REFUSE SHREDDING—PERFORMANCE, TESTING AND EVALUATION DATA

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ABSTRACT

Many different designs of solid waste shredder systems are available for the processing of solid waste streams for direct landfill applications or complex resource recovery programs. Depending upon the infeed material and endproduct use, different design criteria for equipment selection and expected performance levels are possible.

This paper offers some actual field test data as performed by the Allis-Chalmers Corporation on the Model KH 12/18 shredder. It reviews rotor speed modifications and their effect on system energy requirements as well as tests wherein modifications to the lower grate arc and area affected outfeed product characteristics.

INTRODUCTION

There is the potential of energy savings through shredder rotor speed reduction. However, the speed of the rotor in a refuse shredder affects several operating characteristics of the system. The most important of these is the shredding energy, which is reduced with decreasing rotor speed. A secondary element affected is the shredder components wear. Hammers, deflector grating and grates have their wear life extended with speed reduction.

One of the tasks of the test program was to determine the energy required to shred the wide variety of material processed at the shredder facility in Outagamie County, Wisconsin. This task was accomplished by varying the available shredding energy through rotor speed reduction and monitoring the change in shredder performance.

A second task, an evaluation of this Allis-Chalmers Model KH 12/18 refuse shredder, was to determine the value of the 190 deg. arc of grate bars in effective shredding of municipal waste. More specifically of interest was finding the location of the working area of the grate arc and determining the degree of shredder control that can be developed by altering the characteristics of this grate arc.

BACKGROUND

The Solid Waste Processing Operation of Allis-Chalmers was formed in early 1973. The creation of this organization was the direct result of extending ongoing and related types of business that existed within the parent corporation as well as a direct evolution of efforts in the solid waste business developed by our wholly owned subsidiary Svedala-Abra of Sweden.

In the summer of 1973 our first refuse processing system was sold to Outagamie County, Wisconsin. The plant was constructed during the following twelve months and official start-up occurred in October, 1974. During the next six months extensive testing of the facility by personnel of our Advanced Technology Center led to certain operational and performance level reports. This work initiated a thorough and highly technical engineering level study effort which has continued on a yearly basis and has developed into a very comprehensive technical data bank of solid waste processing information.
DESCRIPTION OF THE FACILITY

The refuse processing plant at Outagamie County consists of two parallel shredding lines with a common tipping floor and single line discharge facility. The two shredders installed at Outagamie are Allis-Chalmers Model KH 12/18 designed to process a combined total of 40 tons/hr (36.2 t/h) of municipal solid waste while producing a product with a nominal 3 in. (76.2 mm) particle size. In 1977, the plant processed an average of 200 tons/day (181.4 t/day). The refuse is a mixture of household, commercial and light industrial waste. It is the total amount of shreddable refuse available in Outagamie County, which has a population of 130,000.

CHARACTERISTICS OF THE ALLIS-CHALMERS DESIGN

The Model KH 12/18 shredder is a horizontal rotor design with four rows of pivoting hammers. The design of the shredder provides for three types of size reduction: First, friable material, such as glass and wood is shattered or splintered with initial impact by the hammers. The more durable materials such as sheet metal, corrugated cardboard and plastics are then subjected to a second size reduction of shearing. As these materials penetrate the hammer circle, they are carried onto the deflector grating system which meshes with the hammers. It is at this point that these more durable materials are sheared. Any unshreddable object, such as a crank shaft, is pushed horizontally along the top of the deflector grates and forced out of the shredder through the spring loaded reject doors.

The remainder of the refuse then passes into the grate section of the shredder and is reduced in size by a combination of impacting, shearing, and grinding until it is fine enough to pass through the grate openings.

During test sequences, instrumentation was installed to record power consumption, power factor, shredder drive motor speed and shredder rotor speed.

THEORY OF SHREDDING ENERGY

A short review of some basic mechanics will help in explaining the theory behind energy savings through speed reduction.

Inertia is the property by virtue of which a particle tends to remain at rest or in uniform motion and resist a change in speed. Inertia for a rotating body is determined by its mass, geometry and axis of rotation and is expressed as $WK^2$ in terms of lb-ft$^2$ (kg-m$^2$).

For basic geometric shapes such as pipes and shafts, which are symmetric about the axis of rotation, the inertia is a function of the mass and radius of the object which can be expressed in units as a product of the mass and the length squared or in terms of $WR^2$.

For complicated geometric configurations such as a shredder rotor (complete with hammers, hammer shafts and discs), a detailed calculation is required to analyze the rotational inertia. This analysis consists of reducing a complicated configuration down to a series of simple geometric designs.

The term $K$ is defined as the effective radius used in assimilating a simplified geometric system. The radius of gyration, $K$, is the distance from the axis of rotation to a point in a body where the entire mass of that body can be considered to be acting. This point is called the center of mass.

For elaborate configurations which require this type of analysis, the inertia is still expressed in terms of mass and length where this time the length is an effective radius and is expressed as $K$.

Evaluation of available shredding energy involves more than comparing just the $WK^2$ of shredder rotors. Since $WK^2$ is only a function of mass and the location of this mass in relation to the axis of rotation, the evaluation of shredding energy requires the consideration of rotational speed along with $WK^2$. In comparing the available energy of shredders, the shredding energy should be the basis for comparison.

$WK^2$ is related to shredding energy through the kinetic energy term, $1/2 I w^2$. Where $I = WK^2$, $1/2 I w^2$ is a measure of the shredder's capability to do work and is simply the product of the $WK^2$ and the square of the angular velocity ($w^2$) of the shredder rotor.

It is important to note the relationships between the shredding energy term and the inertia and rotational speed. A change in inertia ($WK^2$) results in a directly proportional change in shredding energy. However, a change in rotational speed causes the shredding energy to change in proportion to the square of the rotational speed. Therefore, changes in rotational speed have a greater effect on the available shredding energy than changes in inertia, $WK^2$.

The amount of $WK^2$ to be designed into a shredder is a function of what is the "toughest" item to be shredded. This establishes the level of energy which the shredder must develop. It is then a matter of de-
signing a rotor assembly with a specific inertia, \( WK^2 \), and rotating this assembly at a suitable speed so that the \( 1/2 WK^2w^2 \) term will equal the ultimate kinetic energy term at designed operating speed.

Therefore, the kinetic energy, which can effectively be considered the shredding energy, can be controlled by the rotating mass, the location of this mass with respect to the center of rotation, and the rotational speed of the mass.

**FIELD TEST PROGRAM**

**ROTOR SPEED REDUCTION TESTS**

The objective of this particular series of tests was to determine the levels of shredding energy required to shred refuse. The shredding energy was varied through a series of reductions in the rotational speed of the rotor.

The Model KH 12/18 was initially installed at Outagamie County for operation at 1000 rpm. As part of the development test program, a speed reduction to 900 rpm and 720 rpm was scheduled.

The drive system on this installation is a 400 hp motor with a fluid coupling and V-belts. To reduce the shredder rotor speed from 1000 to 900 rpm, the motor sheave was changed.

The results of analyzing strip chart records of the kilowatt usage for operation at 1000 rpm and a reduction to 900 rpm showed a 21.6 percent reduction in average kWh/ton consumption for the shredding of refuse. The following chart summarizes our findings:

<table>
<thead>
<tr>
<th>Shredder Rotor Speed (rpm)</th>
<th>1000</th>
<th>900</th>
<th>720</th>
</tr>
</thead>
<tbody>
<tr>
<td>kWh/ton</td>
<td>7.51</td>
<td>5.89</td>
<td>6.37</td>
</tr>
<tr>
<td>(kWh/ton)</td>
<td>(6.81)</td>
<td>(5.34)</td>
<td>(5.78)</td>
</tr>
</tbody>
</table>

The rotor speed reduction from 1000 rpm to 900 rpm resulted in several factors which proved beneficial to this particular system's shredding operation. The test results confirmed preliminary calculations which predicted a substantial reduction in power consumption with reduced rotor speeds. A savings of 1.47 kWh/ton (1.62 kWh/t) was realized for a 21.6 percent reduction in power consumption at 900 rpm.

Startup power consumption was also reduced. At 900 rpm the average peak kilowatt value during startup was 285 kW compared to 325 kW at 1000 rpm. At 1000 rpm the startup time was 27.5 sec compared to 17.5 sec at 900 rpm. The time reduction of 10 sec was a 36.4 percent decrease in startup time.

A second rotor speed reduction to 720 rpm resulted in an average peak startup power draw of 267 kW. The average time required to attain full speed of 720 rpm was 15.7 sec. At 720, the average power consumption was 5.78 kWh/ton (6.37 kWh/t), a slight increase from the 900 rpm figure.

The initial speed reduction from 1000 rpm to 900 rpm permitted a sizeable power cost reduction with essentially no reduction in shredder capacity or performance. The shredder performed satisfactorily at the 900 rpm speed for 16 months prior to the second reduction to 720 rpm.

Because of the increased power consumption from 900 to 720 rpm with full grates, and the decreased power consumption from 900 to 720 rpm with partial grates, our recommendations for shredder rotor speed is dependent upon the end use of the shredded refuse. The minimum energy required to shred materials at a specific throughput capacity while also achieving an exact nominal particle size is dependent upon the system's total kinetic energy. This kinetic energy is a function of \( WK^2 \) times the unit's rotational speed. When the KH 12/18 shredder speed was reduced to 720 rpm, the system's kinetic energy alone was reduced to a level below that required to maintain the same work rate experienced at 900 rpm. Therefore, we had established that this unit's minimal acceptable shredder rotational speed is in excess of 720 rpm when a full grate configuration is used.

Monitoring of the shredder operation both before and after the speed reductions did not show any significant change in shredder operation as related to throughput. Nominal particle size did increase slightly at 2.11 in. (53.6 mm) at 1000 rpm to 2.34 in. (59.4 mm) at 900 rpm. This 11 percent increase in the nominal particle size resulting from the speed reduction is not considered significant for this particular installation as the end product is landfilled.

Our experience with air classification and screening techniques indicates that an increase of 11 percent in nominal particle size will not affect the operation of this type of recovery equipment. Consequently, it can be said that reducing this size shredder rotor speed to 900 rpm would not have any major effect on shredder operation or performance of the back-end processing equipment.

During the lengthy period of operation at 900 rpm, the upper rear grates of the shredder were removed to determine what effects if any this had on power consumption (refer to Fig. 1). In similar fashion, operating tests at 720 rpm with full grates
as well as with the upper rear grates removed provided data to compare with the 900 rpm data. With the upper grates removed, the power consumptions were 2.65 and 3.26 kWh/ton (2.92 and 3.59 kWh/t) for 720 and 900 rpm respectively.

RtAR

UPPER

GRATES

35'

90'

FRONT

HALF

REAR

HALF

LOWER

GRATES

TOTAL GRATE ARC IS 190'

FIG. 1 SHREDDER LAYOUT

When particle size requirements change, most horizontal shaft shredders can easily be adapted to provide the desired particle size. As an example, if a uniform particle size of nominal 2.5 in. (63.5 mm) is required, the recommended operating parameters for the Model KH 12/18 shredder would be 900 rpm with a full set of 4.8 in. (123 mm) grates. The resulting power consumption would be approximately 5.34 kW/ton at an average feed rate of 25 tons/hr (22.7 t/h). The shredding energy at this level is 162.7 hp (121.2 kW). For a situation where the nominal (90 percent passing) particle size could be large, such as 6 in. (152 mm), removing the upper grates in the rear of the shredder will result in producing the larger particle size. Under these conditions, the 720 rpm speed would be appropriate with a resulting power consumption of about 2.7 kWh/ton (2.9 kWh/t) and an average feed rate of 23.4 tons/hr (21.3 t/h). The available shredding energy at this level is 77.1 hp (57.5 kW).

A second area of potential savings is through reduced component wear. The additional component life achieved by speed reduction will require a long range study which is now in progress. Initially, simple logic and an independent test report will be used to support the theory of reduced component wear.

At 900 rpm, the shredder internal wear items, such as hammers and deflector grates, are subject to only 90 percent of the abrasive incidents which occur during shredding at a speed of 1000 rpm. Consequently, the wear due to abrasion should be reduced and result in a longer component life. An increased wear life for hammers, deflector grates, and grates reduces both material and maintenance costs, thus lowering that increment of operating expense.

A long term monitoring program will be required to verify the exact reduction in component wear. Previous work in this area has been carried on at the University of California at Berkeley by George Trezek. His work generally concurs with our analysis. His review of hammer and grate bar wear used a horizontal hammermill operating at 1200 rpm and 790 rpm. The basic conclusions Trezek reported included a reduction in wear of 31 percent for hardfaced hammers, 43 percent for nonhardfaced hammers, and 36 percent for grate bars when the hammermill operating speed was decreased from 1200 to 790 rpm [1].

GRATE ARC AND GRATE AREA TESTS

A second task was to evaluate the shredder’s performance at the same speed with various grate configurations. This was required to determine grate arc effect on power consumption and particle size distribution. The objective was to establish grate arc configurations which would provide a required nominal particle size with optimum shredder performance. This would serve as an alternative to the conventional horizontal shredder approach of grate opening adjustment for product size control.

The current grate arc of the KH 12/18 refuse shredder is approximately 190 deg., which is distributed through three quadrants as detailed in the shredder layout (See Fig. 1). In an attempt to determine what portion of the grate arc is actually providing the work surface, tests were conducted altering the grate arc and therefore grate area. Tests included the removal of the entire grate sections and other test sequences used blocked grate sections. The performance of the shredder was monitored on a continual basis and analyzed.

The work involved in shredding municipal waste was measured on a kWh/ton basis for these tests.
In the order of "increasing power consumption per ton of refuse processed," we have compiled the listing shown in Table 1. The results were that which would logically be expected. As the amount of open area in the grate section increases, the work required to pass the refuse through the discharge area is decreased. Operating with the grates completely removed resulted in the lowest shredding energy consumption and the largest nominal particle size. All of these tests were performed with a rotor speed of 1000 rpm.

The blocked front grate test resulted in the highest usage of power. This test allowed the shredded refuse to exit through a 125 deg. grate arc. As the material was held in the shredder longer, the blocked front grate section acted as a cutter bar assembly for all of the feed material. Consequently, this shredder geometry resulted in more work being done on the product. This test yielded the highest power consumption of 12.5 kWh/ton (13.7 kWh/t) and the smallest nominal particle size of 1.83 in. (46.5 mm) of the series. The throughput rate for this test was 15.4 ton/hr (14.0 t/h) of refuse.

Particle size structure varied with open grate area. The greater the amount of open area in the grate section, the larger the particle size. The nominal particle size of the samples taken is included in Table 1.

To determine a lower limit for the minimum size of grate arc which could be used while still maintaining satisfactory operation with the equipment, a greater portion of the grate arc was closed off. The entire rear half of the machine, a total of 125 deg. or 66 percent of the grate arc, was blocked. With this shredder grate configuration, the feedrate was 18.6 tons/hr (16.9 t/h) compared to a normal operation of 20.0 tons/hr (18.1 t/h) at 1000 rpm.

The conclusion which can be drawn from this data is that the Allis-Chalmers shredder design, which incorporates an internal deflector grating system and an undirectional rotor, can operate at a performance level of 90 percent design capacity with a 65 deg. grate arc. It is, therefore, evident that more than the 65 deg. grate arc contained in the front grate quadrant is required for operation at the shredder's design level.

Another of the many alternate grate arrangements possible with this system is the removal of grates from various sections of the shredder. Removal of grates from the rear half of the shredder results in a configuration with the shredder operating with the deflector grating and 65 deg. of grates in the front section. Primary or rough size reduction is an excellent application of this type of grate geometry. The nominal particle for this particular test was 7.56 in. (192 mm). Some of the plus 4 in. (102 mm) particles were rather large pieces of textiles, shoes and plastic containers.

The power consumption, 5.7 kWh/ton (6.3 kWh/t), was lower than that of normal operation, 6.8 kWh/ton (7.5 kWh/t). Both tests were conducted at 1000 rpm. The reason for the lower power consumption is that the tougher items, which usually receive most of their size reduction in the grate area, are carried over the front grates and discharged through the open area in the rear of the shredder. Therefore, the work done on these tougher items is minimal and consequently results in a lower power consumption.

Operating the KH 12/18 shredder with all the grates out leaves the impact action of the hammers and the shearing action which occurs between the hammers and the deflector grating as the two contributing mechanisms for size reduction. The end product sizing characteristics are similar to those of the preceding section, in that the more durable items may pass through the shredder without being appreciably size reduced. Typically, these items include boots, shoes, heels, plastic milk cartons and textiles.

A shredder arrangement of this type would be most useful in primary reduction of commercial waste such as large cardboard cartons, pallets, empty containers and other light industrial refuse. The power consumption for shredding with all of the grates removed was 3.4 kWh/ton (3.7 kWh/t), the lowest energy input recorded for any of this series of tests. The nominal (90 percent passing)

<table>
<thead>
<tr>
<th>TABLE 1 POWER CONSUMPTION, GRATE ARC AND GRATE AREA TESTS*</th>
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<td>GRATE GEOMETRY</td>
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<tr>
<td>ALL GRATES OUT</td>
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<td>REAR GRATES OUT</td>
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<tr>
<td>NORMAL OPERATION</td>
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<td>REAR UPPER AND LOWER GRATES BLOCKED</td>
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<td>FRONT GRATES BLOCKED</td>
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* 1000 RPM (ROTOR SPEED) — 100 mm GRATE OPENINGS
particle size was 10.8 in. (274 mm) with the average particle size (50 percent passing) of 4.5 in. (114.3 mm). This last test arrangement presents many interesting possibilities.

One area of equipment evaluation for large scale and very complex resource recovery projects centers around size reduction equipment. Large size primary shredders and their large motors are coming under careful evaluation in these high capital cost and energy intensive programs. Interest has risen in high capacity-low energy shredders as demonstrated and/or associated with various styles of reduction units. One of these styles is the Flail-Mill.

The Flail-Mill is commonly constructed with a double rotor-double motor drive design and has cutting blades rotating towards the centerline of the feed chamber. Chains, hammers, discs and other impact devices can be aligned along the horizontal rotors to break up the incoming refuse. In a solid waste system, the final product after flailing may be a nominal 8-12 in. (203-305 mm) particle size (90 percent of the material passing a screen with 8 in. x 8 in. or 12 in. x 12 in. openings).

Data on most standard horizontal shredders indicates that field experience to date has been compiled on raw refuse shred to a nominal 1 in. (25.4 mm) particle size for R.D.F. generating plants and up to a nominal 4 in. (102 mm) size for shredded millfill systems. The necessity for typical sectionized grates to control particle size on horizontal mills has been fully demonstrated.

Our particular design horizontal hammermill and possibly others can be used as a Flail-Mill, primary shredder, or secondary shredder by addition, change or elimination of the grate sections. By removing the entire grate system as reviewed in the last test program, the equipment can take on the high production rate at low energy consumption with larger particle size. Our design still maintains the patented reject capability for elimination of large unshreddables.

Most horizontal shredders allow for the addition of a variety of grates with large or small openings. This allows for a change in the outfeed particle size. Once the system becomes operational, or if after a few years the plant's output needs demand a product size variance, easy adjustments can be accommodated. A minimal size reduction step with a flail mill prior to using a trommel screen or air classifier may enhance a resource recovery system's operational characteristics.

CONCLUSIONS

The Allis-Chalmers Model KH 12/18 solid waste shredder is adaptable to many operating conditions. Because of the flexibility designed into the shredder, a wide range of particle size distributions can be achieved. The modification to change particle size is easily carried out. No structural modifications are needed.

The specific conclusions of the combined test program are:

1. At 900 rpm, energy is conserved, as compared to operation at 1000 rpm. A savings of 1.47 kWh/ton (1.62 kWh/t) was realized: this is a 21.6 percent reduction in power consumption compared to the 6.81 kWh/ton (7.51 kWh/t) at 1000 rpm.

2. System capacity is not affected by operation at 900 rpm. Monitoring of the shredder operation both before and after the speed reduction did not show any significant change in shredder operation as related to throughput or material which could be shredded.

3. Particle size did increase slightly when changing from 1000 rpm to 900 rpm; however, the increase should have no effect on back-end processing equipment such as air classification or screening.

4. Startup power consumption is reduced as the rotor speed is reduced.

5. The grate open area and grate arc of the KH 12/18 refuse shredder have a definite control in shredder operation and performance.

6. Power consumption (kWh/ton) decreases as grate bars are removed from the shredder. Removing all of the rear grates, a 125 deg. arc, resulted in a 22 percent reduction in power consumption when compared to normal operation with all grates in.

7. Particle size increases as grate bars are removed from the shredder.

REFERENCE


Key Words: Cost Reduction, Energy, Power, Refuse, Shredding
Discussion by

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It is encouraging that the authors have chosen the empirical approach in developing their data. They are to be congratulated for presenting field test results from full scale prototype equipment operating over an extended period of time which, in the opinion of this discussor, is the preferred basis for developing realistic performance projections [1].

Referring to subheadings in the paper:

CHARACTERISTICS OF THE ALLIS-CHALMERS DESIGN

It is laudable that their design recognizes the importance of shear force interfaces within the mill and presumably has dismissed the conventional adjustable breaker plate as a useless legacy of warmed-over rock crushers. (There is, however, a modicum of trepidation anent the reliability of any escape or rejection device).

The responsibility for excessive top size fractions so troublesome in most RDF production is at least partially due to the absence of shear interfaces in primary shredding (the breaker plate myth prevailed). Downstream processing, air classification, secondary shredding, etc. has borne the entire guilt burden unfairly.

THEORY OF SHREDDING

The specific energy consumption (kWh/ton) data presented shows reasonable overall agreement with data reported elsewhere [2,3,4] under similar conditions and with significant commonalities, i.e.:

- Long term data collected from operational plants feeding similar MSW.
- Medium to large horizontal shredders producing a similar product nominal top-size, $X_i$, with low to moderate average hourly feed rates.

A comparison, however, with a recent EPA report [5] of theoretical and pilot scale projection techniques for shredder performance is difficult in correlating specific energy consumption versus nominal particle topsize, $X_i$. Curiously, however, the EPA report shows close correlation of kWh/ton vs characteristic particle sizes, $X_0$, compared with several other operational plants.

This suggests that the theoretical approach is close to reality for characteristic particle size relationships ($X_0$), but seems to stray for nominal topsize ($X_i$) parameters.

These disparities must inevitably be due to the infinite heterogenic vagaries of MSW and the universally erratic mass feed rates to operational mills.

Caution, therefore, is urged in expecting the theoretical approach, however sophisticated, to provide a realistic basis for predicting certain performance criteria, i.e., energy peaks and consumption with extrapolations thereof, along with related throughput capabilities. I suspect that the authors will concur with this personal conviction.

Regarding rotor inertia, $W^2$, and mindful that cyclic torque swings from 20 percent to 200 percent of nameplate torque in a second or less are not uncommon, let's continue the authors' discussion.

As they state, $W^2$ is not a direct index of fragmentizing capability [6]. It is vital, however, when the going gets tough, e.g., choke feed or near stall conditions, considering the intolerance of shredder motors to a reduction in rpm. At such times, the flywheel effect of ample $W^2$ is appreciated. Fluid coupling could ameliorate, but such experience to date in auto shredding plants has been poor, -- response, leakage, etc.

The authors' contention that “shredding energy should be the basis for comparison” is undeniable, provided, however, that there is sufficient rotor $W^2$ (flywheel effect) regardless of the greater influence of rpm on shredding energy ($1/2 W^2 R^2$).

Although not at all implied in the paper, an absurd equivalence of kinetic energy can be attained via inordinately low $W^2$ and high rpm, -- a simple less expensive cop-out. This tactic was employed a few years ago by a well known manufacturer and swallowed by an uninformed consultant. Result: delays and abandonment of a mucho needed project.

The minimum rpm to sustain an acceptable throughput and product size without sacrificing the ability to reduce any unavoidable difficult material is, of course, “De Rigeur”.

In discussing rpm, the hammer circle diameter (omitted from the text) might also be stated to establish a hammer tip velocity as a meaningful common denominator. Also missing is the hammer weight and rotor $W^2$, which although not neces-
sarily required in the discourse, helps establish a more complete perception of capability.

**GRATE ARC AND GRATE AREA TESTS**

The authors' data appear to correlate closely in method, scope, and results with other field tests [2,4].

**DISCUSSOR'S CONCLUSION**

It is hoped that the authors will continue the empirical approach to developing shredder performance criteria and with their usual candor.

**REFERENCES**


Discussion by

Leonard F. O'Reilly
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A quick glance at the table of contents of the Proceedings of past Conferences demonstrates the crying need for basic data for evaluation of refuse shredders. One must wait until the Boston Conference of 1976 before finding any papers strictly devoted to shredding of waste or experience with shredding. A notable first step was made in 1976 with the papers of Robinson and Franconeri. This paper adds valuable information to the refuse shredding experience.

Franconeri's paper opens the curtain with qualitative analysis and spread sheet-type comparisons of various types of shredders, followed by Robinson's paper tying together the refuse shredding process into a complete and whole system. The present paper takes the next logical and badly needed step. That is, attempting to quantify such related variables as speed and power consumption as well as particle size and grate section area.

The authors immediately place things in the post-Energy Crisis environment by demonstrating potential energy savings available from proper speed reductions and economical choice of end product particle size. Here we see for the first time an opportunity for comparing at least horizontal shredding mills based upon power consumption for a standard throughput of refuse tonnage. Comparative tests on other manufacturers' equipment, as well as the rest of the Allis Chalmers line, should result in a series of curves, permitting the designer to select the best speed, and hence best economical marriage, for motor, shredder and shredding system. There is no good reason why curves of prime mover power consumption in kWh or other convenient units cannot be plotted against mechanical energy such as WK^2 X rotational speed^2, except lack of installations; and this list is growing every day. Curves can be prepared at various speeds, for example, as in this paper, 1000, 900 and 720 rpm, in a manner similar to system curves for pumps or fans.

The authors also contribute the first solid data on particle size versus grate area for a given speed (1000 rpm). Again, plotted as a curve for this shredder at this speed, the most economical configuration can be selected. The authors are encouraged to repeat the test for the 900 and 720 rpm speeds for comparison with the results at 1000 rpm.

This paper is a good first step in quantifying proper shredder selection. It also issues a challenge to other manufacturers to test and compare numerically their equipment against the Allis-Chalmers installation in Outagamie County, Wisconsin.