Methods and machinery for pulverising solid wastes

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10. Methods and machinery for pulverising solid wastes.   M J Simpkins.
    October 1976.   29 pp.

PURPOSE FOR THE REPORT ON METHODS AND
MACHINERY FOR PULVERIZING SOLID WASTES

This report is published on behalf of the South African Committee for Solid
Wastes which in turn advises the National Committee for Environmental
Sciences on problems concerned with Solid Wastes in South Africa.   It is
particularly concerned with research into the generation, management,
disposal and recycling of these wastes.

In this report a review is presented of the available processes for the
comminution of refuse.   It deals with the choice and description of
existing systems including a comparison of types with a view to assisting
prospective users in the selection of equipment.   There are also brief
sections on shredders and guillotines.

Comments and advice on the report will be welcome.   The Committee for
Solid Wastes would also appreciate it if readers could pass on their
opinions regarding the requirement of a more comprehensive technical guide
on machinery for pulverizing solid wastes.

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INTRODUCTION TO COMMINUTION

The comminution of solid wastes is a technique that is rapidly becoming fashionable, although the ramifications of this operation are not yet fully understood. As the purchase and commissioning of a pulverizing plant represents a great deal of money, the decision to establish such a plant will not be made lightly.

Comminution is essential when considering the process of incineration and pyrolysis as a means of refuse disposal, while for composting and landfill the process is considerably improved by the inclusion of a comminution process.

Once refuse has been pulverized it becomes very much easier to handle, due to its uniformly small particle size and greater density. Typically a load of domestic refuse may be reduced in volume between 50 to 70 percent depending on the size of final product, the smaller the pulverized particle the greater the volume reduction or the greater the density, which can be increased to 400 to 500 kg/m^3.

There are many types of processes available for the comminution of refuse. Each process exercises either the application of tensile stresses, wearing or grinding forces or a combination of each, in order to reduce the inlet material to uniformly small particles.

AVAILABLE PROCESSES

Processes available for the comminution of refuse are :

The Jaw Crusher

This device may be seen as a huge vice, the jaws reciprocating towards and away from each other thereby crushing the material introduced, by the application of very large compressive stresses. As a result of the compressive stresses, tensile stresses are created and result in the material breaking up. Abrasive mechanics are not employed in this technique and the final product has very little uniformity of size.

The Ball Mill

The ball mill process and tumbling rod process utilize wearing and grinding forces to reduce the particle size of the feed material. Due to the rotating of the drum, attritional forces are established in the rotating mass of refuse which breaks up the contents, and the final small particles are squeezed through openings in the periphery of the drum. This process yields particles of a more uniform size but the system has limitations.

The maximum initial size of refuse is limited and plastics are not easily broken up, resulting in a collection of plastic which rolls up into balls, thereby reducing the efficiency of the operation.

The Disc Attritional Mill

This process is very similar to the ancient method of grinding wheat with a mill stone. Inlet material passes between two counter-rotating discs

which apply the necessary attrition forces to break down the particles. The disc surfaces may vary in roughness from smooth (approximately the texture of coarse sand paper) to coarse, which would be as rough as a wood rasp. This system is limited by the rapid wearing of the discs and, more important, by the limiting of inlet material size.

Hammermills

A hammermill is basically a large rotor, with fixed or free swinging hammers attached to its periphery, contained in a reinforced case or housing. The rotation of the rotor creates the application of large tensile forces when the hammers hurl the inlet material against the breaker plates, followed by equally strong attritional forces as the material is worn down between the hammers and the outlet gratings.

Each of these processes, apart from the hammermill process, has a material specificity which is necessary for optimum comminution performance. Jaw crushers handle bulky brittle material, tumbling mills handle very hard brittle material and the disc mills handle fibrous material. Hammermills can, however, macerate a wide range of materials, and accept bulky objects, giving this process of comminution versatility and the durability demanded for municipal solid waste. Because the hammermill and its variants have become the most popular pulverizing tool, it is considered that a clearer understanding of the mechanics involved is necessary.

In this report, refuse comminution will be chiefly referred to as "pulverising". In the USA the term "shredding" is popular. Shredding, in the South African definition is dealt with later in the report.
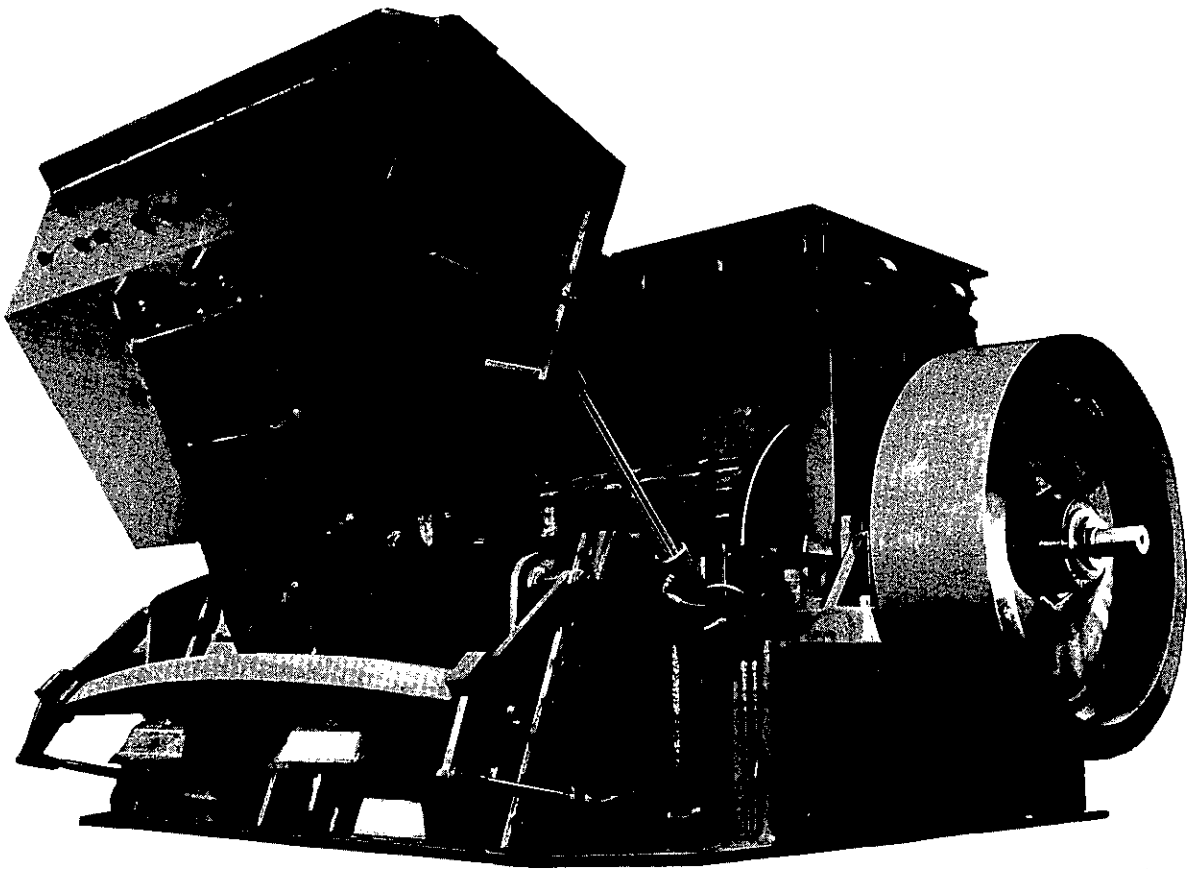
HAMMERMILLS

Choice of Hammermill

Although the average capacity of the pulverizing plant is established by the mass or volume of refuse generated, coupled with any allowance for the increased volume to be generated in the future, the ability of the plant to handle surge loads adequately must be carefully considered. Unless a sufficient refuse storage facility is planned as part of the plant, the mill must be capable of dealing with the inlet stream of waste. Failing this an embarrassing overflow of refuse may develop. In instances where pulverizing plants have failed to meet the design capacity, the most frequent faults have been inadequate horse power or too small a hammermill.

It is difficult to determine the true capacity of an existing plant because its operational efficiency depends on the material handling within an entire system, of which it is only a part. Therefore the refuse delivery rate, reception hopper loading, conveyor operation and automatic feed control systems may make significant differences in the capacity of the same plant.

Hammermills fall into two distinct types; namely those with a horizontal rotor (Figure 1), and those with a vertical rotor (Figure 3). The hammermills with a horizontal rotor are more frequently encountered. In

Jefrey

FIGURE 1.

Typical large capacity horizontal rotor hammermill, with
casing and inspection parts open.
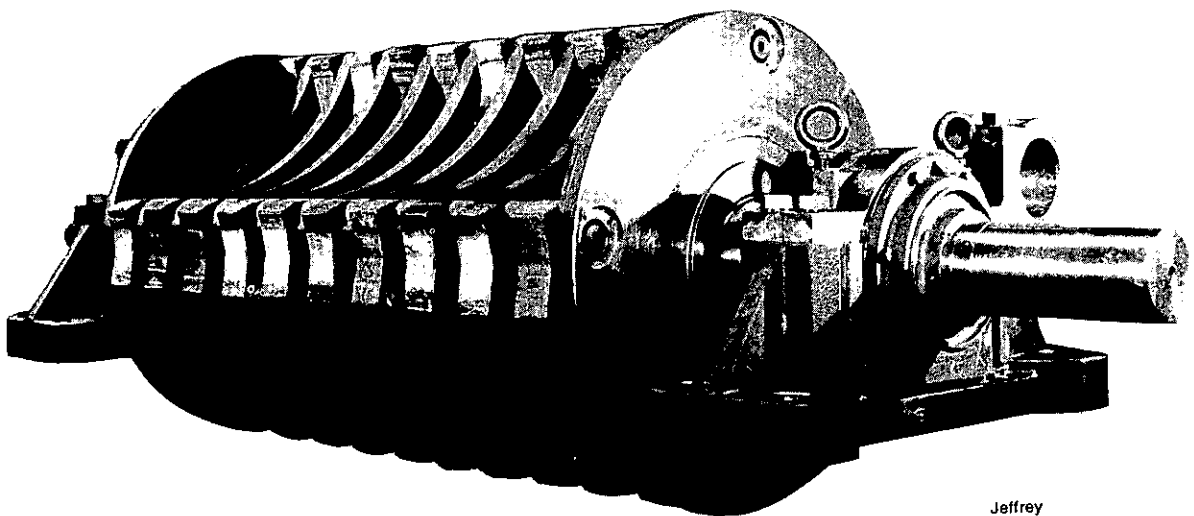
Jeffrey

FIGURE 2.

Disc type rotor, showing hammers, hammer retaining pin and bearing block.

FIGURE 3.
Vertical shaft hammermill.

South Africa there are nine companies marketing hammermills with the horizontal rotor while one company markets the vertical rotor configuration. In the following discussion, unless otherwise stated, the remarks apply to both types equally.
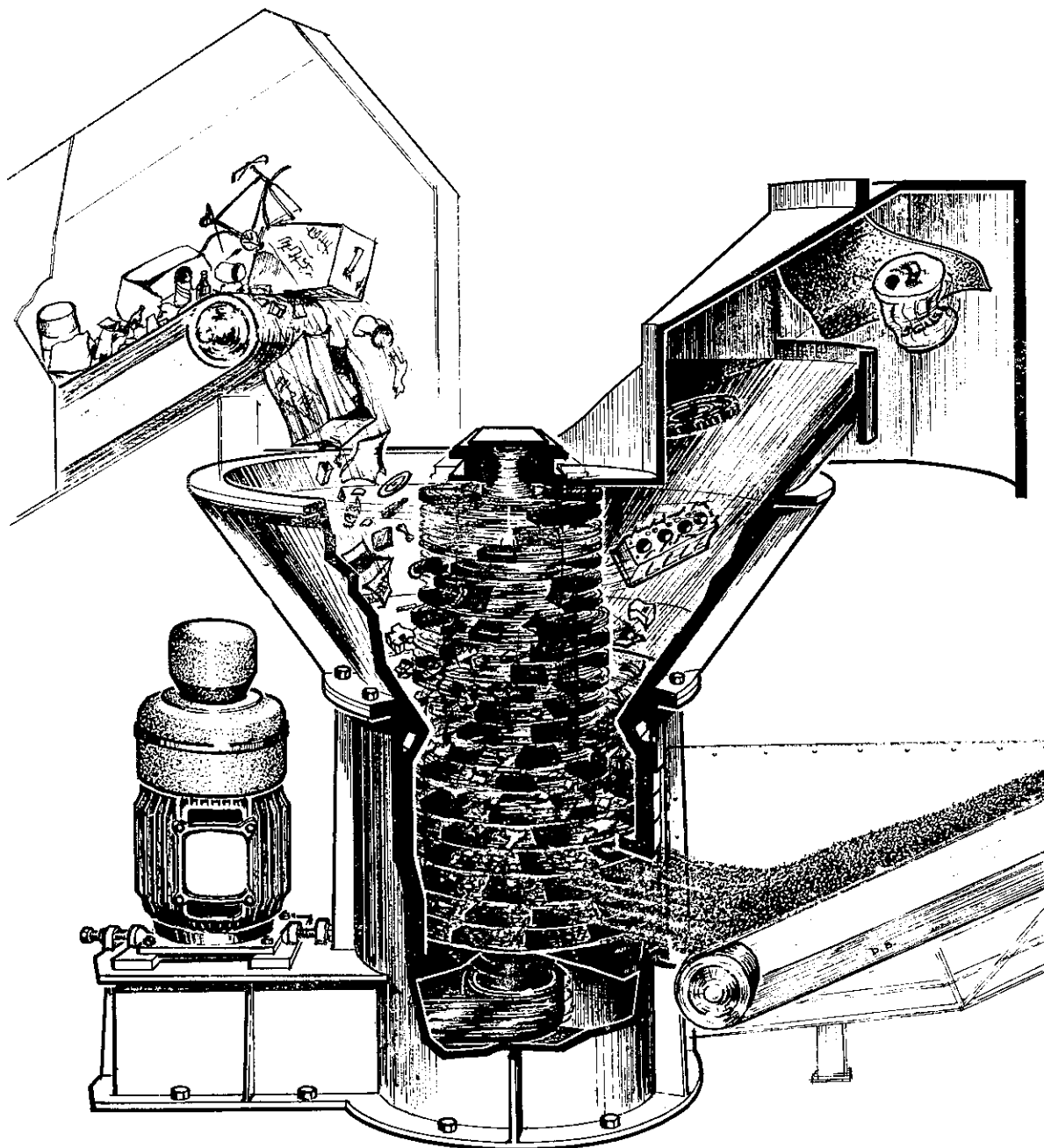
Feed Hopper and Main Frame

The feed hopper guides the inlet raw refuse from the feed conveyor into the mouth of the hammermill. It must be designed in such a way that blockages are prevented. Sides that slope inwards towards the mouth of the hammermill may well hold bulky objects and cause a bridging effect. This in turn could result in a build-up of refuse in the hopper, making it necessary to stop the plant in order to remove the blockage. A large inlet opening in the main frame of the hammermill is desirable. This prevents blockages at this point and ensures a free flow of refuse. However, with the smaller units it may be necessary to remove bulky objects from the refuse inlet stream in order to prevent blockages occurring.

The hopper should be fabricated from at least 12 mm mild steel plate, suitably reinforced, and the areas where excessive wear occurs may be protected with liner plates, which are usually held in place by bolts.

The main frame, or housing, is also fabricated from mild steel plate, of a thickness between 25 mm and 50 mm, depending on plant size. Heavier plate is also used in areas of high stress. The housing is reinforced by ribs of mild steel, presenting a rigid box capable of withstanding the shock loads and impacts generated during operation. The upper portions of the housing should be hinged (Figure 1), so that easy access to the interior is possible for inspection and maintenance. Access doors permit easier maintenance to the wearing parts such as liners, breaker plates, grates and the hammers, and make maintenance far more efficient than if the plant has to be partially stripped. Electrical safety devices must be attached to each access door, or hinged housing, so that the plant cannot be started with the housing open. If these devices are not abused they will prevent accidents and even loss of life.

Rotor Assembly

The inertia of the rotor provides the brute force required for this form of comminution and also absorbs the severe shock loading. The rotor's inertia is an important factor in the performance of the hammermill, and is proportional to the square of the rotor radius. Therefore, as the radius of the rotor increases, the inertia will increase very quickly. Thus to ensure the smooth flow of material through the plant and to eliminate the possibility of the hammermill jamming, the radius of the rotor should be as large as possible.

There are two types of rotors normally used; namely the arm rotor (Figure 5), and the disc rotor (Figure 6). The disc rotor is made up of a series of discs made from high tensile steel plate, between 125 mm and 200 mm thick. Depending on the size of the plant, these discs may be up to two metres in diameter, the discs being keyed to the rotor shaft and held with a clamping bolt. The arm type rotor consists of a series of much smaller discs fixed to the rotor, between which are rows of high tensile steel arms with the hammers fixed to the ends. While the inertia

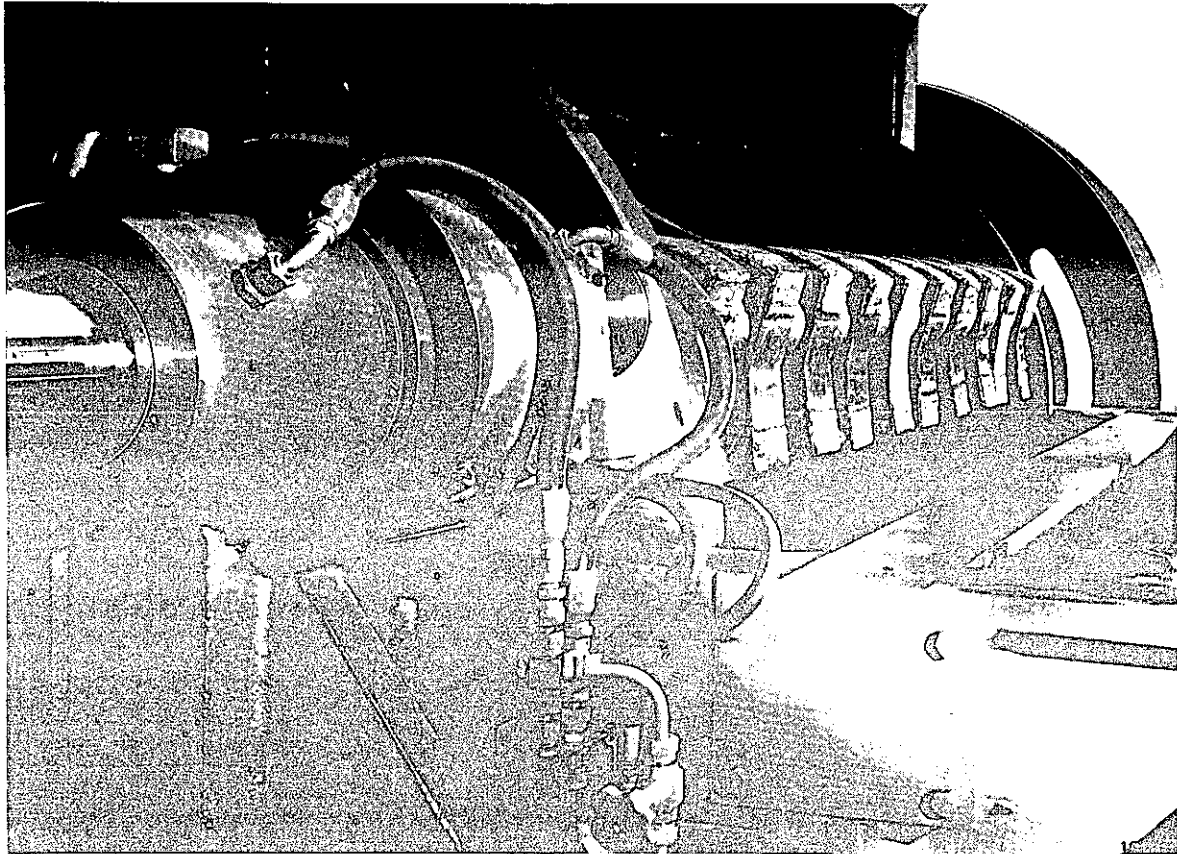**FIGURE 4.**   Jeffrey
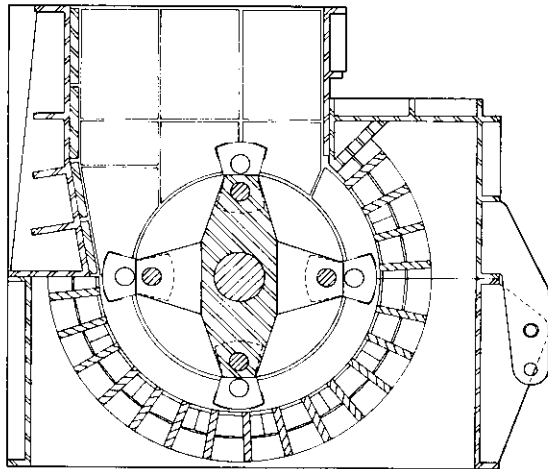
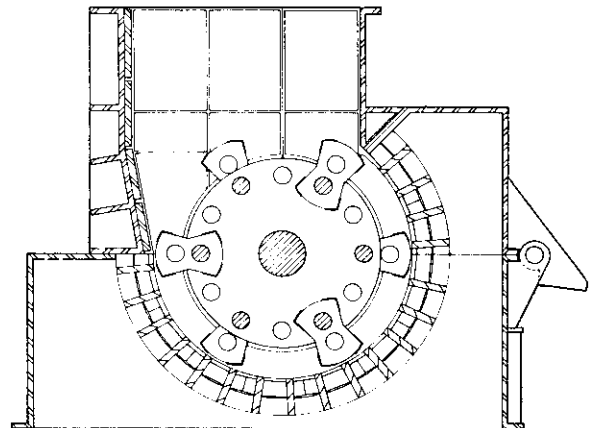Horizontal rotor, showing hammers, bearing lubrication, hammer retaining pin plate.

FIGURE 5.   Jeffrey
Arm type rotor.

FIGURE 6.   Jeffrey
Disc type rotor

factor is of undoubted importance, free swinging hammers which are too light may not provide sufficient shredding intensity and it is therefore necessary to combine high inertia with hammer weight to achieve optimum conditions.

The rotor shaft is usually forged from alloy steel and when the rotor assembly is complete the unit is statically and dynamically balanced, with the tolerance limit not being more than five mils dynamic vibration. The effects of poor balancing will be mentioned under the heading "Hammers".

Hammermills may either have rotors capable of rotation in one direction only, or rotors which are capable of rotation in two directions. A reversible plant is symmetrical about its centre line so that conditions remain the same in the plant, whichever direction is chosen. The advantages of being able to reverse the hammermill are :

(a)　The maximum useful life is obtained from the hammers before maintenance becomes necessary. This means that the need to close down the plant in order to reverse the hammers is eliminated.

(b)　Although hammer maintenance may take longer, the periods between maintenance are lengthened.

(c)　Wearing plate and breaker plate life is extended.

Comparison of Types

It is difficult to determine whether the hammermill with the vertical shaft orientation is superior to that with the horizontal shaft orientation or vice versa. While both types have proven themselves successful in operation, the plant with a horizontal shaft is offered by more manufacturers. In the case of the horizontal shaft hammermill, the shredded material flows through the machine by gravity and the hammer impact. Particle size is regulated by the size of openings in the discharge grates. Particles unable to pass through the grate are swept around by the hammers repeatedly until sufficient size reduction is achieved. There is thus a positive control on product particle size. Also changes in feed flow have no significant effect on the product size, which is an important factor when highly variable loading can be expected, or when final particle size has to be controlled, as for incineration. A number of hammermills have traps for collecting items which cannot be processed (Figure 10).

A disadvantage of the horizontal shaft hammermill is that since it is not free flowing, it is subject to very high rates of wear, and as the discharge grate acts as a restrictor, the plant will try to extrude items difficult to shred, for example, matresses or carpets. This may well require more power than is available, thereby causing a blockage.

A typical result from product analysis may yield the following figures :

Table 1.   Percentage particle size in a nominal 75 mm final product.

Product size	Percentage
+ 75 mm	6 to 10
- 75 + 50 mm	14 to 24
- 50 + 25 mm	21 to 24
- 25 + 12 mm	14 to 19
- 12 mm	27 to 45

In the vertical rotor hammermill, refuse is also fed from the top and the flow through the machine is also by gravity.   Here the flow is parallel to the axis and the fan action of the hammers creates an air current downwards through the plant, helping to draw the waste down and out of the outlet at the bottom.   The refuse enters a pre-breaking or conical section at the top, for initial impact and breakage, to allow the waste to enter the machine.   Unmanageable refuse is ballistically rejected at this stage. The pre-ground refuse now enters the grinding chamber and remains in this chamber until small enough to be discharged.   In the grinding chamber, the cross-sectional area between the rotor and the stationary housing decreases slowly from the top to the bottom (Figure 3).

The advantages of this type of mill are that a more even distribution of wear, and significantly lower hammer wear rates, are possible because input material is gradually reduced in particle size as it passes through the plant, and the wear is spread right around the casing, whereas with a horizontal rotor the breaking plates and grates represent between $180°$ and $210°$ of the periphery.   The manufacturers claim that between 30 percent and 42 percent less electrical motive power is required, in comparison to a horizontal rotor hammermill of a similar capacity.

A disadvantage of the vertical shaft mill is the maintenance of the lower thrust bearing which is necessary to carry the considerable weight of the rotor assembly.   This bearing may require regular servicing which results in considerable down time, as it is not readily accessible.   Indeed, the accessibility of this type of hammermill is, in general, not as good as that on a horizontal shaft plant.

Rotor Bearings

A horizontal rotor is generally supported in heavy duty, double row, self aligning, spherical roller bearings.   For easy maintenance the rotor shaft should be drilled to allow hydraulic removal and seating.   The bearings are housed in heavy duty plumber blocks and should be provided with an efficient system for dust exclusion (Figure 2).
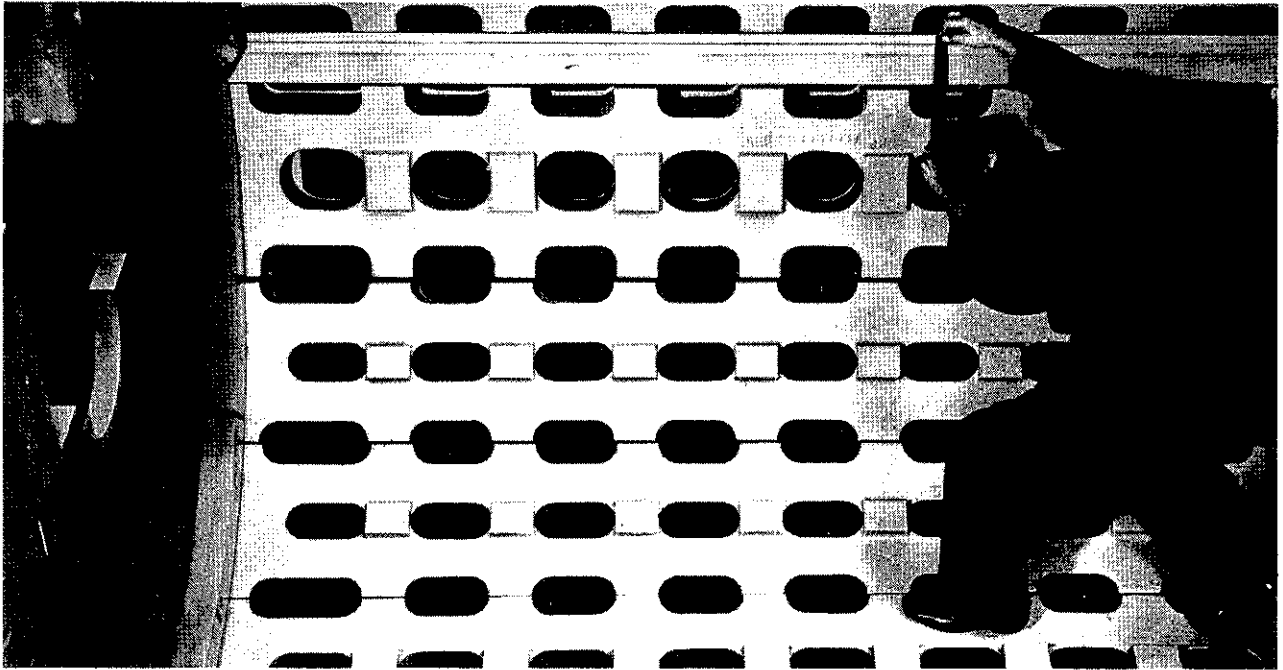
FIGURE 7.

Typical discharge grate. This example is in an automobile pulverizing plant.

FIGURE 8

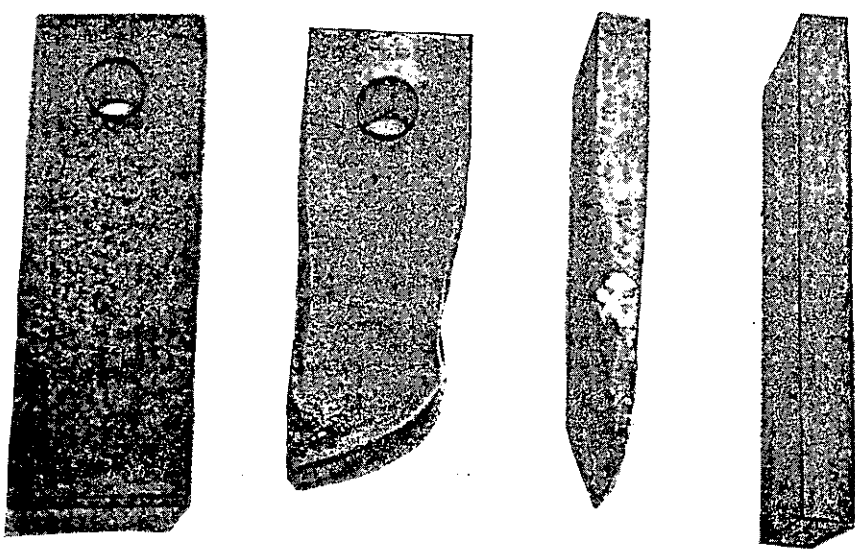Vertical rotor showing hammers and hammer pins.

FIGURE 9.

New and used hammers, vertical shaft hammermill

Lubrication on small machines may be manual but on the larger plants an automatic circulating oil system is usually installed (Figure 4). This system is connected to each point in the plant requiring constant lubrication, the returned oil passing through relief valves, heat exhangers and filters. The cooled oil is now passed through a pump, normally of the rotary gear type, and the lubrication conditions are able to be observed by pressure gauges, sight level gauges and temperature gauges. Good bearing design will include an automatic fail-safe monitor which, in the event of a failure, will trigger off alarms and, should the situation worsen, close the plant down automatically.

The vertical rotor hammermill is supported by three bearings; two radial bearings, one being at either end of the rotor shaft, and, as mentioned before, a thrust bearing located near the lower radial bearing. Lubrication arrangements to the lower bearings are the same as for the horizontal shaft machine, while the upper bearing is normally grease packed.

Hammers

The work of pulverizing is done by the hammers, whose weight, depending on the capacity of the plant, may vary from 15 to 115 kg. The working surface of these hammers are the tips, which wear, becoming blunt and causing rapid loss of efficiency. However, the hammer may be reversed to present a new face and tip at least once, and some manufacturers allow the hammers to be reversed end for end, thus allowing four position changes before re-tipping becomes necessary.

The hammer tip may be rebuilt using a specially selected alloy for building up the hammer profile. This alloy is chosen for economy of cost, economy in welding time and to give the best bond to the parent face of the hammer. Re-surfacing is completed using a hard facing weld deposit which allows the re-faced hammer to cope with the shocks, abrasion and corrosion encountered. (Figures 2, 4, 8 and 9). It has been found overseas that hammers treated in this way wear evenly and well, although, due to the nature of the operation, unpredictable conditions may cause irregular wear.

Materials used for the manufacture of hammers include abrasion resistant alloys containing manganese, molybdenum and chromium. Chromium facilitates re-tipping and reduces ductility.

Hammer life is usually measured in tons of refuse processed before maintanance becomes necessary. In calculating the advantages of hammer steels, hammer life must be measured against the material used since the two are obviously related. Similarly the method of re-tipping the hammers and the weld alloy employed will affect both the cost and the hammer life. Hammers are either fabricated or cast, the fabricated hammers offering the advantage of cheaper replacement.

Since hammers cut by impact, with the hammer shape transferring kinetic energy into impact, cutting action is most important. Several hammer designs are offered, ranging from sharp choppers to blunt beaters; the blunt beater type being the most common.

To reduce the possibility of damage to the main frame, or housing, from hammer impact on a very hard feed object, free swinging hammers are favoured, pivotting on the rotor by either individual or common hammer-

retaining pins (Figures 2, 4), which of course have to be removed before any hammer maintenance can be undertaken. The ease and method of removing these pins should be considered when selecting a plant. These pins are normally made from high tensile alloy steel, heat treated and case-hardened.

Hammermills operate at relatively high speeds. The small and medium size plants operate in the range 900 rpm to 1 500 rpm, while the large instal-lations and plants for oversize bulky wastes and automobiles operate in the range 450 rpm to 600 rpm. Thus it is absolutely essential that the rotor and hammers are accurately balanced, in order to eliminate vibration and even possible damage to the plant. Here is an example to illustrate the gross effect of imbalance. If an out-of-balance mass of one kilogram rotates at 1 000 rpm at a lever arm of 1 m, these figures referring to a medium size plant, a force of 559 kg will be created, exerting tremendous loads on the bearings and the rotor shaft itself. Further, free out-of-balance centrifugal forces created by such rotating bodies create vibration due to the periodic changes in direction and this leads to main frame cracks and possible disturbance to the machine support works. Again it must be stated that correct balancing is essential to safe plant operation and economical plant life.

To maintain a satisfactory rate and quality of reduction at acceptable limits for power consumption, it will be necessary to maintain the hammers frequently. It was reported that on average in a 40 t/h plant, each working corner of a hammer lasted approximately six weeks or 4 800 tons, thus giving a total life of 24 weeks per hammer before re-tipping. In this instance the rotor was equipped with four rows of hammers, 10 hammers in each row. The cost of re-tipping the complete set was approximately R1 500 (converted from English figures quoted in Sterling). Hammer renewal would be programmed between five to ten re-tippings, thus giving an estimated hammer life of between two to five years.

Liners, Breaker Plates, Discharge Grates

The hammermill main frame at the inlet must be protected from the effects of impact, corrosion and abrasion, for which purpose heavy carbon manganese plates are bolted to the main frame in the heavier machines. These plates may be up to 50 mm thick and are made to be reversible : side for side, end for end and back to front, to provide for maximum life as wear patterns develop.

Below the inlet opening some hammermills are fitted with adjustable breaker plates (Figure 10), which take most of the crushing action of the mill. Consequently they must be very strong and able to resist abrasion. They are usually made from cast carbon manganese steel up to 100 mm thick. Most of the wear occurs at the lower extremity where the clearances are smaller. In order to provide maximum service life, the breaker plate may be made to be reversible, or it may be hinged at the top enabling adjust-ments to be made by means of heavy bolts at the bottom.

In horizontal shaft mills the discharge grate (Figure 7) provides a positive control on the product size, the particles being driven through the openings. To extend grate life some manufacturers have made it possible for the grate sections to be repositioned end for end. The grate sections are usually made from cast manganese steel, the depth of the grate varying from 150 mm to 300 mm, depending on the machine capacity.
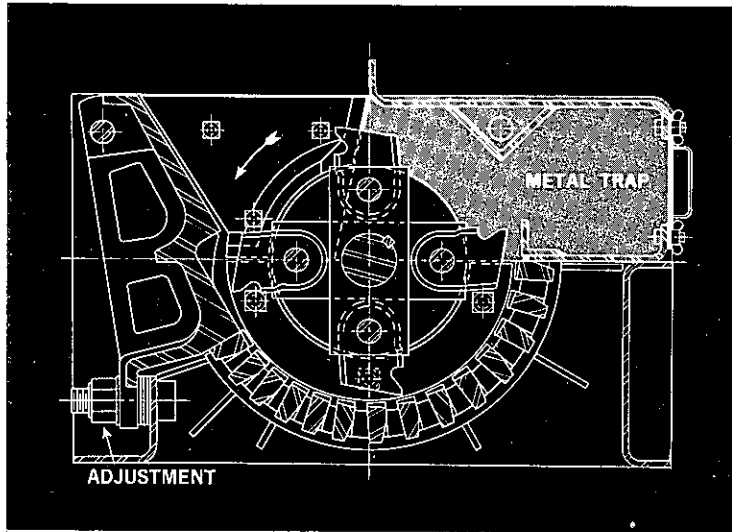
FIGURE 10. Williams

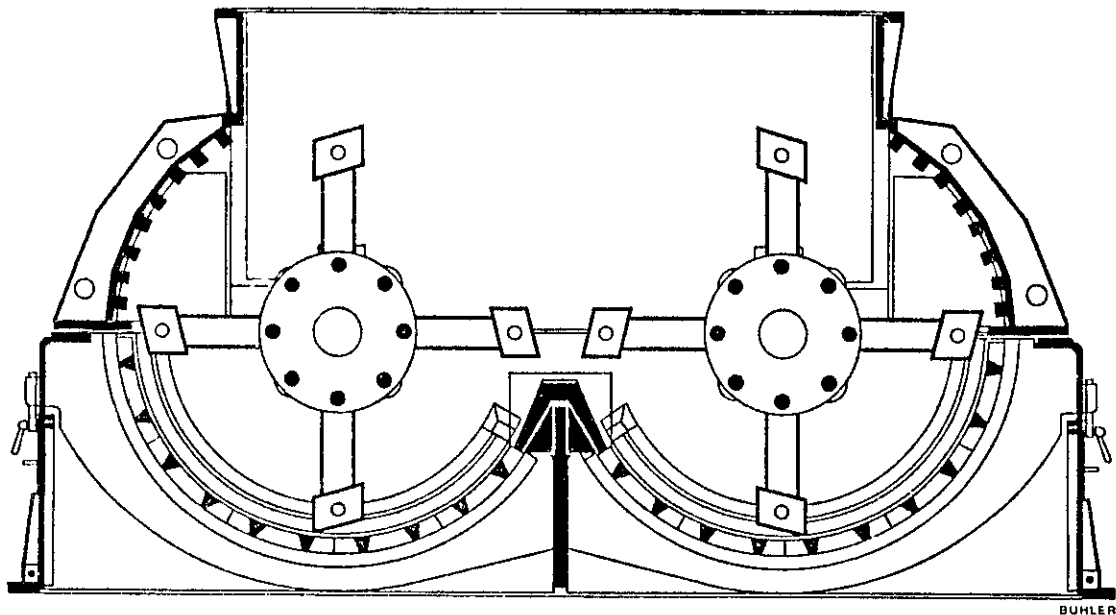Horizontal hammermill showing breaker plate.

FIGURE 11.

Double horizontal rotor hammermill.

Material passing through the grates travels at a high velocity and it is not practical to discharge directly onto a conveyor. Therefore, a chute or deflector fabricated from mild steel is placed directly under the outlet grates. This chute absorbs most of the energy from the discharged particles allowing them to fall onto the removal conveyor without harm. In some installations a heavy duty vibrating conveyor is used under the hammermill removing the possibility of the pulversized material sticking to the chute and causing a blockage.

Power Supply

As comminution plants are normally located near the large towns and cities, the normal prime mover is the electrical motor. The accompanying graph (Figure 12) gives the approximate power requirement for the different types of hammermill. It can be seen that considerable power is required, the greatest part of which is used to rotate the moving parts and provide sufficient torque to drive through the shock loadings, coupled with the demands of a highly fluctuating normal load. In all the hammermill is probably not more than five per cent efficient, relative to the power consumed. If possible, a squirrel cage motor should be used as it is the simplest and most robust. The wound rotor motor should be avoided as the armature windings and commutator may be sources of trouble due to the extreme conditions under which the motor works. As far as the squirrel cage motor is concerned, the starting current required is approximately 200 percent that of the running current, while the wound rotor requires 125 percent. The current increase for the squirrel cage is, however, usually not unacceptable. The cost of a squirrel cage motor with an auto-transformer starter will be similar to a wound rotor motor with its motor-resistance starter.

The size of the motor is usually determined on an empirical basis largely dependent on experience. As the parameters for design vary so widely, accurate determinations are almost impossible. However, the power requirement is a critical factor which should be considered very carefully. When evaluating a plant it should be remembered that an oversized motor is almost as undesirable as an undersized one. If the motor is too small, the plant is quite unable to operate at its designed capacity. While a motor that is too large represents a considerable unnecessary expenditure of funds, with attendant increased operating costs.

Factors influencing the power requirement are :

(a) the proposed final product particle size

(b) the nature of the feed material, including moisture content

(c) the rate at which the refuse is to be processed

Although there is very little data available, it would seem that the power requirement increases exponentially as the desired final particle size decreases with the most common nominal product size being between 75 mm and 150 mm. As solid waste varies widely, only a broad idea of the nature of feed material can be made. Consequently there must be a large safety factor included to enable the plant to cope with possible unusual circumstances.
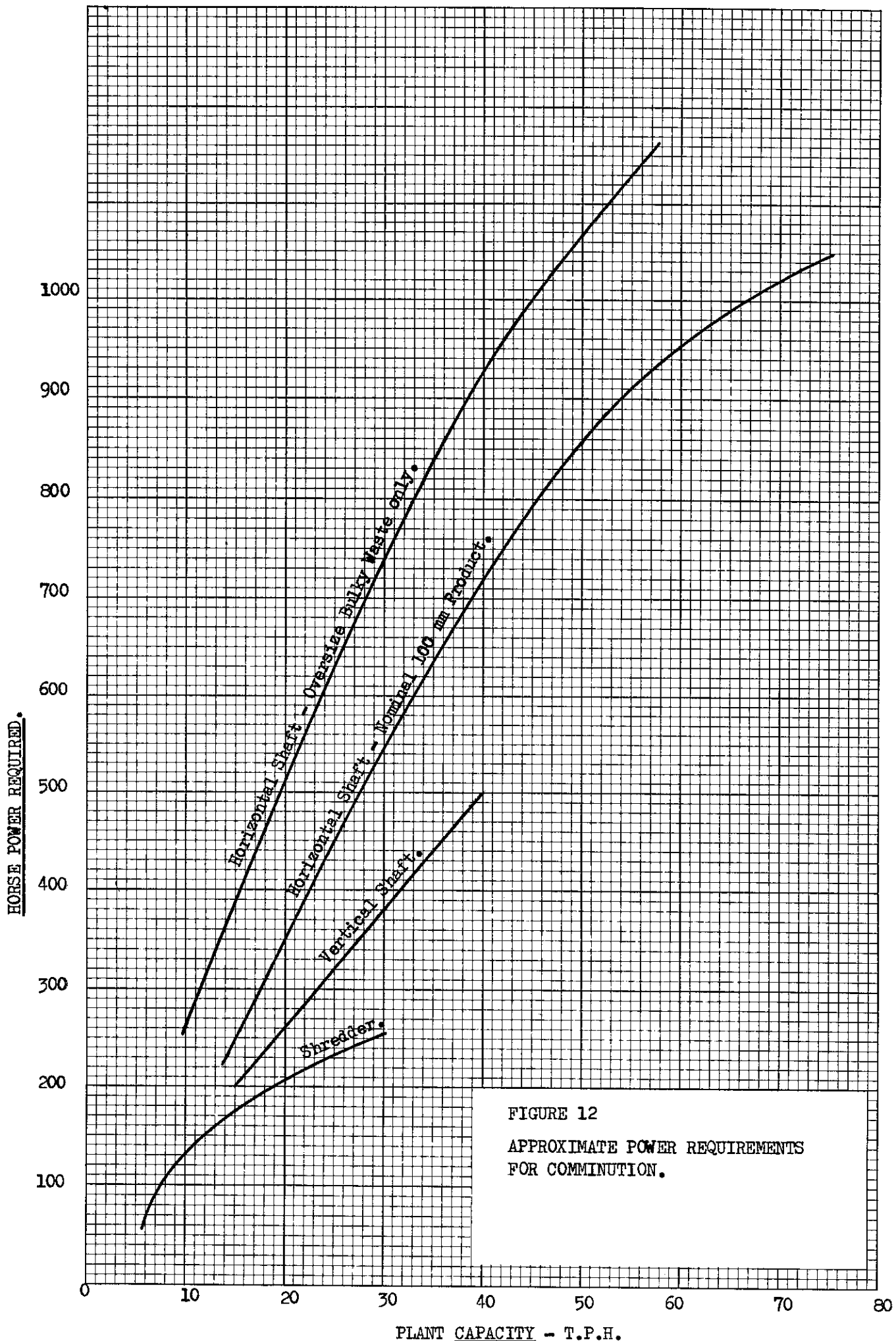
FIGURE 12

APPROXIMATE POWER REQUIREMENTS
FOR COMMINUTION.

Main Drive

The main drive is the connection between the hammermill and the electrical
motor and may be either by a gear train, a direct coupling (Figure 14), or
a multiple Vee belt drive (Figure 13). Gear trains are seldom used as
there are many disadvantages. A rigid structure is required on which to
mount the gear train. A total enclosure is essential both from the safety
aspect and also to keep dust and dirt away from the gears. The gear train
must have lubrication and heat sensors to detect any failure, and one must
also remember that shocks are directly transmitted from the hammermill to
the electrical motor. The gear train drive is expensive to install and
expensive to maintain.

A practical main drive should not only transmit energy to the hammermill
but should be able to accommodate a reasonable tolerance in misalignment,
to absorb some of the shocks coming from the hammermill and to protect the
motor in the event of the hammermill jamming.

The simplest form of coupling is by a direct coupling, between the
electrical motor and the hammermill rotor shaft, with a flexible coupler.
This procedure is the easiest and the least expensive. Most manufacturers
of horizontal shaft hammermills recommend a direct drive, but it requires a
good deal of space. Consequently, if space is limited, a belt drive is
used. The belt drive meets the requirements of a good drive connection,
it is comparatively cheap and while belts need to be changed, the main-
tenance is not frequent and is easily completed. It must be noted that
when a belt breaks it is not to be replaced by one new belt amongst the
remaining old ones. The complete set of belts must be renewed with a
matched set of belts. All new belts must be of the same length in order
to ensure an even power distribution throughout the drive. A belt drive
is flexible, is capable of absorbing some shock and is not critical to
alignment. Furthermore the system is self-cleansing, allowing a mesh
safety guard to be used rather than the dust-free cover necessary for a
gear train.

The vertical shaft hammermill is usually driven through a belt drive
(Figure 3) or a gear train, direct coupling not being usually practical.
In this case the motor is mounted alongside the hammermill and the drive
taken to the shaft below the lower set of bearings.

Noise

If it is planned to install a hammermill in a developed township or a
proposed area of development, it will be necessary to ascertain that the
level of noise created by the plant will not be a disturbance. Figures
reported by the GLC Folkestone Road (England), are obtained from a 40 t/h
plant which was pulverizing large metallic waste, namely refrigerators,
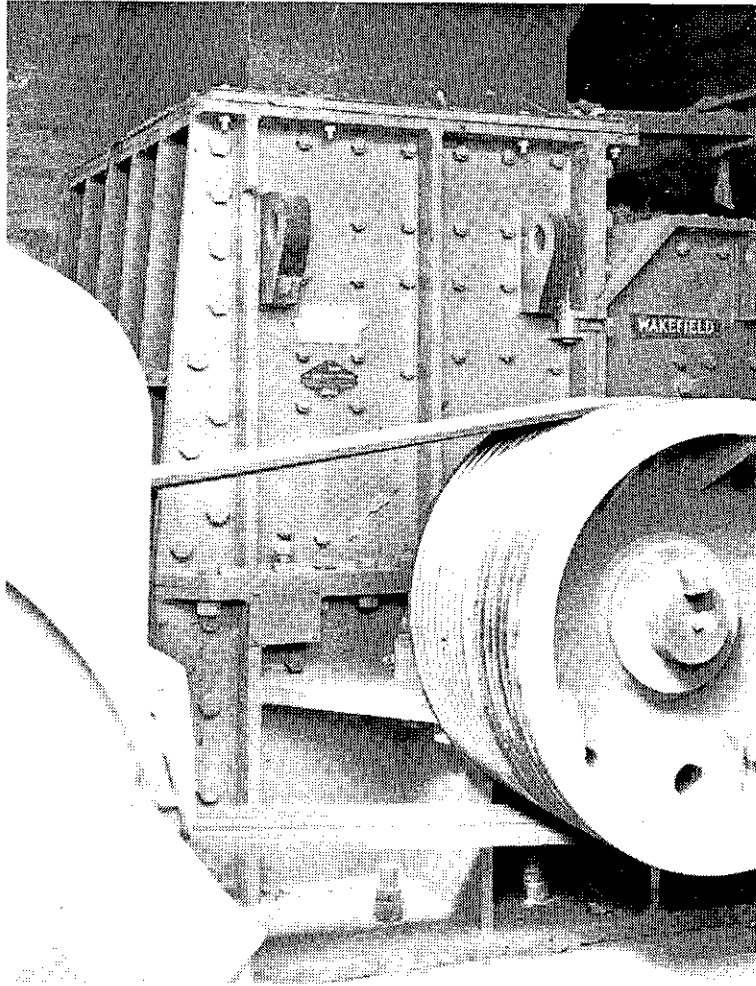washing machines, etc. (Pulverizer On).

FIGURE 13. Wakefield
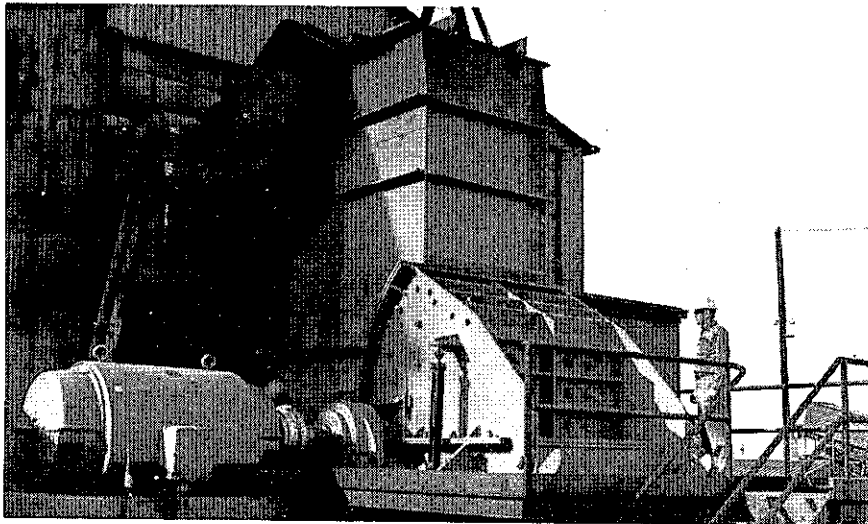
Belt drive with safety guard removed.

FIGURE 14. Williams

Direct flexible coupling.

Table 2.　Noise levels

Location	Distance from Pulverizer	Noise levels in decibels			
		Pulverizer off		Pulverizer on	
		Background	Peak	Background	Peak
1. Near pulverizer	3 m	66-76	82	90	108
2. At site perimeter (Near houses and road)	100 m	45-58	80	61	80
3. At site perimeter (away from houses and road)	100 m	45-58	60	61	66

Ancilliary Equipment

In most cases the hammermill is fitted with certain equipment which, while not essential in the pulverizing process, provides greater safety and ease of operation.　Fire is an ever present hazard and carbon dioxide or water systems are fitted to spray directly and automatically into the housing. The fire control system is controlled by heat sensors in the hammermill housing.

If dust is found to be a problem, dust suppression systems may be introduced.　There are two methods which may be used.　Water spray nozzles installed in the feed hopper produce a high pressure water mist inside the hammermill.　This creates a cool damp environment inside the plant which results in less dust, but can increase the abrasive qualities of the refuse.　If moisture is undesirable, pneumatic dust collectors may be used.

A jib crane, or a gantry crane will assist in the maintenance by making light work of lifting in or out the rotor shaft, liners, breaker plates, discharge grates and hammers.　As far as maintenance is concerned the plant should have a welding plant for its sole use, of sufficient capacity to cope with all the plant maintenance welding.　A further maintenance tool, essential in large capacity machines, is a hammer retaining pin puller.　This is usually powered hydraulically although mechanical pullers are available.　After usage, the hammer retaining pins become difficult to remove and a method of pin removal, which is both easy to use and which is not time consuming, is obligatory.

Service and Parts Available

The quick availability of spare parts and service arrangements should be a critical factor in plant selection. Prolonged down time is not only costly but may be embarrassing when all the available refuse storage space has been filled. The wearing parts and more common replacement parts, for example bearings, are in most cases readily available from the agents or are manufactured locally. However, it is essential that this matter is clarified in the planning stage as subsequent importation may be slow and expensive.

Maintenance

Hammermill maintenance programs depend largely on individual plant usage, and the following is a general guide for maintenance requirements :

(a) Discharge grate : The sections are replaced or reversed end for end every six months. Hard surface welding is used as required.

(b) Liners : These are inspected and either replaced or reversed every six months. Wear may be repaired by hard welding. Complete replacement occurs between three to six years.

(c) Breaker plates : These are inspected every six months. If necessary, wear is repaired by hard welding.

(d) Rotor shaft : These are inspected for wear every six months. In order to do this the complete shaft is removed from the housing. Wear to the discs or arms is repaired by hard welding, and after this, re-balancing is essential.

(e) Bearings : These are inspected every three months and replaced every four to six years.

(f) Lubrication : Circulating oil is checked daily. Every week the oil filters should be cleaned or replaced. The oil is changed every six months.

(g) Hammers : Reversal or replacement approximately every four to six weeks, or as necessary. This maintenance item will be gauged from experience.

(h) Hammer Pins : These are replaced whenever a new set of hammers is installed. This will prevent excessive wear, which makes the task of removal more difficult.

(i) Main Drive : The coupling or belts are examined every two months and adjusted as necessary. The coupling is greased every six months, while belt replacement will be completed as necessary.

Operating and Maintenance Costs

It is often difficult for a manufacturer to provide reliable figures relating to the operating and maintenance costs. Very limited performance data is available, both in this country and overseas, and most of these figures are obtained under uncontrolled conditions.

Some of the difficulties in providing reliable cost figures, which can be used in comparison with others, are :

(a) Operating and maintenance techniques vary between plants, some variables being number of hours the plant works, maintenance practices, safety standards, quality of supervision and operating personnel.

(b) The feed rate plays an important part in cost analysis. If the plant is processing less than its programmed norm, then the cost per ton will skyrocket, through no fault of the plant or operating staff. It is important to remember that the hammermill is only part of the system, thus inefficiencies upstream or downstream of the hammermill will result in less material being pulverized and the costs being adversely affected.

(c) The feed composition varies seasonally and this may result in various differences in pulverizing operating costs in the same plant.

(d) Methods of accounting and the accent on recording information varies from plant to plant, sometimes making it very difficult to arrive at a comparison.

Because of the potential variables, operating and maintenance costs are best estimated in broad terms; namely, cost per ton. The operating and maintenance cost of a hammermill installation should include the cost of amortization electrical power, labour costs, overheads, maintenance labour and materials costs and the costs of replacement of parts.

Summary

When operating a hammermill plant the following points must be observed :

(a) A machine which has excessive vibration must be shut down immediately and the balance of the rotating parts re-checked very carefully.

(b) When installing new or re-tipped hammers, they are to be weighed and assembled to ensure that static and dynamic balance is maintained.

(c) All the hammers must be changed or replaced at the same time in order to maintain balance.

(d) When hammers are turned to present a new cutting face, they must be re-installed in their original positions; again, all the hammers being turned at the same time.

(e) Worn or missing fixtures (nuts, bolts, washers, etc) should be replaced immediately.

SHREDDERS

Introduction

Various types of machinery used to pulverize refuse are often loosely described as shredders, which may then also include hammermills. In fact,

hammermilling and shredding are not the same at all. In hammermilling, as has been portrayed, the process of reduction is completed by a moving hammer striking the material against a stationary housing, thereby converting momentum into compression, and tension forces together with attritional forces cause the material to break up. In a shredder the size reduction is achieved by using low speed, high torque motors which apply shear forces to the material.

Electro Hydraulic Drive

In the process of shredding, very high torque is required. The most efficient method of providing this is by using a hydraulic system. An electrical motor is coupled to a variable torque oil pump (Figures 15 and 16), allowing the manufacturer to design the motor exactly, since the pump requires a constant power input. This is due to the pump characteristic in that as the torque increases the speed decreases. It is reported that the electrical power required is approximately one half to one third of that required for hammermilling.

Shredding Unit

The shredder (Figures 15 and 16) consists of a rigid frame constructed from mild steel. There are no wear protection plates as the comminution does not involve the frame at all. In this frame two counter-rotating horizontal shafts, mounted in spherical roller bearings, are located at either end. The hydraulic motor is bolted, through a rigid flange coupling to the end of one shaft while the heavier shredders have a second hydraulic motor on the second shaft. The lighter machines have only the one motor, the second shaft being driven by a gear train.

The shredder shafts have interrupted splines to which are bolted the shredding teeth section, six teeth in each set. The teeth of adjacent sets are staggered; this evens the load and prevents shock loading. A shredder shaft, once assembled with its teeth, has the appearance of a very large gang miller.

Operation

Inlet material to be macerated is introduced to the top of the shredder through a hopper. Because of the relatively small reach of the teeth, larger items of refuse can bridge them. This, if left unattended would lead to a blockage. This condition is controlled by having compression rams in the feed hopper which alternatively press down on the inlet material, forcing it into the shredder teeth. The shafts rotate between 10 rpm to 40 rpm depending on the torque requirement. On rotating, the teeth force refuse down between adjacent tooth discs, thereby shearing particles from the inlet material, these particles then fall freely onto a conveyor passing underneath the shredder. This process creates no vibration and consequently no heavy foundations are required. The shredder is normally mounted on steel joists at the desired height.

Hammermills, particularly the smaller capacity ones, do not tolerate certain waste items, namely old motor car tyres, matresses, carpets and wire rope. These items tend to cause blockages and reduce the efficiency of the plant. A shredder is able to macerate this type of refuse with no trouble but is unable to deal with crankcases, gearboxes and similar heavy steel items.
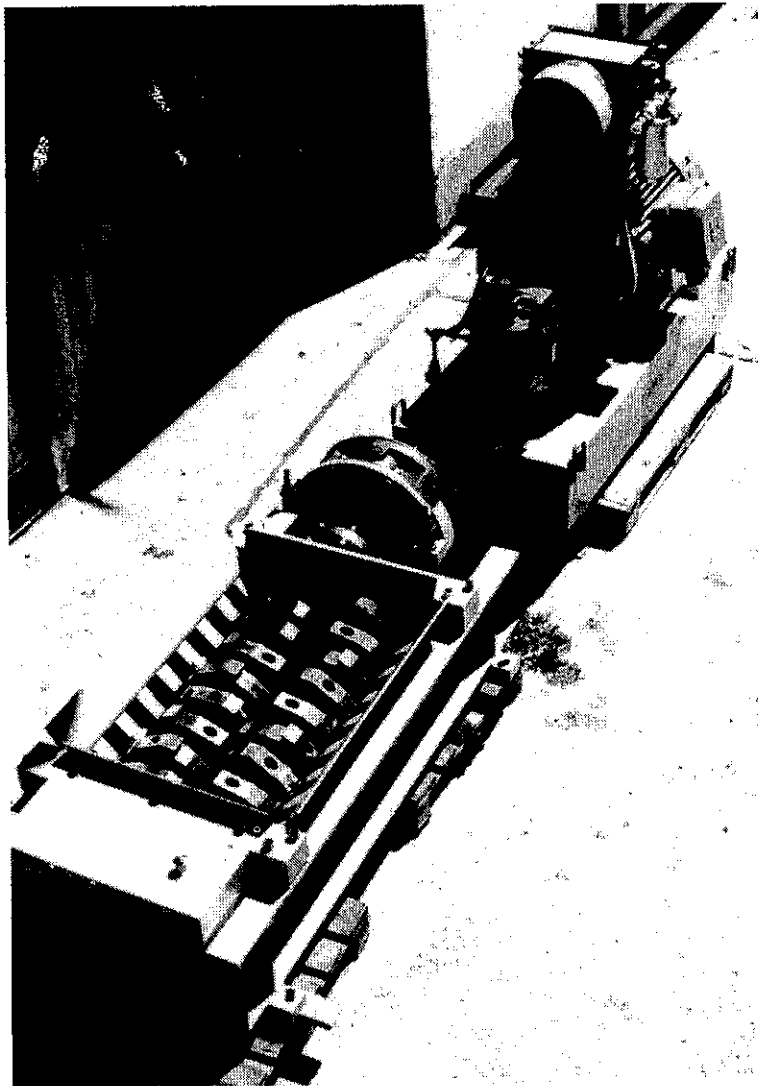
FIGURES 15.   Bema

Electro-hydraulic shredder showing rotors and rotor knives.

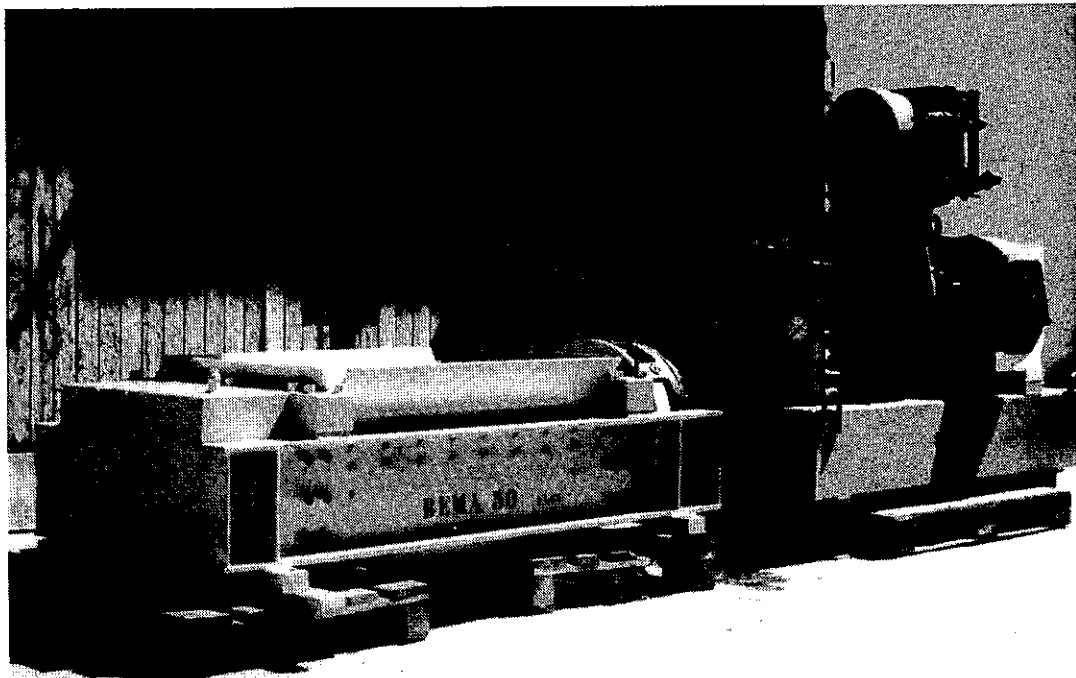**FIGURE 16.**   Bema

Shredder showing housing construction.

If such an item sticks in the machine, a safety device automatically
reverses the plant for a short time and then allows the shredding to
continue.   Should the shredder jam again, or after a predetermined number
of consecutive jams, the shredder unit pivots about a hinge pin, auto-
matically causing the waste creating the blockage to spill out.   The
shredder is now automatically returned to its normal position and shredding
is again continued.   While the shredder is in the lowered position, the
compression rams in the feed hopper automatically close off the hopper
opening, thereby preventing unshredded waste from falling onto the conveyor
below.

Maintenance

The teeth on the shredder shafts work at close tolerances and as the edges
wear, so the shredding efficiency falls off.   The wear occurs usually on
the leading corners of the teeth, which are then built up with hard weld.
Due to the close running tolerances the edges of the re-tipped teeth have
to be ground flat, which may be done with a hand-held angle grinder, thus
enabling the maintenance welding to be completed without removing the teeth
from the shaft.   It is reported that maintenance welders soon grasp the
technique of grinding the weld to leave an acceptable finish.   Naturally,
if the teeth are removed and the re-tipping done in the workshop, the
grinding may be done with a surface grinder, thus attaining an "as new"
finish.

Summary

This method of comminution is more sophisticated than hammermilling, and
while the initial capital outlay is more for the shredder than the
hammermill, the running costs are considerably less.   To date, shredders
are made in the small to medium capacity range only, although it is under-
stood that plans are being made to extend the range of models to include
larger capacity machines.

GUILLOTINE COMMINUTION

A well known method of handling metallic waste is to fill a reinforced
steel container, close it with a reinforced steel lid and, by using a
hydraulic ram, compress the metallic waste, producing a tightly compacted
bale of metal.   This process has been enlarged and taken a step further.
A large form of press compacts heterogenous waste, after which the end
opposite the horizontal hydraulic ram automatically falls away, allowing
the ram to extrude the compacted refuse.   After allowing a predetermined
thickness to be extruded, a guillotine falls, slicing off the extruded
refuse.   This process is repeated until the press is empty whereupon the
lid opens, the hydraulic ram returns to its original position, as does the
drop end, and the process is repeated.

The obvious disadvantages to this process are that it is cyclic rather than
continuous and that the guillotine has to be robust to withstand very hard
treatment.

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De Szabo, J 1973. Hammermills. Lecture notes. May 1973.

Franconeri, P 1975. How to select a shredder. Solid Wastes Management R R J, June, July, August 1975. pp 24 et seq.

Sanders, T G 1970. Grinder evaluation and development, US Dept of Health, Education and Welfare. Progress Report WP-02-69-26.

Tworeck, W C 1975. General guide to the selection of shredders for municipal solid waste - A literature survey. Project Report. April 1975.

APPENDIX A

MANUFACTURERS AND DISTRIBUTORS OF HAMMERMILLS

NAME	REPRESENTING
1. Hans Baars, Industrial Consultant 7 Lindavil Tamboerskloof CAPE TOWN Telephone : 43-2935	Williams Crusher and Pulverizer Co
2. E L Bateman Limited Bartlett Road BOKSBURG NORTH Telephone : 52-7246, 52-8188	Pennsylvania Crusher Corp
3. Buhler - Miag S A (Pty) Limited Raschers Corner Loveday Street JOHANNESBURG Telephone : 838-2131	Buhler Hammermills
4. Cu - Al Engineering (Pty) Limited 2 Enfield Road Dalbridge DURBAN Telephone : 357-133	Gruendler Crushers and Shredders
5. Peter M Duys (Pty) Limited 127 Old Main Road PINETOWN Telephone : 724-581	Gondard
6. Hauni South Manufacturing (Pty) Ltd Dorsetshire Street Paarden Eiland CAPE TOWN Telephone : 51-5741, 51-2140	Condux
7. Industrial Machinery Supplies (Pty) Ltd I M S House Loveday Street JOHANNESBURG Telephone : 836-5261, 834-1551	Hazemag USA Inc
8. Jeffrey Manufacturing Co (Pty) Ltd Tedstone Road WADEVILLE Telephone : 34-1550, 34-1563	Jeffrey, Wakefield
9. Newell Dunford Hadfields (Pty) Ltd 249 Dyson Road WADEVILLE Telephone : 34-2546	Tollemache

10. Samuel Osborn (S A) Limited   American Pulverizer
    350 Main Reef Road   Company
    DENVER
    Telephone : 616-2130

The preceeding list may not be complete and does not intend to select the best suppliers of equipment.

AUTHORITIES USING HAMMERMILLS

MUNICIPALITY   TYPE

Bellville   Andrag combination hammermill/rotary
                                   screen, incorporated in a compost
                                   plant.

Cape Town   Adjudicating tenders for pulverizing
                                   plant.

Johannesburg   Tollemache pulverizing plant.

Parow   Buhler hammermill incorporated in a
                                   compost plant.

OVERSEAS COMPANIES WITHOUT LOCAL REPRESENTATION

1. Allis Chalmers

2. Tracor Marksman

3. Eidal (vertical rotor shaft)

4. Vanesco (Hammermills Inc)

SHREDDERS

1. Bema Engineering, Switzerland

2. Unicrex, Germany

GUILLOTINE COMMINUTORS

1. Lindemann, Germany

APPENDIX B

INFORMATION REQUIRED

Reception pit/hopper

(a) General requirements (Size etc).

(b) Any special requirements (operational ease, safety, best materials, optimum slope of sides).

Conveyors (both feed and hammermill outlet)

(a) Types of conveyor available (belt, screw, chain).

(b) Advantages of these conveyors and where they are best used.

(c) Costs.

(d) Economical life.

(e) Typical maintenance and preventative maintenance (parts replacement) requirements.

(f) Usual areas of breakdown.

(g) Possible causes for stoppage (bearing collapse, blockage from refuse).

(h) Effect of large articles of refuse (furniture, electrical appliances on conveyor selection).

(i) Safety devices (overload, runback, mechanical failure, jamming).

Hammermill

(a) Types of hammermill available, general characteristics (horizontal or vertical rotor, one or two rotors, advantages, disadvantages, best applications for the various types).

(b) Hammermill housing (types of material, designs, stress relief, specifications).

(c) Housing wearing plates (access, frequency of renewal, suitable materials, times required for replacing, methods of securing, costs, maintenance costs, effect of breakage).

(d) Grates (materials, access, time required for renewal, frequency of renewal, costs, effect of breakage).

(e) Size of product (normal distribution of size of final product particles, power requirement relative to product size, effect on wearing parts, resultant bulk reduction of solid waste, other advantages and disadvantages).

(f)   Rotor (types commonly used, method for retaining hammers, rotor
      materials, maintenance requirements to the rotor, replacement time,
      maintenance costs, access to rotor).

(g)   Bearings (types used, advantages, disadvantages, lubrication methods,
      life expectancy, maintenance and replacement costs, mountings, safety
      devices).

(h)   Hammers (types, weights, materials, cost of new hammers with respect
      to materials. Methods of replacement, time for replacement,
      balancing, effects of unbalanced hammers, effect of worn hammers.
      Hammer maintenance and cost related to different hammer materials).

(i)   Hammer retaining pins (types, materials, methods of withdrawing for
      hammer maintanance, expected life, maintenance, costs).

(j)   Explosion relief (causes for explosion, methods of plant protection,
      warning devices, safety devices, personnel protection, fire preven-
      tative devices).

(k)   Rejection capability (how is this achieved, effect on wear and shock
      on plant, objects dangerous to plant operation, ie wire rope).

(l)   Electrical motor (suitable types, advantages, disadvantages, calcu-
      lation of power requirements, life, maintenance, cost of maintenance,
      safety devices).

(m)   Main drive (types available, advantages, disadvantages, safety
      requirements, maintenance, expected life, maintenance costs).

(n)   Electrical starters (types available, maintenance, cost of main-
      tenance, life, safety devices).

(o)   Vibration (causes, isolation, maintenance).

(p)   Hammermill outlet requirements.

(q)   General operational requirements.

(r)   Noise levels (near plant, outside buildings, acceptable levels in
      built-up areas).

MAGNETIC SEPARATORS

(a)   Types available, general specifications.

(b)   Advantages and disadvantages of separating before or after pul-
      verizing.

(c)   Cost, maintenance cost.

(d)   Expected life, maintenance methods, preventative maintenance.

(e)   Common failures, effects of breakdown.

ECONOMICS

(a)   Expected economical life of plant and buildings.

(b)   Economics that may result from hammermilling.

(c)   Circumstances which indicate the use of pulverization.

(d)   A method of approximating the cost per ton for a proposed capital
      outlay at a known rate of interest and a predetermined economical
      life.