Meal Pelleting and Cooling

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ABSTRACT AND SUMMARY

Pelleting is a process of conditioning, compacting, and extruding a finely divided material resulting in larger particle sizes with greater bulk density and improved flow characteristics in which dust is essentially eliminated. The process has a relatively short history beginning in 1929 with the conception and design of equipment using the die and roller principle. Conditioning is accomplished by the use of good quality steam added at a controlled rate to a regulated flow of material in a paddle type mixer integrally mounted on the pellet mill. This steam adds heat and moisture to enhance the pelleting characteristics of the material. Compaction is accomplished by the action of the rolls upon the die face which also supplies the force necessary to extrude the material through the die holes thus forming pellets. In the pelleting of oilseed meals the sizes of pellets are generally limited to 1/4 in. diameter for export with 1/4 in., 3/4 in., and 7/8 in. being quite common for animal feeding. Many times the 3/4 in. or 7/8 in. pellets are broken through crumbling rolls to form a coarse, granular product. A cooling and drying step is necessary following the pelleting process to remove heat and excess moisture to result in a stable product. This step is accomplished by the use of either a vertical or horizontal cooler by means of which ambient air is drawn through a moving bed of pellets. Exhaust air from this process must be discharged to atmosphere through an efficient cyclone collector to remove entrained dust and feed particles. Following the cooling step the pellets are usually screened to remove the particles smaller than the pellet, though in the export trade this step may be eliminated. It is desirable to remove extraneous material from the feedstock ahead of the pellet mill in order to protect the dies and rolls. This is accomplished by magnets in the case of magnetic materials and high capacity centrifugal screeners for nonmagnetic materials. In the case of solvent extracted meals with a very low residual oil content, it is usually customary to blend back refinery residues to supply a small amount of oil to enhance pellet quality and equipment capacity. Various oilseed meals exhibit different pelleting characteristics resulting in a wide variation in pellet mill performance.

Pelleting is a process in which a finely divided, usually dusty, sometimes light in bulk density, and in most cases difficult to handle material, is, by the application of heat, moisture, and mechanical pressure, densify and extrude into large particles of a stable nature. These large particles, somewhat similar to bulk grain, are generally heavier in bulk density and are less likely to bridge and hang in bulk bins, trucks, railroad cars, barges and ships and are relatively dust free in handling. These improvements in handling characteristics enhance bulk storage and handling operations through improved flow, less dust in handling, and greater utilization of bin and shipping space.

The pelleting process as we currently know it is about as old as the Space Age. In 1929 Mr. E.T. Meakin, owner of the California Press Manufacturing Company, which later became the California Pellet Mill Company, as a result of being called upon to repair European screw type extrusion pellet mills, then being used experimentally by American feed and oilseed companies, conceived the idea, designed and built the prototype of the California pellet mill utilizing the die and roller principal of compaction and extrusion. This principle is currently used in the feed and ingredient pelleting field throughout the world. Coincidentally it was also in 1929 that Dr. Goddard, father of modern rocketry, successfully launched his first liquid fueled rocket. Although the pellet mill industry has not had the unlimited funds of NASA to put pellet mills on the moon, on Mars, or in outer space, pellet mills are, in general use in practically every area of the Earth.

While it is difficult to separate fact from fiction, the prototype pellet mill is to current units as the 1900 model automobile is to the 1977 model automobile. The prototype was a 20 HP unit producing about one ton per hour of poultry feed. It is interesting to note that the drive utilized a set of gears from the differential of a one-ton Ford truck. The life of a set of gears was 1 wk to 10 days, and the company operating the unit had a standing order with the local Ford agency for a set of gears a week. Apparently this was lower in cost and less trouble than were the various screw and gear type pellet machines which were then being built in Europe and being used in a limited fashion in the United States.

The first 30 HP mill of practical design was installed on poultry feed in 1931, and not far behind in 1932 the first unit on oilseed meal was installed in the plant of Traders Oil Mill in Ft. Worth, TX, operating on expeller cottonseed meal. It was capable of producing 1½ tons per hour of ¾ in. round pellets or cubes. It was apparently the first practical approach, as repeat installations were made by both Traders and other oil mills.

The principal of this original pellet mill is shown in Figure 1. A flat die was used of the appropriate hole size and thickness, and four rollers were turned on the top of this die driven by a column supporting arrangement. The

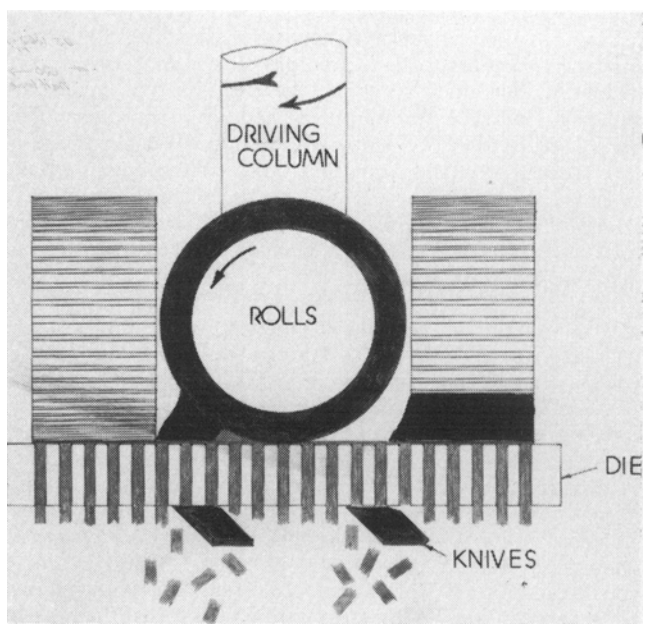


FIG. 1. Principle of original flat die pellet mill.

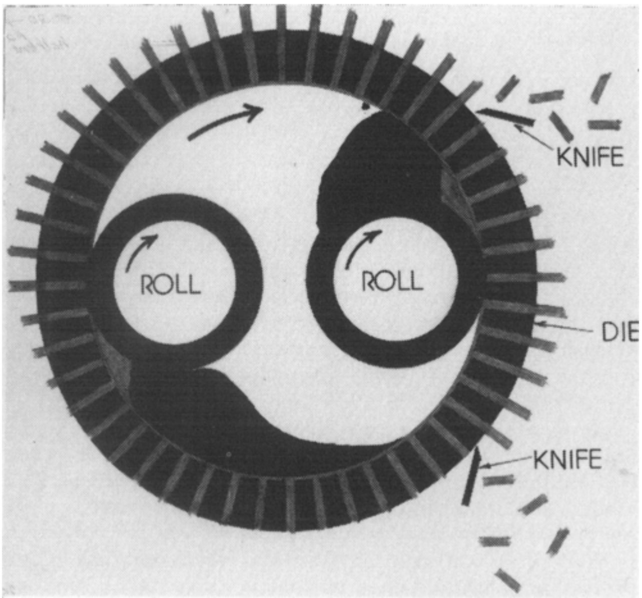


FIG. 2. Principle of modern ring die pellet mill.

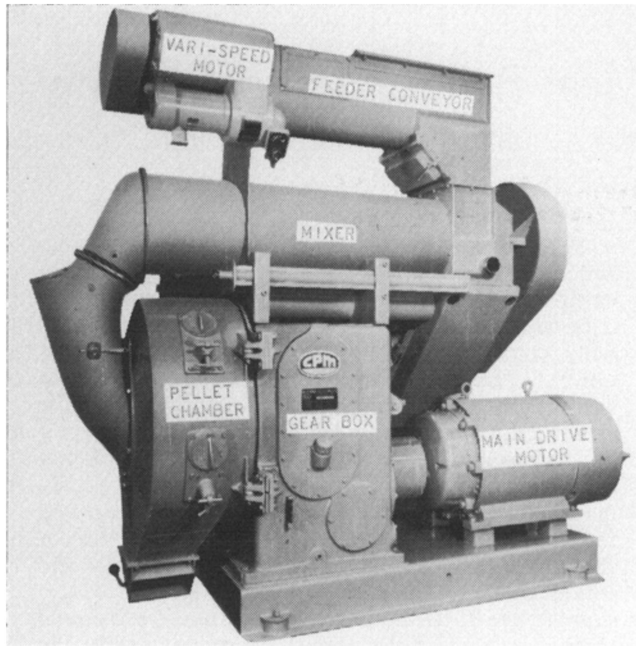


FIG. 3. Pellet mill – component parts.

rolls turned through contact with the die. The length of the pellet was determined by a series of knives driven by the driving column when making small pellets and by a special variable speed drive when making large pellets or "range cubes." The die was held by a tapered clamp and was easily removed from the bottom of the pellet mill. The first mill of this type was driven by a 30 HP motor, and through three models of the unit the horsepower was increased to 40, 50, and 60 horsepower. A few hardy souls went to 75 HP though it began to overtax the unit. Even though this unit was discontinued shortly after World War II, judging from personal observations and current die and parts orders, there are still a considerable number of these units in daily use throughout the U.S. Actually there is still a pellet mill using this principle of a flat die and rolls currently being built and installed by a German firm.

In operation you will note that the conditioned feed is carried in front of the rollers by means of deflectors; it is compressed on the face of the die and is extruded as pellets (Fig. 1).

Pellet mills utilizing the flat die and four roller principle were used for pelleting a very large percent of the feed pelleted in the U.S. until shortly after World War II. At this time the necessary die technology and gear transmissions had been developed to make the ring die type pellet mill superior from the standpoint of reduction of horsepower usage, maintenance cost, and installation space per ton.

Consequently the ring die type pellet mills, initially designed in the mid to late 1930s using a die in the form of an annular ring with holes drilled radially through the ring, took over the market and manufacture of the flat die machine was discontinued.

Figure 2 illustrates this principle of pelleting which is still in use today. The die is mounted in a vertical plane affixed to a driving member by clamps or bolts and rotates about two or three rolls which are held in a fixed position. The conditioned material is introduced between the die and rolls by means of gravity and deflection. It is compressed between the die and roll and is extruded as pellets as shown in Figure 2. Two or three knives (depending upon the number of rolls) are used to control the pellet length.

These units were first designed for 25 to 30 HP and at about the time of World War II a 50 HP unit made its appearance. Following World War II the horsepower race began going from 75 to 100 to 125 to 150 to 200 to 250; currently it is at 300 HP. I am sure that the future will bring higher horsepower units where practical and that development of technology will produce the larger dies which will be required.

Figure 3 shows a modern version of the pellet mills currently being used. It is comprised of a screw feeder driven by an electric variable speed drive. This controlled rate of feed is introduced into a paddle type mixer driven by a separate motor. This mixer is a constant speed mixer though the speed of the mixer shaft will, by design, vary depending upon the materials being pelleted. Generally speaking, this speed can vary between 150 and 500 rpm's. In the mixer the feed is usually conditioned by the addition of steam and in some cases, where the meal is extremely low in moisture content, water may be added.

Steam used for this purpose should be a good quality, constant pressure, process steam. Usually high pressure (60 to 125 lb) steam is introduced to the pellet mill through a so-called steam harness designed to remove entrapped moisture and to control and insure the constant desired pressure. Pressues used for oilseed meals usually vary from 20 to 60 lb per sq. in. though, if required, acceptable operations can be established using heating pressure steam that is less than 15 lb per sq. in., though this does at times somewhat limit the flexibility of the steam addition. If water is added at the mixer, care should be taken to use a pressure regulator on the water stream, as water lines have a habit of varying widely in pressure depending upon upstream usage. Many times when the meal is extremely dry water can be more successfully added in the flow as far ahead of the pellet mill as possible; such a procedure makes possible a more thorough blending and even penetration of the moisture.

The conditioned feed is then introduced into the pellet chamber containing the die and roller assemblies as previously shown in Figure 2. The die is driven by the main-drive motor through a precision gearbox at a constant speed. This speed, while constant in operation, will vary by design depending upon the material being pelleted and the size of pellets. Generally speaking, speeds from 160 rpm to as high as 400 rpm are selected.

Usually when making pellets 3/8 in. in diameter and under, on materials weighing over 15 lb per cubic foot, a speed of 250 to 275 rpm is indicated. On lighter materials in pellets of this size a higher die speed is sometimes used to aid in the distribution of the material in the die cavity. In the production of larger pellets or so-called

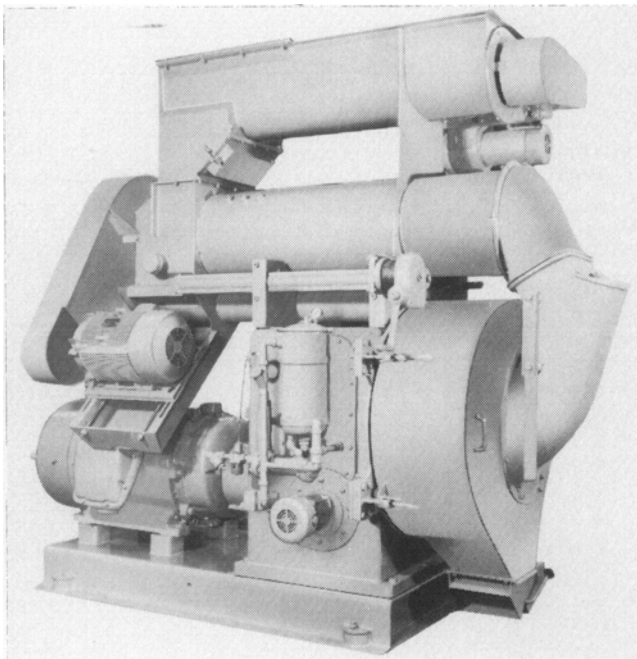


FIG. 4. Pellet mill – oil cooling and circulating system.

"range cubes" 1/2 in. in diameter and up, a low die speed is indicated; usually a speed of 160 to 175 rpm is used.

Today some mills are equipped with speed change mechanisms to accommodate both small pellets and "range cubes." Either these speed change mechanisms are in the form of gearshifts incorporated within the gearbox, or a separate speed change gearbox is incorporated in the drive train.

Usually a magnet is incorporated in the pellet mill in a position to remove "tramp" magnetic metal from the material being pelleted, since foreign material within the meal can contribute to mechanical problems and accelerated die and roller wear. In the case of the mill shown; this unit is located between the feeder and the mixer on the dry, unconditioned meal. In some mills, it is located immediately after the mixer on the conditioned feed. In any event, no matter where the magnet is installed, unless it is cleaned, it can become ineffective in a relatively short time due to the build up of magnetic material and material encrustation on the face of the magnet.

Because pellet mills have increased in size and horsepower, the old system of a splash oil bath lubrication is inadequate. Today all high horsepower power units incorporate piped forced oil lubrication using some type of oil pump, oil filtration, and either water or air coolers for keeping the oil temperature within reasonable limits. Figure 4 shows the reverse side of the pellet mill shown in Figure 3, illustrating an externally driven oil pump, an oil filter, and piping for a water type oil cooler.

Once the pellets have been made, it is necessary to condition them because in the pelleting process, the moisture in the pellets may be increased to as much as 15-16% and the temperature may go as high as 180-195 F. This cooling and drying is accomplished by drawing ambient air through a uniform bed of pellets. No matter what the initial relative humidity, the ambient air, upon being warmed by the pellets immediately transforms into a low relative humidity and then, by a rather complex thermodynamic reaction involving evaporative cooling, conduction, convection, and radiation removes the heat and moisture added during pelleting. Between 10-12½% moisture is left in the pellets, and the temperature of the pellets is reduced to within 5-10 F above ambient temperature.

Generally speaking, pellets made from oilseed meals cool relatively easy, but for export purposes involving large quantities and extended periods of storage it is essential to size cooling equipment at least 1½ times larger than for conventional pelleting operations in order to lower the latent heat as much as possible.

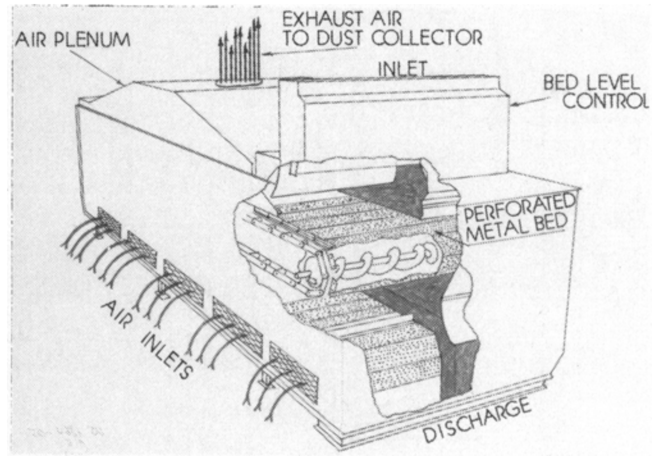


FIG. 5. Horizontal pellet cooler.

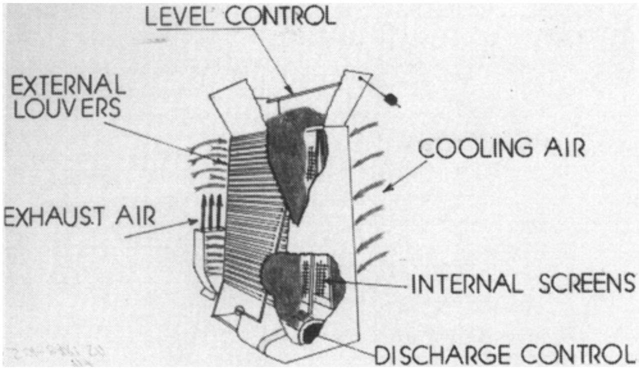
Pellet mill coolers are made in two types, horizontal and vertical. The choice is usually made considering space available, cost, and effectiveness in operation. The horizontal pellet cooler usually costs more, requires more floor space but less height, but is more reliable in operation in that even if operators are inattentive it will not allow passage of uncooled pellets. This unfortunately can happen through channeling of vertical coolers if the operators are inattentive. Generally speaking, most of the high volume pelleting installations made today incorporate horizontal coolers in the flow.

Figure 5 is a typical horizontal cooler. The pellets are delivered from the pellet mill to a device known as a bed level control in order to spread the pellets in an even bed on a perforated cooling belt. This bed level control may be either an oscillating feeder using a constant speed belt or a hopper type leveling device controlling the rate of speed of the cooling belt to conform to the flow rate and selected bed level. As a general rule, the bed level control, even though slightly more expensive, is considered to be the more desirable method in that its use results in lower maintenance on the equipment and also produces a much more even bed for cooling which will cut down thin spots and air channeling.

The cooling belt is currently almost universally made of perforated overlapping metal pans which are mounted on chain carriers. These coolers may be either single or double deck depending upon requirements of the installation. The double deck unit does offer the advantage of somewhat more cooling for the same dollar invested in that a common enclosure can be used for the two belts. As shown in the illustration, air is drawn through the beds by means of a suction fan and exhausted to a cyclone collector to remove any material drawn off of the pellets.

Figure 6 illustrates a typical vertical cooler using two vertical columns of pellets, usually with louvers on the outside surface and with a bar type screen on the inside surface. The material flow through the cooler is regulated by a leveling device in the hopper which controls the rate of the discharge mechanism. While bindicators are sometimes used on smaller coolers resulting in intermittent discharging, the larger vertical coolers have a modulating device which regulates the rate of discharge to correspond to the rate of material delivered to the cooler. Air is drawn through the columns by means of a suction fan and discharged to a cyclone as in the case of the horizontal cooler.

It is important that the material being delivered to the



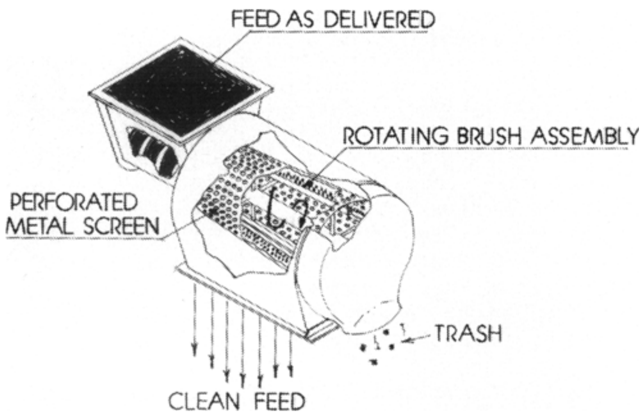


FIG. 7. High capacity feed cleaner.

pellet mill be free of foreign material such as bolts, nuts, welding rods, rocks, wood, and other large extraneous material. Insofar as magnetic material is concerned, the pellet mill magnet, if kept clean, is relatively effective. For nonmagnetic materials other means must be applied. This can be done by some means of screening the feed stock immediately ahead of the pellet mill. One very effective machine in current use is shown in Figure 7. This unit is a compact, trouble-free power driven screener. The units are available in varying ranges of sizes up to 100 tons per hour, are relatively inexpensive both to purchase and to operate, and are highly efficient in removing foreign material.

To have an effective pelleting installation, the various equipment must be properly installed giving a straightforward, uninterrupted flow. A pelleting installation can be simply a pellet mill, a pellet cooler with fan and cyclone, a source of steam and necessary screw conveyors, belt conveyors and bucket elevators to handle the raw material to the system and the pellets from the system. Optionally a feed cleaner is desirable to remove extraneous materials from the feedstock to the pellet mill, and in some cases a conventional screener on the finished pellet stream is used. However, in most pelleting installations handling material for export, no screening is done. In a few rare cases where it is desirable to break the pellets or cubes, a pellet crumbler, using corrugated rolls, is incorporated in the flow, usually immediately below the cooler. A word of caution–it is not a good idea to handle pellets in screw conveyors, because considerable damage can result to the pellets through attrition by the screw conveyors. Rather it is better to use belts, drag type conveyors, or some more gentle means of handling.

All of this equipment can be tied together in a rather simple flow as shown in Figure 8. There is certainly complete flexibility with one exception: you should never elevate hot pellets. They are friable, and they give off steam

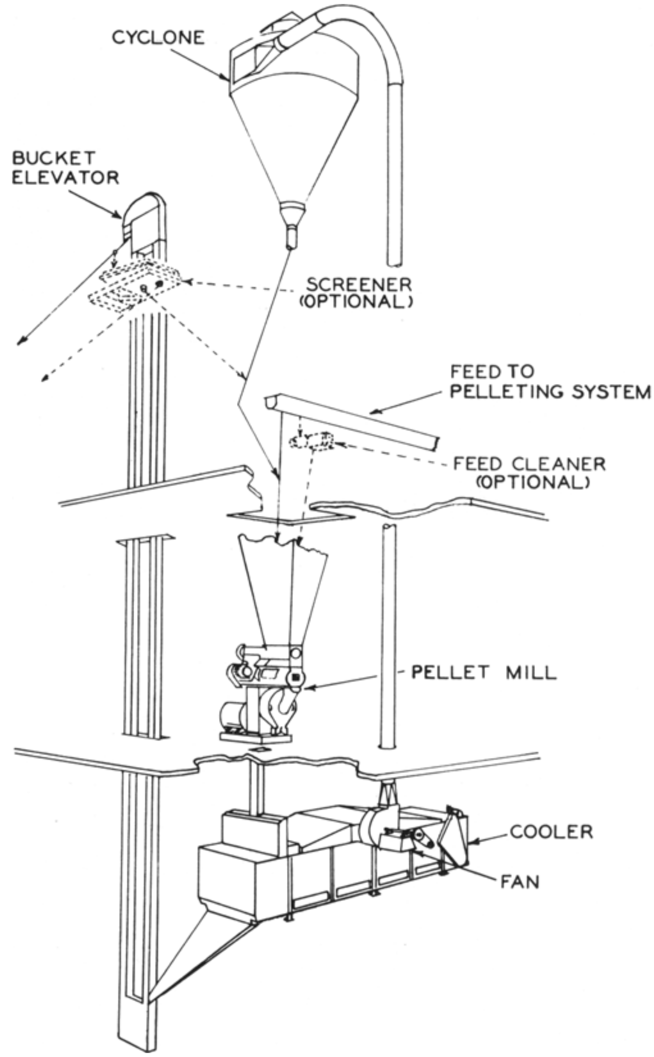


FIG. 8. Recommended pelleting flow.

which condenses causing material buildups and in some cases corrosion to the metal parts of the system.

In order to determine boiler size necessary to produce the quantity of steam required by a pelleting installation a relatively simple formulation as follows can be used.

$$HP = \frac{F \times M}{34.5} \times .83$$

Where	HP	=	boiler horsepower
	F	=	pounds of feedstock per hour
	M	=	moisture to be added; 6% is usually considered maximum
	34.5	=	pounds of water evaporated per hour from and at 212 F equaling 1 boiler horsepower
	.83	=	factor necessary to correct for 100% makeup water at 50 F

This steam should be supplied to the pellet mill as mentioned above through a steam harness recommended by the pellet mill manufacturer, and the piping should conform to good steam flow principles. Care should be taken to provide any low spots in the steam line with drip legs and traps to remove accumulated moisture, since moisture will build up and then be carried by the steam flow through the system at a rate exceeding the capabilities of the water removal equipment of the steam harness.

Dies can be supplied for making pellets in round dimensions from 3/32 in. to as large as 1¼ in. by varying increments of size. Also, in some of the larger sizes, square and oval shapes can be supplied. Insofar as oilseed meal pelleting goes in the U.S., a 1/4 in. round pellet is relatively standard though some range cubes, 1/2 in., 3/4 in., and 7/8 in. round and square are made. In South America for some obscure reason a considerable quantity of 1/2 in. pellets are made apparently moving into the export trade. Frankly, this does not seem too logical as 1/2 in. pellets are harder to cool, and, being larger, are harder to handle through bulk equipment than are the smaller 1/4 in. pellets, which resemble corn in size. For export shipping and/or bunker feeding the 1/4 in. pellet is desirable because it gives the best pellet mill capacity, cooling characteristics, and flow characteristics.

Today basically all of the oilseed meals being pelleted are a product of the solvent extraction process with a relatively low residual oil content. Usually it is customary to blend back the accumulated refinery residue to the meal. This blending serves two purposes. (a) It is a means of disposing of these residues, and (b) the contained oils and gums provide a certain amount of lubrication enhancing pellet quality and pellet mill capacity.

Referring to the pelleting of the materials covered in the morning session, we must deal in generalities as there are many variations in the way the products are handled, all of which affect the pelleting results.

In the case of soybean, cottonseed, and rapeseed oil meal we are dealing with materials that are relatively easy to pellet. Capacities of one ton per 10 HP per hour are common. A large portion of the pellets made are in a 1/4 in. size though in the case of cottonseed in some areas 1/2 in., 3/4 in., and 7/8 in. cubes are made and generally broken up with a standard crumbling roll. Considerable steam is used and, when meal is too dry to condition completely with steam, water may be added. The pellets cool and store well.

Copra meal is a more difficult material to pellet and produce an acceptable product. Capacities will approximate 1 ton to 20-25 HP per hour. Usually depending upon the efficiency of the extraction process, it is desirable to add back some low grade fat or oil. In some cases it is reported that the use of liquid lignin materials are a great advantage from a binding, operating, and wear standpoint.

The pelleting of sunflowerseed products is many and varied. It may involve (a) the pelleting of the hulls alone or in combination with some meal, or (b) in the case of some extraction processes, the entire seed, hull, and extracted meal, or (c) in some cases only the extracted meal. Lately a considerable pelleting operation has been built up around the pelleting of a mixture of sunflower by-products blended with flax shives.

In the pelleting of hulls and materials containing hulls, a fine grind is essential. On the grinder 1/8 in. screens are common and 3/32 in. screens are preferable. In the case of meal, the use of steam is limited as it will darken and even turn the meal black. Capacities will vary widely depending upon materials being pelleted, and, in many cases due to the extreme light bulk density of the materials, the power potential of a pellet mill cannot be utilized. For instance, on a 100 HP mill on straight hulls 2-3 tons per hour is good production, and on straight meal 7 tons per hour has been reported.

There is not a lot of safflower meal pelleted, but it is reported to be similar to sunflower products. Safflower meal must be ground fine and is light and fluffy. Capacities of 4 tons per hour on ground hulls and 6 tons per hour on meal using a 100 HP mill have been reported, with the mills not pulling full horsepower.

Peanut meal seems to be used exclusively in blends with animal feeds and ground peanut shells. No record of pelleting straight peanut meal has come to our attention, and even in our laboratory we have not been called upon to test this material. It does act as an excellent binder for fibrous material when used at a 25-40% level. Certainly there seems to be no reason why it would not pellet as a straight material, but no data are available.

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