

THE PLACE OF THE TROMMEL IN RESOURCE RECOVERY

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ABSTRACT

This paper describes the applications of and specifications for trommels as used in various waste processing and resource recovery operations. It provides system design engineers with general guidelines and rules-of-thumb useful in defining performance requirements, as well as creating design and construction specifications for trommels being used in areas such as raw MSW processing, classifying C&D debris, sorting for MRFs, screening mass-burn incinerator ash, and compost processing. Additionally, the paper compares the trommel to alternative screens, such as the vibrating and disk screens.

F = Fill fraction
 g = Acceleration due to gravity (L/t^2)
 K_v = Velocity correction factor
 L = Drum length (L)
 N = Drum speed (R/t)
 N_c = Critical drum speed (R/t)
 Q_v = Volumetric throughput (L^3/t)
 Q_m = Mass throughput (M/t)
 T = Residence time (t)
 V = Material axial velocity (L/t)
 V_{est} = Estimated material velocity (L/t)
 x = Material advance per revolution (L)
 α = Drum slope (deg.)

NOMENCLATURE AND UNITS

In order that the equations presented in this paper work with both English and metric units, they have been derived without presuming any particular units. All variables defined below have units specified simply by length (L), mass (M), time (t), degrees ($^\circ$), or revolutions (R). Application of the equations requires the user to convert all input data into values with consistent units; for example, mass throughput may need to be defined in pounds per second, instead of the more customary tons per hour, if other variables in the equations use pounds for mass and seconds for time.

A_f = Flow area (L^2)

D = Drum diameter (L)

d_b = Material bulk density (M/L^3)

SCREENING MACHINES

The purpose of any screening operation is separating an incoming product stream into two or more fractions based on size. In solid waste processing, three types of screening machines are most commonly encountered: the trommel, the disk screen, and the vibrating screen.

The vibrating screen, illustrated schematically in Fig. 1, consists primarily of a screen panel mounted in a box. Screens are either punched plate or wire mesh. A drive imparts either a vibratory or gyratory motion to the box. The feed material is agitated, allowing fine material to pass through the screen.

The disk screen, outlined in Fig. 2, consists of a series of shaft-mounted disks. The screen opening is defined by the distance between the disks in one direction, and

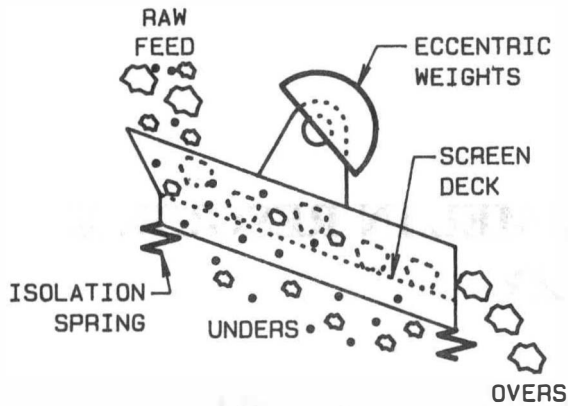


FIG. 1 INCLINED VIBRATING SCREEN

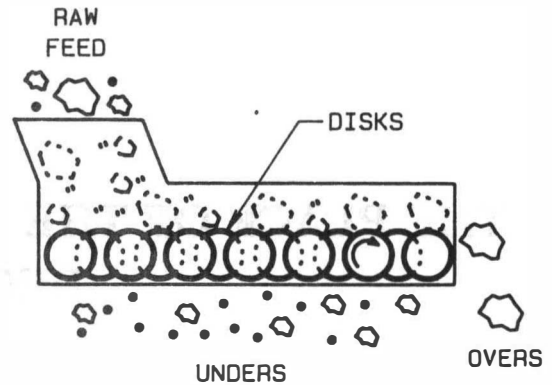


FIG. 2 DISK SCREEN

the distance between the shafts in the other. The shafts rotate, transporting the feed along the length of the machine and presenting the material to the screen openings.

The trommel is a sloped, rotating, screen-covered drum as shown in Fig. 3. As with a vibrating screen, the screen surface may be either a wire mesh or punched plate; punched plate is used much more commonly. The feed advances through the drum by virtue of both the slope and the rotation. The rotation continually turns the material, ensuring that all of the feed is presented to the screen apertures.

Each machine described above has both advantages and weaknesses based on the nature of the feed and the separation desired. Vibrating screens work best with relatively dry, granular mixtures such as grit, separating well and offering a substantial advantage over the trommel in terms of cost and space requirements. The vibrating screen under any circumstance performs poorly when the amount of undersize is a small fraction of the feed stream. Mixtures of this sort (i.e., dry and granular with a high percentage of undersize) are rarely found in waste processing systems, however, so good applications for the vibrating screen are quite few in this field.

Most waste streams consist of damp, heterogeneous mixtures with broad size distributions. They typically contain a high percentage of large, flat oversize items like paper, plywood, or plastic sheeting. Furthermore, a good percentage of the waste may be packed in plastic bags. In order to effectively separate such streams, the feed must be tumbled to prevent these large oversize items from shielding the undersize from the screen. This shielding occurs when undersize material rides across the screen on top of the oversize, never being exposed to a screen aperture. For primary screening

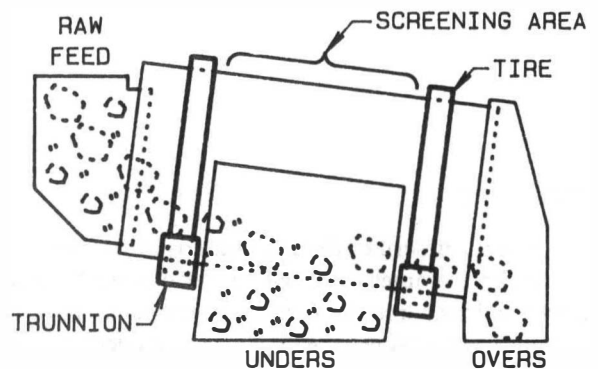


FIG. 3 TROMMEL (ROTARY) SCREEN

(i.e., screening prior to any other operation such as shredding), the screen should be able to break open the plastic bags in order to liberate the material for screening.

The disk screen's inability to turn material over strongly limits its usefulness in solid waste processing. It is prone to the undersize carry-over described above; further, it doesn't break open plastic bags. It shines brightest in applications requiring removal as oversize of long pieces that could conceivably pass on-end through a screen opening. In fact, one of the original purposes of the disk screen was to remove long wooden shives from streams of wood chips. The tumbling action of the trommel can up-end long pieces and pass them to the undersize; the disk screen has little tendency to do that. Disk screens may sometimes be used when scalping, i.e., when the oversize constitutes no more than 10% to 20% of the incoming feed, and large, flat oversize is absent. Disk screens may offer some advantage over trommels in terms of cost and space requirements.

The nature of waste streams generally favors the use of trommels. The primary advantage of the trommel is that, unlike either the disk or vibrating screen, it does thoroughly mix and tumble the feed stream. Further advantages of the trommel include its mechanical simplicity, and its ability to break open many, or, if properly equipped, almost all, of the plastic bags in the feed.

SPECIFYING THE TROMMEL

Creating a trommel specification requires determining the size of opening in the screen or punched plate, the diameter and length of the drum, the operating conditions, the type of drum construction, the drive mechanism, and any special features required by either the application or installation.

The most difficult aspect of trommel specification revolves around the lack of specific statistical data about the feed stream, variances in feed rates, and variances in the composition of the feed. In his excellent book, *Refuse-Derived Fuel Processing*, Floyd Hasselriis presents a very thorough statistical treatment of "typical" MSW samples, as well as a large compilation of empirical data taken at several production and research facilities. Mr. Hasselriis' book covers in detail some of the concepts that will be touched on here; readers needing more detailed information are referred to it.

The definition of a few terms is in order before proceeding with detailed descriptions. Screening efficiency is defined as the percentage of the available undersize that passes through the screen divided by the total available undersize in the feed. Available undersize is defined as undersize material that is not contained in an oversize container such as a box, bag, or can. Efficiency may be broken down to specific undersize components such as aluminum beverage cans. Screen capacity is the smaller of the feed rate that achieves the desired efficiency or the feed rate that the machine can physically handle. Assuming all other things equal, screen efficiency declines as total throughput increases.

SELECTING SCREEN OPENING SIZE

Determining the size of the screen apertures depends on a combination of factors. The maximum size particle that should pass through the screen, obviously, sets the absolute minimum hole size. The efficiency of the screen in removing particles of a given size, however, depends heavily on how much smaller the particle is than the hole. Particles ranging from half the nominal hole size (half-size) to the nominal size are called near-

size, and show much lower screening efficiencies than smaller particles.

Selecting a hole size thus becomes a matter of identifying a cutpoint or particle size, and trading off between the size of the trommel, the efficiency of removing certain components, and the tolerance for passage of items larger than those whose removal is desired. Consider the example of an RDF plant that also wants to recover aluminum. Aluminum beverage cans have diameters from about 2–2¼ in. (51–57 mm). Crushed cans may expand even further, to say 3 in. (76 mm). To easily concentrate these from MSW in the undersize, the hole should be at least twice the size of the diameter, or at least 6 in. (152 mm). Having a hole of this diameter will also pass some 6 in. (152 mm) material suitable for fuel. Reducing fuel in the undersize by shrinking the hole size reduces the can removal efficiency, thus necessitating a larger trommel to remove the same percentage of cans. Enlarging the hole to 8 in. (203 mm), on the other hand, enables using a smaller trommel, at the expense of more fuel contamination in the can concentrate stream.

The specific details of the system, coupled with the experience of both the user and the equipment supplier, typically dictate the hole size specified. Listed below are some typical hole sizes used in different applications.

MSW

A variety of hole sizes are used depending on the separation desired, and the upstream processing operations. For processing raw or flail-milled MSW, hole sizes from 1 in. (25 mm) to 2 in. (51 mm) are used to remove grit consisting of dirt, broken glass, small rocks, and organic fines. Screening may also be done on 6–8 in. (152–203 mm) holes to concentrate beverage cans. Quite often, trommels in this and other services have two or more different screening sections to produce different size fractions in a single machine. These multi-stage trommels are discussed in more detail in the section on efficiency.

Incinerator Ash

Usual purpose is to concentrate ferrous-rich oversize for more efficient magnetic separation downstream. Holes tend to be small, running from ½ in. to 1 in. (13–25 mm) in size. Also, trommels with no holes are sometimes used as mixers in ash combining or conditioning systems.

Compost

Compost screening may be done either before or after composting. Screening prior to composting removes plastic sheeting and other noncompostable oversize, and typically uses a hole size of 3–4 in. (76–102 mm). Post-composting screening, using screen openings from $\frac{3}{8}$ in. to $\frac{3}{4}$ in. (10–19 mm), typically is done to remove plastic film, or any bulking agent such as wood chips, when processing thin, wet material such as sewage sludge.

Shredded Tires

In most tire shredding operations where the shreds are used as a product, a trommel or disk screen is used to size the product to a 2 in. (51 mm) nominal or smaller piece. Typically, square holes at 2 in. (51 mm), or slightly smaller like 1 $\frac{7}{8}$ in. (48 mm), are used.

MRF Sorting

Screening at 6 in. (152 mm) concentrates cans in an undersize fraction, leaving most paper, corrugated, and plastic bottles in the oversize. As with other MSW processing operations, a smaller screen in the range of 1–2 in. (25–51 mm) can drop out broken glass and other fine grit. One possible drawback to using any mechanical separating device, including trommels, is the tendency for these machines to break glass containers in the feed. This drawback must be balanced against the economic benefit of mechanical sorting.

C & D DEBRIS

Two stage trommels have been employed following disk screens that receive crusher discharge. The trommel separates the disk screen fines into a fine reject stream at around $\frac{3}{4}$ in. (19 mm) that may be used for landfill cover, and a second stage producing a $\frac{3}{4} \times 1\frac{1}{4}$ in. to 1 $\frac{1}{2}$ in. (19 × 32–38 mm) mixture of wood chips and broken aggregate pieces for subsequent separation, usually in a wet process. Oversize is hand sorted into different material types.

DRUM SPEED

The drum speed primarily affects the behavior of the material in the trommel. Drum speed is usually determined relative to the so-called critical speed, which is the angular velocity which produces a centripetal acceleration of 1 g at the screen surface. The formula for critical speed N_c is given by

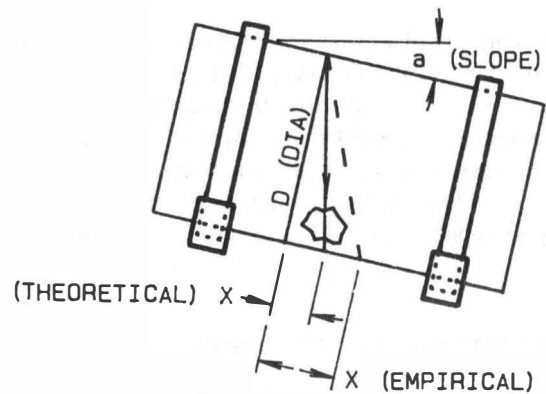


FIG. 4 MATERIAL ADVANCE

$$N_c = (2g/D)^{0.5}/2\pi \quad (1)$$

Note that the time units of “g” must be in minutes if N_c is to be in rpm. According to Hasselriis [1], the screening efficiency increases with speed up until about 50–60% of critical speed, after which it falls off sharply. At the critical speed, material would in essence remain stuck to the screen surface, and the trommel would plug. At about 75% of critical speed, violent agitation tends to keep material in the air and away from the holes. At very low speeds, tumbling action is poor, limiting efficiency, and the drop height is low, limiting total throughput. Normally, drum speed is specified as 50% of critical.

MATERIAL VELOCITY

The slope of the drum will ultimately affect the length, diameter, and efficiency of the trommel. The slope, coupled with the drum diameter and rotational speed, determines the travel rate, and hence the residence time, of the feed. A lower slope increases the probability that a given particle of undersize will pass a hole by increasing the number of times that particle is exposed to a hole, hence improving the efficiency.

Trommels transport materials by lifting them as the drum rotates, and dropping them further down the drum as shown in Fig. 4. The maximum possible lift equals the drum diameter. The maximum material advance per revolution is thus approximated by the equation

$$x = D \tan \alpha \quad (2)$$

Since this advance occurs once with each revolution, the maximum material velocity through the drum is given by

$$V_{est} = Nx = ND \tan \alpha \quad (3)$$

TABLE 1 VELOCITY CORRECTION FACTOR

Slope	K_v
3°	1.35
5°	1.85

If we assume a 9.75 ft (2.97 m) diameter trommel at a 5 ft slope running at 11 rpm, the predicted value for V_{est} equals about 9.4 ft/min (0.048 m/s). Measurements made at the National Center for Resource Recovery (NCR) in New Orleans of the actual travel through a similar drum showed average travel of 20 fpm (0.102 m/s). A second example from a trommel in a North-eastern RDF plant with a drum diameter of 10 ft (3.05 m), slope of 3 ft, and rotational speed of 13 rpm has a calculated velocity of 6.8 fpm (0.035 m/s), and an observed velocity of about 10 fpm (0.051 m/s). Furthermore, other observations of 10 ft (3.05 m) diameter trommels show average velocities of as high as 20 fpm (0.102 m/s) at 50% of critical speed and a 3 ft slope. Obviously, Eq. (3) by itself is a poor predictor of actual average material velocity.

Several reasons exist for Eq. (3)'s failure to match measured results. The assumption that the material travels to the top of the drum is obviously invalid, but suggests that the actual velocity would be lower than calculated, not higher. On the other hand, Eq. (3) neglects any forward momentum that the material possesses. The upstroke portion of the cycle would provide forward momentum, and result in the particle following a downward path more like that shown by the dotted line in Fig. 4. The addition of forward momentum could also result in an acceleration of material in the drum. Since the velocity to use in determining the drum diameter would be the slowest, which would occur at the feed end of the drum, using observations of average velocity may result in undersizing the diameter by overstating the feed end velocity. Measured average velocities would also fail to take into account any acceleration of the material due to the declining percentage of fill in the drum as undersize is removed from the feed. Additionally, no allowance is made for the effect of gravity helping the material flow through the drum.

In order to bring Eq. (3) into better agreement with observed facts, we can add an adjusting factor so that it matched better with our empirical observations. Noting that the most significant difference between the first two examples is drum slope, we rewrite the equation as

$$V_{est} = NDK_v \tan \alpha \quad (4)$$

where K_v is an empirical factor based on slope that adjusts the velocity. Assuming that the actual minimum velocity is three quarters of the way between the value predicted by Eq. (3) and the measured average

values described earlier in the text, we develop the values for K_v , shown in Table 1.

DRUM DIAMETER

Generally, the total throughput determines the diameter of the trommel. While occasionally the maximum particle size in the feed dictates the drum diameter required, normally the drum is sized to be between 25% and 33% full of material. If the fraction of the volume of the trommel that is filled with material is defined as F , the effective flow area in the trommel is

$$A_f = F(\pi D^2/4) \quad (5)$$

The volumetric flow through the drum is

$$Q_v = VA_f \quad (6)$$

If we assume that the actual velocity of the material through the drum at 50% of the critical rotational speed is the value given by Eq. (4), then the volumetric capacity is given by

$$Q_v = 0.088 FK_v D^{2.5} g^{0.5} \tan \alpha \quad (7)$$

It is significant to note that Eq. (7) gives the basic capacity equation for the unit as the trommel is a device whose capacity is properly based on volume, not tonnage.

The throughput based on weight is related to the volumetric throughput by

$$Q_m = d_b Q_v \quad (8)$$

Combining Eqs. (7) and (8) yields a formula for the diameter in terms of the tonnage, bulk density, and drum slope.

$$D = [11.36 Q_m / (d_b FK_v g^{0.5} \tan \alpha)]^{0.4} \quad (9)$$

For example, screening a 50 tph (45.5 mtp) stream of MSW at 8 pcf (128 kg/m³) through a drum at 3 ft requires a diameter of 9.75 ft, (2.97 m) assuming a

33% fill factor. (Remember that all input units must be consistent when using the equations presented.)

Again it is important to note that the diameter is determined by the volumetric capacity not the mass. For a trommel of a given diameter, the feed tonnage must be reduced if its bulk density falls below the design point. Additionally, other than the selection of a rotational speed that, on average, maximizes screen efficiency, no consideration has been given here to screen performance.

DRUM LENGTH

The drum length, in combination with the selection of the hole size, primarily determines the overall screen efficiency in a well designed trommel. The overall efficiency increases with length; however, the amount of improvement decreases as the total length increases.

Trommel drums typically range in length from two to six times the diameter for a single stage unit. As a rule, the material should remain in the drum for no less than 2 min, with residence times of 3–5 min being more common. The residence time of the material in the drum is easily calculated using

$$T = L/V \quad (10)$$

Solving for L , assuming a running speed of 50% of critical, and substituting in Eqs. (2) and (4) yields

$$L = 0.113 T D^{0.5} g^{0.5} K_v \tan \alpha \quad (11)$$

Using the example following Eq. (9) above, and assuming a residence time of 5 min and an actual diameter of 10 ft, the length predicted would be 43 ft.

As with the equation derived for calculating the diameter, Eq. (11) contains no specific reference to efficiency. Either experience or testing is used to determine an appropriate residence time.

SEPARATION EFFICIENCY

The subject of separation efficiency poses perhaps the most difficult part of specifying a trommel. The system engineer must first determine his objective in screening the material in order to define his efficiency requirements. For example, removing grit and organic fines from a stream of raw or flail-milled MSW in order to reduce the loading on a shredder is a fairly simple separation, and the penalty for lower than expected efficiency is quite low. On the other hand, attempting to isolate a fairly valuable commodity like aluminum

cans out of the same stream, or attempting to minimize the ash content of an RDF product, requires more attention be paid to the actual performance of the unit.

Many studies and analyses predicting trommel efficiency have been made. Harvey Alter et al. [2] produced a rather involved mathematical model for predicting capacity, efficiency, and operating conditions for trommels. Much has also been written about tests conducted at the NCCR Recovery I facility in New Orleans: Hasselriis [1] summarizes much of this information in his book.

Despite these efforts, accurately determining efficiency in actual applications remains a near impossible task. Indeed, even producing a verifiable specification for efficiency is an elusive job. Perhaps the most significant difficulty centers on the variability of the feed itself. As was previously mentioned, screening efficiency is defined as the amount of undersize removed divided by the amount of undersize present in the feed. Typically, if the percentage of undersize is not particularly large, screening efficiency declines as the percentage of undersize in the material being screened declines. Variations in the feed, therefore, lead to variations in the unit's efficiency. Variations occur seasonally, as in the case of yard waste in MSW, and they also occur continually in MSW situations as waste from different areas is processed.

This situation creates serious difficulties for a screen manufacturer who guarantees specific screening efficiencies that are close to the limit: he may perform on target with the feed defined in the specification (if, indeed, such a definition is even provided), and yet frequently fall out of spec as the nature of the feed changes. Furthermore, determining actual average efficiencies is difficult and expensive, requiring the taking and analyzing of many samples over a relatively long period of time. If a system designer requires that a manufacturer provide efficiency guarantees, responsible vendors are apt to quote oversized units, or unusually low performance levels.

As is often the case with screening equipment, the system engineer's best course of action is to carefully define his requirements, gain a working knowledge of the basic tradeoffs in screen performance, and work with a knowledgeable supplier to tailor a unit to his needs. It may also prove necessary to build some flexibility into a system by specifying a unit whose screens can be replaced, or whose slope or speed varied.

In spite of the difficulties in accurately determining efficiencies, some generalizations can be made. Rarely will efficiency exceed 80% when removing particles smaller than half-size. Particles half size and larger are generally limited to about 65%. Efficiencies of as much

as 90% may be possible when screening very small pieces through large holes. The larger the hole relative to the cutpoint desired, the greater the efficiency. Efficiency improves with added length, and falls off with greater feed rates. Additionally, as mentioned above, efficiency is less when screening materials with a small fraction of undersize.

The relationship of efficiency to percentage undersize becomes of particular importance when referring to multi-stage trommels. When mixing hole sizes in a single drum, the smaller holes obviously must come first. The small undersize must be removed from the entire feed stream, hence the efficiency is relatively poor. Much higher efficiencies can be realized by screening first on the larger holes, and then screening that undersize on a second unit with the smaller apertures. As always, the economic advantages of an improved efficiency of removal of the smallest undersize must be balanced against the higher cost of using two machines.

A final consideration on screen efficiency is the problem posed by blinding. Rags, nylons, computer tapes, and plastic sheeting are some of the materials that can reduce efficiency by effectively reducing the number of holes in the screen. Some trommels used for finished compost have been equipped with cleaning devices like rotating brushes in order to reduce blinding; at a minimum, the screen should be designed with enough access to allow manual cleaning.

DRIVE MECHANISM

Trommel drums are typically driven either by a chain, or friction driven through the trunnions. (Gear drives, sometimes found on rotary kilns, are rarely used on trommels.) Each system has its advantages, and both are discussed below.

Chain-driven units employ a large main sprocket attached to the drum, and a base-mounted pinion that is generally driven through a gearbox by an electric motor. On larger units, chain drives have fewer mechanical components than their friction-driven counterparts, but are more susceptible to wear in the chain and sprockets in the dirty, gritty environment often found in waste processing operations. On smaller units, the chain and friction models both have about the same number of drive components, but the chain-driven model has the added expense of the drum sprocket and chain.

Friction drive trommels power the drum directly through the support trunnions. The weight of the drum and its contents determine the size of the trunnions and the number that must be driven. On smaller units, the

two trunnions on one side of the unit are generally enough to power the unit. Larger, heavier units generally require powering all four trunnions. In all but very long models, a gearbox coupled electric motor can drive both trunnions on a side, one directly and the second through a longitudinal shaft coupling one trunnion to another. Very long, heavy units require driving each of the four trunnions separately, which generally puts a chain drive at some cost advantage.

DRUM CONSTRUCTION

While trommel drums have been built in a wide variety of ways, two basic types of construction are used. One type is the rigid frame method. In a drum of this sort, screen cloth or punched plate is attached to a rigid, self-supporting frame. If screen cloth is used, this is the only type of construction that is possible. Care must be taken that the frame can indeed support itself between the trunnions. Because of the difficulty in constructing a large frame with sufficient rigidity, this method of construction is typically found only on smaller units.

In the alternate method of construction, the punched plate screening surface itself contributes to the strength and stiffness of the drum's frame. Built in this semi-monocoque fashion, quite large trommel drums are possible. The punched plate can be either welded or bolted to the frame; bolting, however, offers some advantage if the plates ever need replacing, either due to wear or the need for a different opening.

One of the most significant components mounted on the drum is the tires. (The tires are shown in both Figs. 3 and 5.) On small, light units, the tires are often made from rolled channels, tubes, or fabricated sections. While adequate for small units, these types of tires are best avoided on larger, heavier machines. The better quality large units employ one-piece machined ring forgings. Additionally, attention must be paid both to the mounting of the tire and the portion of the drum to which the tire is attached. The best system welds the tires directly to heavy rolled-plate inlet and discharge shells.

Most buyers specify the use of lifters in the drum. The lifters, illustrated in Fig. 5, help both by increasing the tumbling action, and by raising the material higher in the drum, thus increasing the axial velocity, and hence the unit's volumetric capacity. Lifters are usually between 4 in. and 8 in. (102–203 mm) deep, depending on the drum diameter. Lifters do suffer from two drawbacks. First, moist fine material tends to agglomerate on them, requiring periodic cleaning. Lifters also tend

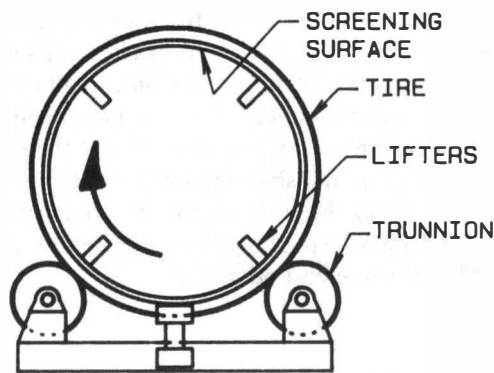


FIG. 5 TROMMEL END VIEW

to up-end long pieces, enabling them to pass through the screen. Some units are built without lifters to eliminate just that problem. In that case, volumetric capacity is reduced.

OTHER COMPONENTS

One of the most important components of the base assembly are the trunnions. The trunnions in most quality trommels are either steel castings or weldments, supported on either side by heavy-duty pillow block bearings. Less expensive, light-weight units may use rubber covered trunnions with pillow blocks, or, in even cheaper units, forklift wheels with a single bearing mounted in the center of the wheel. While on units with very light drums and friction type drives the use of rubber covered trunnions may be mandated in order to create enough friction for the drive to function properly, the covered trunnions wear less well and are more subject to damage.

The angular alignment of the trunnions relative to the drum controls axial movement of the drum assembly, so regardless what type of trunnions are used, they must have a provision for rotating. Usually, the pillow blocks supporting the trunnions can be adjusted along a line at right angles to the drum, allowing for either rotation or axial movement of the entire trunnion. The angle of the trunnion mounts should not be so steep as to make moving the bearings too difficult.

Finally, units with steel trunnions should have provision for lubricating them. Drip oilers, located above the trunnions that are downrunning on the drum side, are sufficient to lubricate both trunnions and the tire. Lubrication helps eliminate galling or scoring of the tires and trunnions. Furthermore, while friction-driven drums actually enjoy better full-speed drive capacity with oiled trunnions, slippage may result when starting, or at low RPM.

Another important part of the base are the product collection spouts. Care must be given in designing the hoppers to prevent excessively shallow gathering angles, or pinch points between the drum and the hopper. Some access should be provided in case plugs do occur. Additionally, the feed point should be designed in a way to minimize the possibility of spillage at this point.

The specification of a trommel wouldn't be complete without considering the system of which the screen is a part. Some waste processing systems, for instance, are slug-fed by front end loaders. Feeding in this manner creates spikes in the feed rate that may overwhelm a machine designed to see only the average feed rate. Care must also be given in sizing discharge conveyors so that they can handle extremes in terms of undersize passing the screen, or variances in bulk density.

SUMMARY

While the trommel is a relatively simple device, there can be many hidden pitfalls in their application. They vary widely in quality; purchasing a "bargain" unit may result in extensive downtime. The wide range of composition of most waste streams results in the system engineer needing to carefully consider the full range of possibilities, and be prepared to deal with them. As with any piece of capital equipment, the buyer is well advised to work closely with a knowledgeable, reputable manufacturer.

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