 12,000 cubic feet of milled refuse per hour. The flights shall be hard-surfaced on their leading edges and shall have heavy wear-resistant digger bars welded to their outside edges at 90-degree intervals over their entire length to provide a digging action on the refuse in the bin. High screw efficiency and positive material removal shall be provided over the entire length of the screws.

The drive carriage shall consist of an all steel welded frame, complete with drive shafts, roller bearings, four 8-inch diameter roller bearing support wheels and sweepers. The drive motor and reducer shall be mounted on heavy steel base plates on the carriage and an oil-tight guard furnished for the chain drive.

The thrust carriage shall be of all steel welded construction, complete with thrust shafts, bearings, hold-down wheels, support wheels and high capacity yoke. The hold-down beam, support beam and brackets and thrust rail shall be furnished ready for assembly to the bin structure as shown on the accompanying drawings.

Replaceable wear strips shall be furnished as raceways for the drive carriage and thrust carriage along the entire length of traverse. Anchor pads shall be provided for floor mounting on concrete surfaces.

The traversing mechanism shall consist of a separately powered chain drive attached to the drive carriage and thrust carriage. The traversing drive shall consist of a 1/2 horsepower, squirrel cage induction, TEFC, 480 volt, 3 phase, 60 cycle motor, driving a differential speed reducer, with a ratio of about 950 to 1, through a variable speed pulley with a ratio of about 2.5 to 1. The output of the speed reducer shall be connected to the traverse chain drive through a roller chain drive and a suitable safety clutch.

The drive for the screws shall consist of a constant speed, squirrel cage induction motor and reducer combination of no less than 150 horsepower and of adequate output speed to discharge the quantity of milled refuse specified. The motor shall be TEFC for 480 volt, 3 phase, 60 cycle service, NEMA Design "B".

4. PIT UNLOADER:

The pit unloader shall be similar or equal to Miller Hofft Type H design. It shall be designed to operate in a pit with inside dimensions of 12 feet width and 21 feet length, and shall be capable of discharging 8,000 cubic feet per hour of milled municipal refuse with a loose bulk density of 10 to 15 pounds per cubic foot.

The pit unloader shall consist of twin screws, with a 21-foot traverse, over the full length of the pit. The twin screws shall each have a 16-inch flight diameter, and shall be fabricated of heavy steel plate. The flights shall be securely welded to a heavy steel tube 8 inches in outside diameter with a wall thickness of 1-1/2 inches. The flights shall be designed with variable pitch and outside diameter of the flighting carefully proportioned over their length to discharge 8,000 cubic feet of milled refuse per hour. The leading edges of all flighting shall be hard-surfaced and the flights shall have heavy wear-resisting digger bars welded to their outside edges at 90-degree intervals over their entire length to provide a digging action on the milled refuse in the pit. High screw efficiency and positive material removal shall be provided over the entire length of the screws.

The drive carriage shall consist of an all-steel welded frame, complete with drive shafts, roller bearings, four 8-inch diameter roller bearing support wheels and sweepers. The drive motor and reducer shall be mounted on heavy base plates on the carriage and an oil-tight guard furnished for the chain drive.

The thrust carriage shall be of all-steel welded construction, complete with thrust shafts, bearings, hold-down wheels, support wheels, and high capacity yoke. The hold-down beam, support beam and thrust rail shall be furnished, together with the supporting framework shown on the drawings, ready for assembly to the concrete structure as shown on the accompanying drawings.

Replaceable wear strips shall be furnished as raceways for the drive carriage and thrust carriage along the entire length of traverse. Anchor pads shall be provided for floor mounting on concrete surfaces.

The traversing mechanism shall consist of a separately powered chain drive attached to the drive carriage and thrust carriage. The traversing drive shall consist of a 1/2 horsepower, squirrel cage induction, 480 volt, 3 phase, 60 cycle, TEFC motor driving a differential speed reducer, with a ratio of about 950 to 1, through a variable speed pulley with a ratio of about 2.5 to 1. The output of the speed reducer shall be connected to the traverse chain drive through a roller chain drive and a suitable safety clutch.

The drive for the screws shall consist of a constant-speed, squirrel-cage inducation motor and reducer combination of no less than 75 horsepower and of adequate output speed to discharge the quantity of milled material specified. The motor shall be TEFC for 480 volt, 3 phase, 60 cycle service, NEMA Design "B".

5. DIMENSIONS:

Minor dimensional changes of the supporting members of the equipment may be necessary. The lump-sum bid prices shall allow for such minor changes.

6. SHOP PAINTING:

All exposed surfaces of ferrous metal parts of the bin, structure, and unloaders, shall have all rust, mill scale, dust, dirt, grease, oil, and all other foreign substances removed by means of wire brushes, chisels, hammers, or by washing with water or benzine, as is necessary. Immediately after cleaning, the surfaces shall be given one shop coat of Koppers Rustinhibitive Primer No. 612 (phenolic), or approved equal, applied to achieve a minimum dry thickness of 1.5 mils.

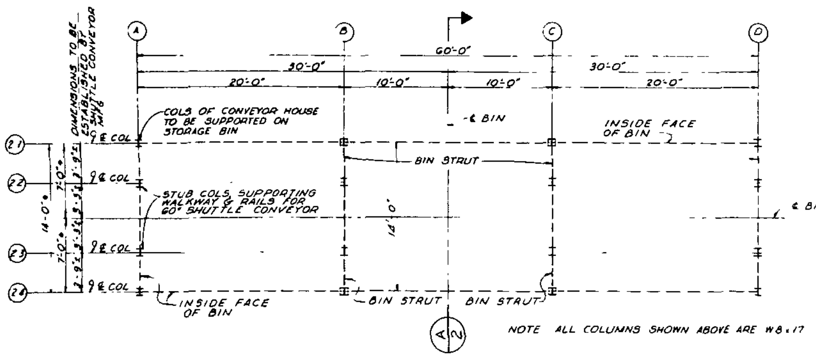
7. <u>PERFORMANCE</u>:

Should the equipment specified herein not provide the unloading rate of the respective quantities called for, within the limits of the bulk densities and conditions herein described, the manufacturer will be required to make such modifications as necessary to provide the required unloading rates. Such modifications, if required, shall be made with the cooperation of the Contractor installing the equipment, and shall be made at no additional cost to the City, and shall be initiated within five days of the date of notification by the President to the manufacturer that the equipment is not performing as specified. Correction of any such inadequacies shall proceed in the most expeditious manner. The President shall be the sole judge of such inadequacies.

8. <u>PAYMENT</u>:

Payment for the equipment included in this Specification, together with the drives and parts specified herein shall be on the basis of the individual lump-sum prices stated in the Proposal, and on the terms stated in the Instructions for Bidders, as follows:

Item No. 1 - Storage Bin, Unloader and Drives	One Item
Item No. 2 - Pit Unloader and Drives	One Item



PLAN AT TOP OF BIN

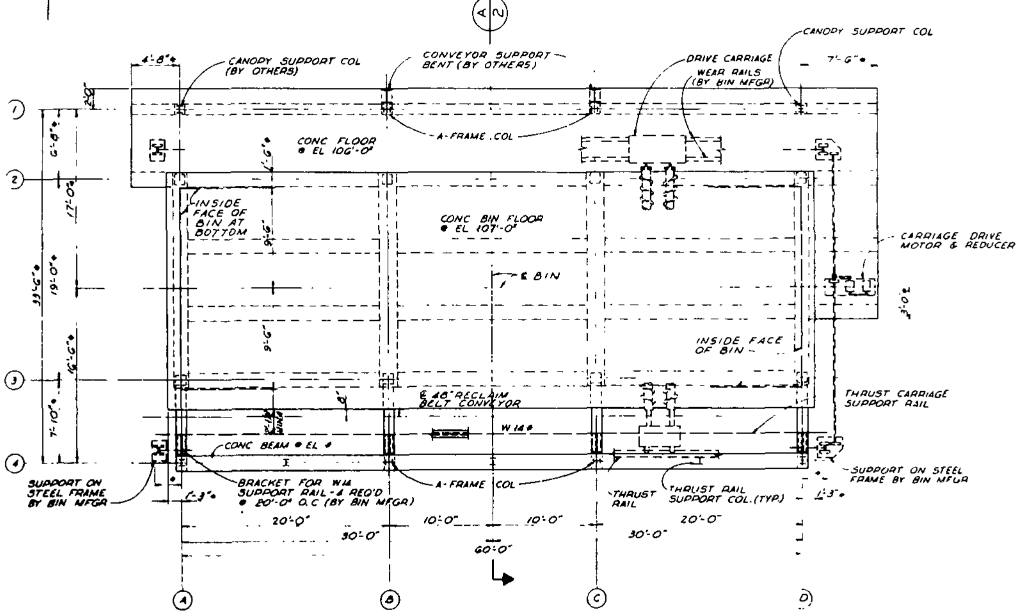
(CONVEYOR NOT SHOWN)

SCALE 3/16" = 1'-0"

TABLE OF SUPERIMPOSED LOADS ON STORAGE BIN FROM CONVEYOR HOUSE, MAGNETIC SEPARATOR, 60" SHUTTLE BELT CONVEYOR, MAGNETIC METAL CHUTE & WALKWAY. ALL SUPERIMPOSED LOADS ARE APPLIED AT COL PTS. SHOWN IN "PLAN AT TOP OF BIN" AND ARE LISTED BELOW

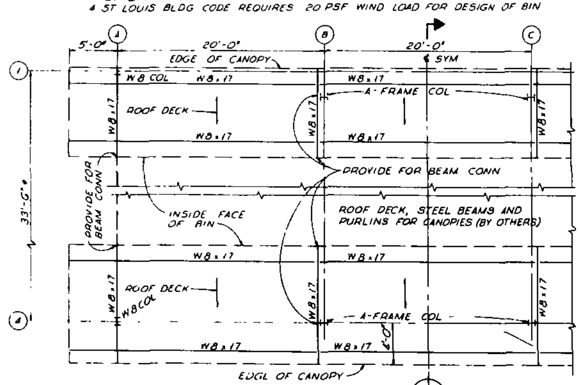
LOADING CASE	COLUMN MARK											
	A-21 & D-21		B-21 & C-21		A-24 & D-24		B-24 & C-24		A-22 & D-22	A-23 & D-23	B-22 & C-22	B-23 & C-23
	VERT	NS SHEAR	VERT	NS SHEAR	VERT	NS SHEAR	VERT	NS SHEAR	VERT	VERT	VERT	VERT
1 DL (INCLUDING EQUIP DL)	2K	0	8K	0	2K	0	8K	0	2K	2K	5K	4K
2 TL = DL + LL (INCLUDING EQUIP LOADS + IMPACT)	6K	0	17K	0	6K	0	18K	0	4K	4K	9K	7K
3 TL + WIND FROM NORTH	5K	1K	14K	4K	7K	1K	21K	2K	4K	4K	9K	7K
4 TL + WIND FROM SOUTH	7K	1K	20K	2K	5K	1K	15K	4K	4K	4K	9K	7K
	E W SHEAR		E W SHEAR		E W SHEAR		E W SHEAR		EW SHEAR	EW SHEAR	EW SHEAR	EW SHEAR
5 WIND ONLY FROM EAST OR WEST TO BE INCLUDED WITH CASE 2	1K		1K		1K		1K		—	—	—	—
6 EQUIP THRUST FROM TRACTION OF SHUTTLE CONVEYOR (SAY TOTAL THRUST = 4K)	—		—		—		—		1K	1K	1K	1K

NOTES
1. 54" BELT CONVEYOR BRIDGE CANTILEVERED OVER STORAGE BIN AND DOES NOT TRANSMIT ANY LOADS TO STORAGE BIN
2. MAGNETIC SEPARATOR, 60" SHUTTLE BELT CONVEYOR, MAGNETIC METAL CHUTE, WALKWAY AND CONVEYOR HOUSE ARE SUPPORTED BY STORAGE BIN. BIN SUPPLIER SHALL DESIGN BIN TO SAFELY SUPPORT THE SUPERIMPOSED DEAD LOADS, LIVE LOADS, EQUIPMENT LOADS AND WIND LOADS. SEE SHT SB-1 FOR LOADS
3. DIMENSIONS MARKED * TO BE ESTABLISHED OR VERIFIED BY BIN MFGR
4. ST LOUIS BLDG CODE REQUIRES 20 PSF WIND LOAD FOR DESIGN OF BIN



PLAN OF BIN FLOOR

SCALE: 3/16" = 1'-0"



NOTE BIN AND A-FRAME COLS SHALL BE DESIGNED TO SAFELY SUPPORT 30 PSF ROOF L L ON CANOPIES

HALF PLAN OF BIN AT CANOPIES

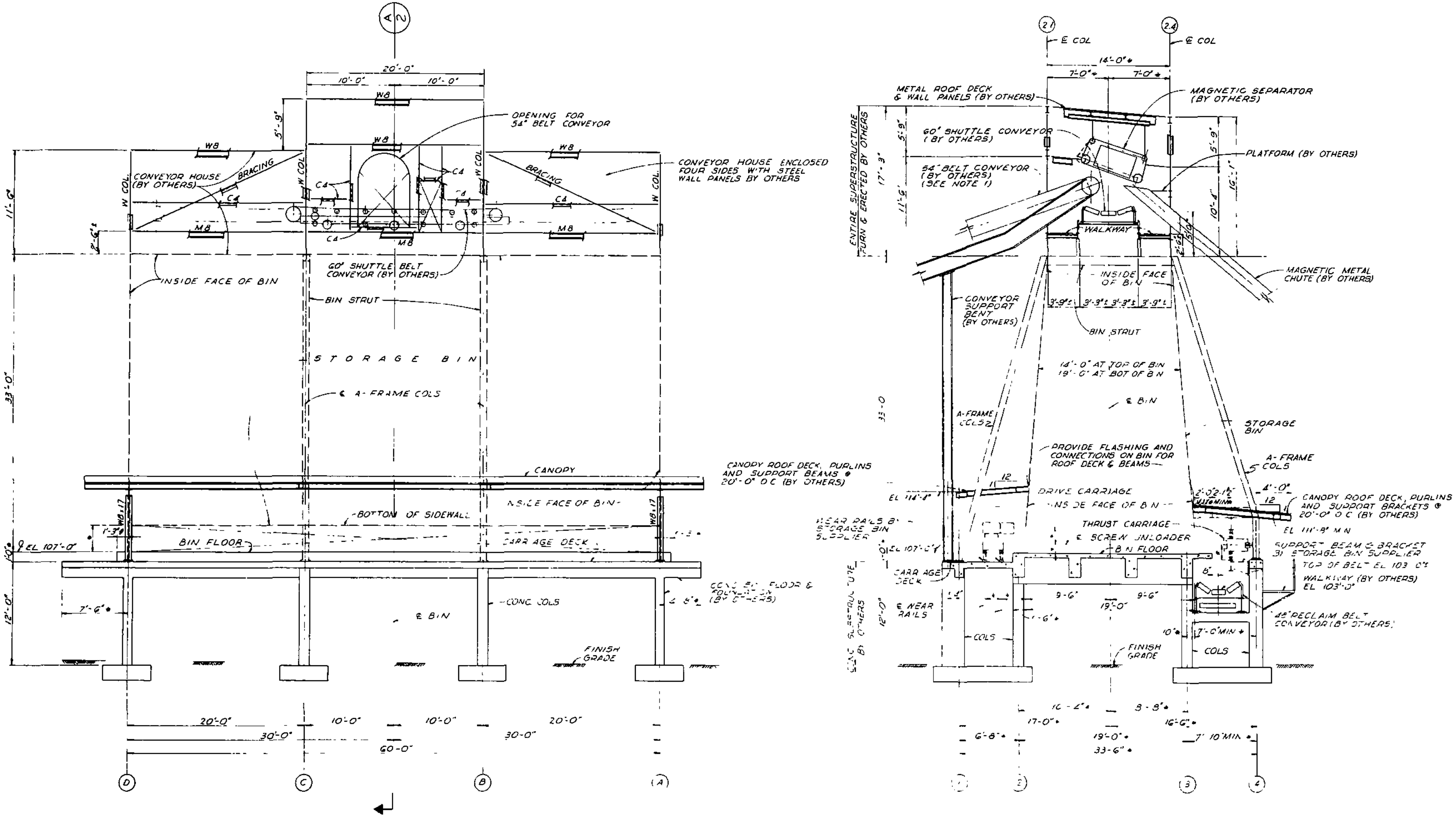
SCALE 3/16" = 1'-0"

PLAN OF STORAGE BIN FOR PROCESSED REFUSE

REFUSE PROCESSING PLANT

DESIGNED BY V.C.L.JR / DRAWN BY D.E.C / CHECKED BY H.S.H.	HORNER & SHIFRIN, INC. CONSULTING ENGINEERS ST. LOUIS, MO.		DRAWINGS: SHEET NUMBER SB-1 / TOTAL SHEETS 3
ENGINEERING AND ARCHITECTURE DIVISION / FRANCIS L. BEAN, CHIEF ENGINEER	DEPARTMENT OF THE PRESIDENT BOARD OF PUBLIC SERVICE / C. L. UNLAND, PRESIDENT	DEPARTMENT OF STREETS / P. H. SPELBRINK, DIRECTOR	SCALE AS NOTED / DATE DEC. 31, 1970

CITY OF ST. LOUIS



NORTH ELEVATION

SECTION A/2

ELEVATION OF STORAGE BIN FOR PROCESSED REFUSE

REFUSE PROCESSING PLANT

DESIGNED BY V.C.L.JR. DRAWN BY D.C.E. CHECKED BY H.B.H.

HORNER & SHIFRIN, INC. CONSULTING ENGINEERS ST. LOUIS, MO.

ENGINEERING AND ARCHITECTURE DIVISION

FRANCIS L. WEAN, CHIEF ENGINEER

DEPARTMENT OF THE PRESIDENT BOARD OF PUBLIC SERVICE — C. L. UNLAND, PRESIDENT

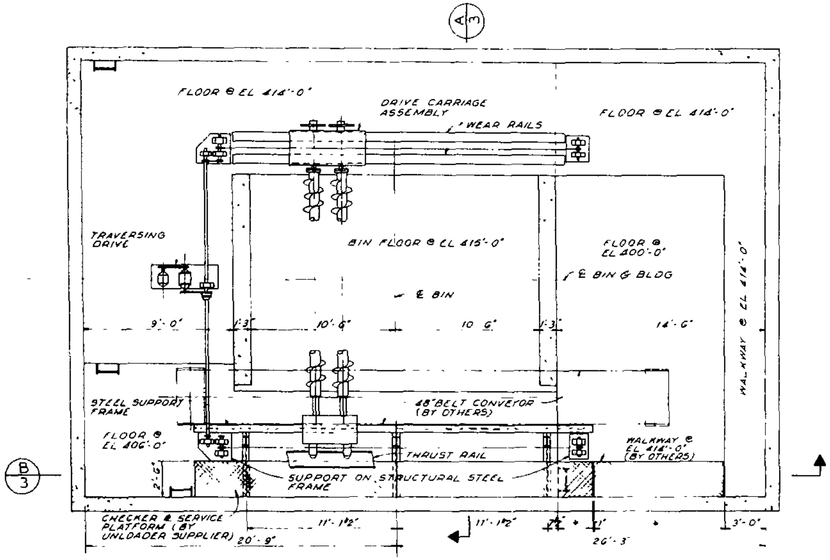
DEPARTMENT OF STREETS — P. H. SPELBRINK, DIRECTOR

DRAWINGS	
SHEET NUMBER	TOTAL SHEETS
SB-2	3

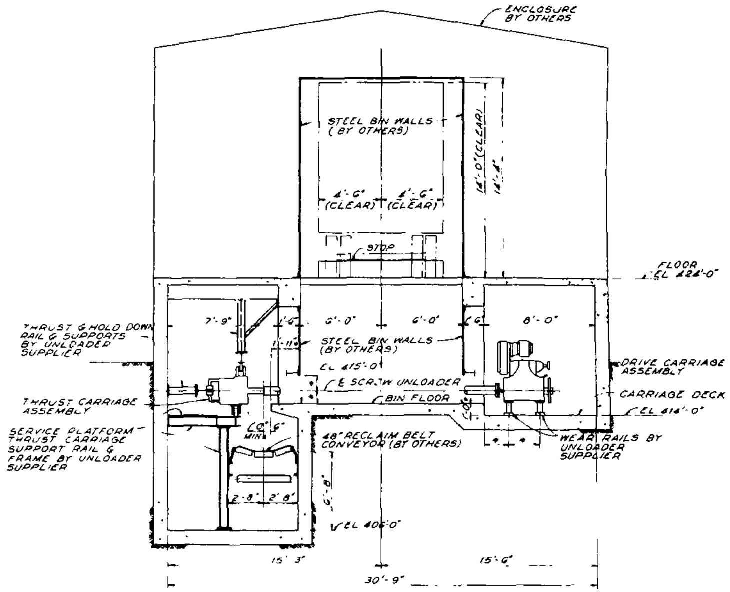
SCALE AS SHOWN

DATE DEC 31, 1970

CITY OF ST. LOUIS

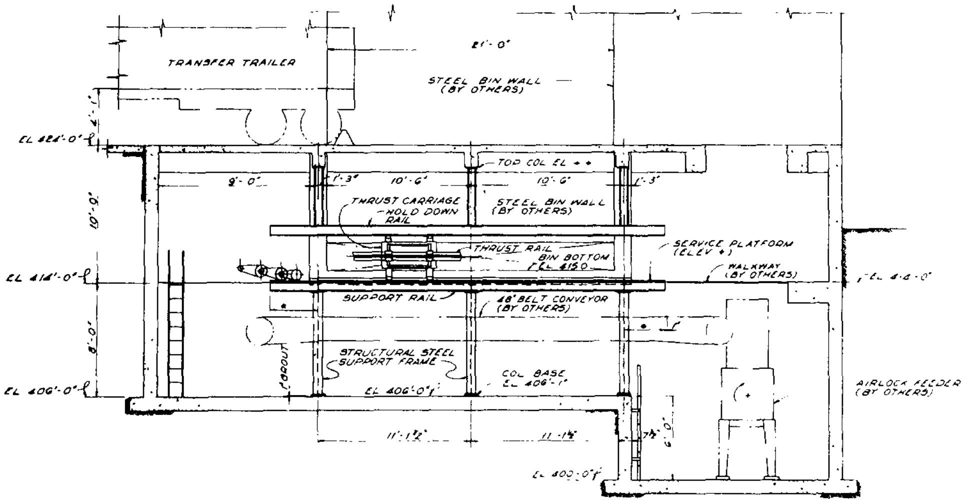


PLAN AT ELEV 415'-0"



SECTION A/3

* SEE NOTE SHEET 1
** TO BE DETERMINED BY ENGINEER



SECTION B/3

PIT UNLOADER PLAN AND DETAILS

SUPPLIMENTARY FUEL RECEIVING STATION

DESIGNED BY H.B.H.
DRAWN BY D.E.E.
CHECKED BY V.C.L. JR

HORNER & SHIFRIN, INC.
CONSULTING ENGINEERS
ST. LOUIS, MO.

ENGINEERING AND ARCHITECTURE DIVISION
FRANCIS L. BEAN
CHIEF ENGINEER

DEPARTMENT OF THE PRESIDENT BOARD OF PUBLIC SERVICE
C. L. UNLAND
PRESIDENT

DEPARTMENT OF STREETS
P. H. SPELBRINK
DIRECTOR

DRAWINGS	
SHEET NUMBER	TOTAL SHEETS
SB-3	3

SCALE 1/4" = 1'-0"
DATE DEC. 31, 1970

VANCE C. LISCHER JR. NUMBER E 9590

CITY OF ST. LOUIS

Appendix IV

Example Specification*

1.0 Equipment Classification

1.1 Municipal Solid Waste Shredder

2.0 Number Required

2.1

3.0 Scope

3.1

4.0 Performance Requirements

4.1 Capacity - 62½ TPH daily average basis with surges to 75 TPH.

4.2 Feed Material - Municipal solid waste with a bulk density of approximately 280 pounds per cubic yards as delivered by packer trucks containing occasional bulky items including refrigerators, household furniture and appliances such as dryers, stoves, mattresses and washers, over the road tires and demolition debris. For guidance the feed material may contain the following types and quantities per 750 tons of the normal packer waste per day:

3	refrigerators	7' x 4' x 3'
12	mattresses	7' x 6'
8	rugs	15' x 20'
3	dryers	
3	stoves	
3	washers	

---

* Sample of specifications shown in Appendix III were used in St. Louis, Missouri, in conjunction with EPA demonstration project and should not be considered as universally applicable. These are for illustration only.

30 passenger car tires, 1/2 with wheels
10 tons of wood demolition items, not more than 7 feet x 16 inches x 16 inches and masonry not more than 500 pounds per piece.

4.3 Product Material - 99% of the shredded material must be less than 5" in any direction.

4.4 As a guide to the design of the cage bars or grates, the following table gives a product particle size distribution range which is considered to be acceptable:

Mesh	% Passing Range	
4"	98	92
3"	92	84
2"	65	55
1½"	55	45
1"	42	34
3/4"	35	28
1/2"	28	22
1/4"	18	14
3/16"	15	11
2M	5	3

It is desirable that cans be torn and opened out rather than squashed.

4.5 Occupational Safety and Health Act - Manufacturer will recommend measures necessary to operate unit in compliance with applicable requirements of the Occupational Safety and Health Act.

4.6 Machine must be able to comply with all applicable local and state regulations.

4.7 Maintenance - Machine must be equipped with hydraulic opening devices to provide ready accessibility to interior parts for replacement of hammers, wear plates and grates and also a crane with a capacity to lift wear plates, grates and hammers, etc. All special tools required to facilitate maintenance such as a hydraulic pin puller shall be supplied with the shredder. The shredder must be able to be opened for hammer maintenance by one man in 10 minutes. Possible quick disconnect hold down devices should be considered.

4.8 Shredders must be operated for a one-week period producing an average of defined capacity when operated 16 hours per day.

5.0 Electrical

5.1 Power Characteristics - 3 ph, 60 Hz, 4160 and 480 V
single phase, 60 Hz, 120 V

5.2 Motor Specifications - Motors shall be T.E. or T.E.F.C. except for the main shredder drive motor which will be open drip proof.

5.3. General For Shredder Motor - The drive motor shall be adequate for starting and driving the hammermill, which will have a high inertia and wide and sudden load variation. The load may occasionally be great enough to stall the motor. The motor and all motors parts shall be adequate for the hammermill duty. The hammermill drive motor and its starter shall be furnished by one manufacturer.

The motor in all respects shall incorporate the highest quality of modern engineering design and workmanship. All material shall be new and of the best quality suited for the requirements of the work. It is not the intent to specify details of design and construction; motors shall be constructed and equipped with accessories in accordance with the seller's standard practices where they do not conflict with these specifications. Design and construction of the motors shall be coordinated with the driven equipment requirements. The equipment shall be the product of Allis-Chalmers, General Electric, Westinghouse, or approved equal.

5.4. Motor Type and Rating - The motor shall be of the following type and rating:

Type:	Squirrel-cage induction, horizontal or vertical (Round rotor optional)
Horsepower:	1,000
Speed:	720 RPM

Voltage:	4,160 volts, 3 phase, 60 cycle
Service Factor:	1.15
Slip:	3-5%
Breakdown Torque:	250%, with 100% rated motor voltage
Temperature Rise:	90° C by resistance above 40° C ambient, at 1.15 service factor
Insulation:	Class F
Starting:	Reduced voltage at 65% of rated line voltage ± 10%
Inertia:	It is the motor manufacturers responsibility to obtain this information from the shredder manufacturer.
Load:	Direct connected; inertia of hammermill motor; load varies from 5% to 100% in a few seconds of time, and may stall the motor occasionally.
Enclosure:	Open drip-proof.

5.5 Electrical Characteristics - Motors shall be direct connected, induction type. Motors shall be designed and braced to withstand the heating effect and forces of full voltage starting and shall be on the type generally described as normal starting current unless otherwise specified.

The motors shall be designed so that locked rotor current shall not exceed 65% of rated full load current.

Motors shall have sufficient thermal capacity in both the rotor and stator to properly accelerate the connected loads with no reduction in expected motor life. The torque characteristics shall be such as to permit successful operation and acceleration from rest at 50% rated voltage.

5.6 Stator Frame and Core - The stator frame shall be fabricated from heavy steel plate and structural sections to ragidly support the bearings, to provide a means of supporting and securing the motor to the sole plate, to provide air inlet and discharge openings, and to support the stator core and winding. The bottom of the frame is to have longitudinal feet with the bottom surface finish machined and of ample cross section and with bolt holes for securing the motor to the base. The feet shall each have at diagonally opposite corners of the motor a partially reamed taper dowel hole for permanently locating the motor to the base after final alignment. Final reaming will be by the Installing Contractor. The stator core is to be either permanently and integrally secured in the frame or separately supported in the frame.

The motor frame shall have suitable means for attaching a ground conductor in accordance with the grounding requirements of National Electrical Code, unless otherwise specified. The dimensions of the grounding pad, cap screw, or other grounding means shall be adequate to meet the requirements of Article 250 of the 1968 National Electrical Code or the latest revision thereof. The ground location shall be on the same side of the motor as the main lead terminal box.

The core is to be made up from laminations punched from precoated nonaging electrical sheet steel and is to have air vent ducts spaced at intervals through the length of the core. The core is to be uniformly and tightly compressed between end heads and is to be securely supported in the frame.

5.7 Shaft - The rotor shaft shall be horizontal, solid, of heat-treated alloy steel.

5.8 Rotor - Ring-type motor laminations are preferred. If segmental rotor punchings are used every lamination is to be welded to the rotor spider. These laminations are to be punched from the same high-quality, pre-coated steel used for stator laminations. Heavy steel end heads which compress and retain the core rapidly to insure uniform tight core throughout the motor life shall be used.

The rotor shall be pressed and keyed to the shaft. Rotor windings shall be of high strength high temperature copper bars with copper end rings. The connection between the rotor bars and end rings is particularly critical in shredder mtors because of the extreme mechanical and thermal stresses encountered in operation. For this reason, notched end connectors are to be used to increase the contact area between the rotor bars and the end rings.

5.9 Bearings and Bearing Brackets - The continuous pounding encountered in shredder operation places a severe demand on the bearings. For this reason, double row spherical roller bearings shall be used exclusively. The bearings shall be grease lubricated wherever possible. Bearings shall be retained in a stiff one piece bearing capsule. This construction, compared to conventional split designs, resists fretting and vibration, and minimizes bearing deflection to ensure long bearing life.

To further insure rigid support of the bearings, bearing capsules shall be located and retained by machines fits in reinforced one piece bearing brackets. The bearing brackets are to be similarly located in the motor frame by machined retaining fits.

All bolts used in the motor construction which are not normally removed during the course of normal maintenance operation shall be tack welded to prevent them from working loose. All other bolts shall be locked in place with bent metal tabs to assure continued tightness from the severe shredding duty.

The same degree of care to insure a low maintenance rugged design applies to a vertical motor if required.

5.10 Stator Coil Construction and Insulation - The stator winding shall be insulated with Class F or better throughout, with mica as the fundamental component of ground insulation. The insulation system shall be a combination of materials and processes which provide high resistance to moisture, and other contaminants as experienced by a motor driving a shredder.

All windings are to be assembled using form wound coils of the same size and shape to facilitate interchangeability. Coils are to be wound with rectangular copper wire covered with strand insulation consisting of asbestos, glass, dacron, Nomex, or other high temperature flexible insulating film, or a combination of these. In addition, turn-to-turn insulation shall be adequate to ensure that all coils will be capable of withstanding switching or other surges well in excess of normal turn-to-turn voltage.

Ground insulation consisting of mica and a suitable bonding resin applied in sheets or as tapes shall be applied to the end turn, as well as the slot portion of the coil, to ensure all parts of all coils are fully insulated to ground for the voltage class of the motor.

After insertion of the coils in the stator slots, all end connections shall be either brazed or welded and insulated with essentially the same materials as used on the coil itself to assure that end connections will be of the same quality and dielectric strength as the coil. After the coils are properly wedged, end turns braced and all moisture removed, the entire stator assembly shall be vacuum pressure impregnated with thermal setting epoxy resin free from voids. The complete stator frame shall then be heat cured.

The end bracing system shall completely support each coil, as well as the entire assembly, to essentially eliminate all vibration that occurs during full voltage starting and expected operating conditions. Whenever possible, it is desired that all binding, and blocking materials be of the thermosetting type that, when combined with the impregnating resin, will successfully withstand repeat stresses such as occur during normal shredder operation.

5.11 Conduit Box - A conduit box of ample size to permit stress cone termination shall be provided. The conduit box shall be capable of being rotated in 90^{o} increments.

5.12 Special Corrosion Resistant Hardware - The motor shall be equipped with corrosion resistant fittings and hardware throughout.

5.13 Guard Screens - The motor shall be equipped with suitable corrosion resistant guard screens over intake and exhaust openings.

5.14 Stator Temperature Detectors - Resistance temperature detectors, two 10 ohm resistance type temperature detectors (RTD) per phase, shall be installed in the stator winding with leads brought out to a separate terminal box. Control equipment will be furnished by others.

5.15 Bearing Temperature Detectors - Each bearing shall be equipped with a dial-type indicating thermometer. The thermometer shall be furnished with adjustable contacts, so that motor can be tripped slightly above maximum normal operating temperature.

5.16 Space Heaters - Each motor shall be provided with space heaters of sufficient capacity to keep the motor windings and internal parts dry when the motor is not running. Heater voltage shall be 240 volts single phase a.c. Heater leads shall terminate in a separate terminal box.

5.17 Sole Plates - The motor shall be equipped with suitable sole plates for imbedding in the foundation providing a machined surface on which the motor may be mounted. Hold down bolts between the motor and the sole plates shall be furnished by the motor manufacturer. Foundation bolts will be supplied by others. Shims shall be furnished by the motor manufacturer.

5.18 Nameplates - Nameplates shall be of stainless steel and shall show the following information as per NEMA Standards:

Manufacturer's Type and Frame Designation
Horsepower Output
Temperature Rise
RPM at Full Load

Frequency
Number of Phases
Voltage
Full Load Amperes

5.19 Tests - Each motor shall be given a standard commercial test in accordance with NEMA recommended standards to ascertain that the motor is free from electrical and mechanical defects and in accordance with design specifications.

5.20 Codes - Materials and workmanship for all motors and starters (where included) shall meet the requirements of the following:

National Electrical Manufacturing Assoc.
National Electrical Code
A.I.E.E.
A.S.A.

6.1 Reference Drawings and Instructions - Manufacturer will supply three copies with quotation and six copies after receipt of the order of the following:

Spare Parts Lists
Installation Instruction Necessary to Design Supports and Foundations and Recommendations for Feeding and Discharging
Operating and Maintenance Instructions
Estimated Material and Labor Hours Required to Maintain Unit is to be supplied.

Detail drawings of shredder showing the following data:

WR^2
RPM
Feed Opening
No. Hammers
Hammer Weight
Hammer Material
Hammer Pin Dia.
Grate Weight
Grate Material
Lever Material
Lever Weight
Shaft Dia @ Hammer
Shaft Dia. @ Bearing
Rotor Dia.

6.3 Construction and Start-up Assistance - Manufacturer will furnish an engineer as required to assist in the assembly of the machine on its foundation during the construction phase and again to assist in operator instruction and machine start-up.

6.4 Spare Parts - Manufacturer will supply a list with prices of recommended spare parts to be carried to insure against prolonged outages. Their detail drawings and material composition will be included.

7.0 Material Supplied by Customer

7.1 Foundations and Anchor Bolts

8.0 Warranty - Minimum Requirement

8.1 Manufacturer warrants that all materials, machinery and equipment are free from all defects in material and workmanship for a period of twelve (12) months after initial start-up of the unit and agrees to promptly replace and install without cost to the owner any defective parts which may develop during the period of warranty.

REFERENCES

1. Ham, R. K., W. K. Porter, and J. J. Reinhardt. Refuse milling for landfill disposal. In P. L. Stump, comp. Solid Waste Demonstration Projects; Proceedings of a Symposium, Cincinnati, May 4-6, 1971. Environmental Protection Publication SW-4p. Washington, U.S. Government Printing Office, 1972. p.37-72.

2. Reinhardt, J. J., and G. Rohlich. Solid waste reduction/salvage plant--an interim report; City of Madison pilot plant demonstration project, June 14 to December 31, 1967. Cincinnati, U.S. Department of Health, Education, and Welfare, 1968. 25 p.

3. U.S. Environmental Protection Agency. Thermal processing and land disposal of solid waste; guidelines. Federal Register, 39(158): 29327-29338, Aug. 14, 1974.

4. Brunner, D. R., and D. J. Keller. Sanitary landfill design and operation. Environmental Protection Publication SW-65ts. Washington, U.S. Government Printing Office, 1972. 59 p.

5. Stirrup, F. L. Public cleansing; refuse disposal. Oxford, Pergamon Press, 1965. 144 p.

6. Gr. Brit. Department of the Environment. Refuse disposal; report of the Working Party on Refuse Disposal. London, Her Majesty's Stationery Office, 1971. 199 p.

7. Gr. Brit. Department of the Environment. Report of the Working Party on Refuse Disposal. Circular 26/71. Apr. 1971. 7 p. (Unpublished report.)

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