

Troubleshooting pelleting operations

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To paraphrase poet Robert Burns: The best laid plans of mice and men often go awry, and leave us nothing but grief and pain instead of promised joy. The pelleting operation is a complex process that deserves careful planning and execution. But inevitably, as is the case in any process where people and machines are involved, desired results will not always be achieved. The following are some key troubleshooting factors to consider that can help reduce “grief and pain” and maximize quality and output during the pelleting operation.

Effective preventative maintenance

Pelleting systems are a multi-faceted integration of mechanical, electrical, hydraulic and pneumatic systems that require an effective preventative maintenance program in order to optimize quality and production output. A good maintenance program will incorporate methods to maintain desired operating conditions, while minimizing unexpected equipment failures and the costs associated with them.

The success of the pelleting operation, as well as all other areas associated with feed mill operations—such as quality, safety, housekeeping and customer service—are greatly influenced by the performance of the mill’s preventative maintenance program.

A preventative maintenance program that works consists of three major parts. These parts are:

- Program goals or objectives
- Program structure and organization
- Management of the established program

Feed Pelleting Reference Guide

Preventative maintenance goals

Goals are essential in developing and maintaining a maintenance program. Unfortunately, at times, mill management may view the costs associated with preventative maintenance as being excessive and burdensome. In these cases, maintenance personnel may simply become a rescue unit, springing into action to try to repair mill breakdowns when they occur, and then standing by for the next emergency. In contrast, appropriate goals provide the maintenance program and associated personnel with a defined direction and structure. A maintenance program that has established goals can become proactive to prevent equipment breakdowns, rather than just reacting to problems as they occur.

Any goal or objective, whether for a maintenance program or other area of mill operation, should have the following characteristics:

- Goals need to be realistic: A goal that is impossible to attain does little but discourage those who are trying to achieve it. Goals should be developed with high standards, but be within reach. Also, a goal is unrealistic if the employees involved have little control over the outcome.
- Goals need to be measurable: A goal should be quantifiable. Most goals should have numbers tied to them. If goals are vague or cannot be measured, no one will know if they have been accomplished or not.
- Goals need to be time-specific: Goals should be developed that have specific time deadlines that

*Section 6: Troubleshooting
Chapter 24: Troubleshooting Pelleting Operations*

provide maintenance personnel defined timeframes to work within.

Preventative maintenance goals can relate to several factors, such as expenses, safety and productivity. Mills can develop specific goals by using historical records, industry standards or computerized models. Each mill operation is unique and should develop goals that meet the needs of their situation. In addition, goals are best developed through the combined input of the employees associated with the maintenance program. Getting employees involved in goal setting gives everyone involved a sense of ownership in what is to be accomplished. Some examples of maintenance goals are:

- Maintain mill maintenance labor and repair/equipment expenses within budget guidelines during the fiscal year. Expense guidelines can be developed on a total dollar basis or a per metric tonne basis. Once expense guidelines are established, actual results can be measured against these guidelines.
- Ensure both the feed mill equipment and facilities are in compliance with mill and government safety standards during the fiscal year. Much of the feed mill's equipment and facility needs to be periodically inspected by maintenance personnel to ensure it meets safety standards. To accomplish this need, goals can be established to help ensure the maintenance department completes these inspections in a timely and thorough manner. This type of goal could be measured through the use of safety or insurance audits.
- Limit mill downtime to allow mill productivity goals to be achieved during the fiscal year. Most mills have systems in place to measure productivity, but the maintenance department often is excluded, since it is sometimes more difficult to quantify its results. However, an effective maintenance program is necessary to achieve desired mill productivity. Thus, it may be appropriate to develop efficiency goals for the maintenance department. Productivity goals can help promote an atmosphere of timeliness in maintenance activities.

Preventative maintenance program structure and organization

To achieve the established goals, an effective preventative maintenance program will have several key elements that help make the program successful. These areas include:

- **Maintenance personnel:** The first step in hiring and employing qualified mill maintenance personnel is determining the necessary skills for each maintenance position. This is especially important in the areas of specialized mechanical and electrical systems. To measure qualifications in these areas for hiring or promoting employees, it may be appropriate to develop tests to ensure individuals meet standards for these skills. Formal job descriptions also play an important role in assigning responsibilities to maintenance personnel. Each maintenance position should have a job description that clearly defines 1) who maintenance personnel report to; 2) who is authorized to assign work; 3) what physical parts of the mill and equipment personnel are responsible for, along with routine lubrication and inspection assignments; 4) documentation and recordkeeping requirements for maintenance activities; 5) personnel spending authority; and 6) objectives for the program.
- **Equipment data/history records:** Every item of equipment in the feed mill at some time or another will require maintenance attention. The various components that make up each piece of equipment must be identified before determining a maintenance schedule. The amount of information required will depend upon how complex the equipment is and what information will be useful. For some equipment, information about motors, gearboxes, drive belts and bearings will be adequate. For other machinery, it may be necessary to collect data on all mechanical, electrical, hydraulic and pneumatic items associated with the equipment. Some of the sources of information for creating equipment data files include: Manufacturers' bulletins and manuals; mill blueprints; purchase records; and conducting a mill walk-through to inspect equipment and gather data. In addition to having

equipment data available, historical repair records on equipment are an essential part of a preventative maintenance program. Equipment history logs need to be developed and major repair or adjustment work posted to these logs as maintenance work is completed. Repair logs can provide valuable information for establishing inspection and lubrication schedules, for determining spare part needs, for tracking repair costs and for justifying equipment upgrades or replacements.

- **Maintenance schedules:** The maintenance department needs to establish routine inspection and lubrication schedules for each piece of equipment in the mill. Management and maintenance personnel can work together utilizing experience and manufacturers' recommendations to determine the most appropriate schedules and procedures for equipment lubrication and inspection. The established schedules should outline the specific work to be completed. For example, the maintenance schedule procedures for a machine should outline what to check during the inspection, and provide information like the type and quantity of lubricant required. Since there typically is a high degree of duplication of equipment within the feed mill, much of the equipment can be lubricated and inspected within the same time intervals, such as weekly, monthly or quarterly. Consolidating equipment inspection and lubrication into the same time intervals, as much as possible, makes scheduling of work and management of the maintenance program easier.
- **Spare parts criteria:** Management and maintenance personnel should review the equipment throughout the mill and identify parts that are critical for the operation. Once identified, management should check with suppliers on the availability of these critical parts. By assessing the part's cost and availability against the potential cost of downtime, a decision can be reached on which parts should be maintained in the mill's inventory. Equipment data and repair history records also are an excellent source of information about parts necessary to keep the mill operating. A review of the maintenance work can show what equipment has required repair parts in

the past and can provide an indication of what parts will be necessary in the future. Evaluating equipment data information can help identify common parts among different pieces of equipment and streamline the number of spare parts needed. Equipment purchasing decisions also should be influenced by the availability of parts for the equipment from suppliers. Standardizing equipment can have many advantages to the mill in terms of operation, ease of maintenance and spare parts availability.

- **Program organization:** Documents associated with the preventative maintenance program such as equipment data sheets, equipment history records, maintenance schedules, equipment manuals, spare parts inventory, and purchase records need to be stored and organized within an orderly system. This system should provide easy access to information and records, allow information to be readily updated and provide an effective way to schedule maintenance work and document required activities. Two systems for organizing preventative maintenance programs are paper file folders and computer software programs. A file folder maintenance system involves establishing file folders for each piece of equipment in the feed mill, developing standardized forms to record equipment data and repair history, making a spare parts list, putting together routine equipment lubrication and inspection schedule forms and providing a method to schedule non-routine maintenance work. Computerized maintenance software programs typically include systems for the areas of equipment data and repair history, parts inventory/ordering, preventative/predictive maintenance schedules, maintenance work scheduling and report generation. Generally, each area is interactive by design. An example of interaction would be that as repair parts are used during maintenance activities, the parts inventory levels are reduced and equipment repair history updated. This type of interaction reduces the time required to manually update separate records and improves recordkeeping accuracy.

Management of the established program

After the mill has put together and implemented the maintenance program, mill management needs to routinely evaluate the program's results against the program's goals. Through this process, management can identify areas of the program that need attention and develop plans for corrective action. Overall, the success of the maintenance program relies on reviewing results and taking the appropriate action to maintain and improve the program.

Managing the maintenance program also should include meeting with maintenance personnel and giving them formal feedback on their job performance. During the evaluation, identify employee's strengths along with their weaknesses. Make plans to help develop employee skills in areas that will benefit the maintenance program. Most maintenance personnel want feedback from their supervisors on their job performance and how they can improve their skills and perform their job better.

Pelleting system design and operation

Avoiding trouble during the pelleting process depends on both a good understanding of how feed ingredients pellet as well as proper pellet system design and operation.

Feed ingredient issues

Both pelleting capacity and pellet quality are influenced by feed formulation and feed particle size.

Feed formulation

Typically, least-cost formulation is used to minimize feed cost based upon the nutritional needs of the animal. However, least-cost formulation may result in a feed that produces a poor-quality pellet and undesirable production rates. Although formulating for pellet quality and capacity may not be entirely possible, using the following basic guidelines can help:

- Generally, the addition of fat to feed mash

before pelleting aids production rates, but also causes lower pellet quality. Adding more than 2% fat at the mixer into corn/soy diets can cause excess fines and low pellet durability. If higher levels are needed, add the fat through post-pellet application systems.

- Increasing protein and fiber content in feeds tends to improve pellet quality. For example, increasing the level of wheat midds in swine feeds enhances pellet durability.
- Certain feed ingredients contain "natural" binding properties that help improve pellet quality. Examples include wheat, barley, canola, whey and blood plasma.
- The relative natural protein content and density of ingredients or finished feeds are a general indication of expected pelleting production rates and pellet quality. Ingredients or feeds with high natural proteins generally produce good-quality pellets, while feeds with low natural proteins produce lower-quality pellets. Ingredients or feeds with high densities generally have good production rates; feeds with low densities have lower production rates.

Feed particle size

Smaller mash particle size generally enhances pellet quality since the material has a larger surface area that allows heat and moisture from steam to more quickly and thoroughly penetrate the particle. Smaller particles also have more surface area to adhere and bind to other particles in the pellet. Smaller ingredient particle size also typically increases bulk density, permitting higher production rates. However, the cost of grinding to obtain smaller particle sizes needs to be weighed against the benefits of improved pellet quality. From a cost-benefit standpoint, the optimal particle size for corn/soy poultry diets may be in the 650-700 micron range (Dozier, 2001).

Pellet mill supply bin

A good pellet mill supply design will supply a steady flow of mash to the pellet mill. To avoid

feed bridging, the supply bin hopper should have two adjacent vertical sides that attach to the beginning of the feeder screw. The other two bin hopper sides should have different slopes to produce a shearing effect as feed flows down the hopper. Whenever possible, one side should have a minimum 60° slope to the horizontal and the other side should have a minimum 70° slope to the horizontal.

The pellet supply bin hopper should have a vibrator of adequate force mounted to it to help ensure the constant flow of feed through the bin and complete feed clean-out at the end of the production run. The pellet supply bin also should have a low-level indicating device mounted in the hopper. The output from the indicator can help control efficient pellet mill shutdown and supply bin vibrator operation.

Pellet mill feeder screw

The pellet mill feeder screw needs to supply the pellet conditioner with a uniform supply of feed mash. A tapered or variable-pitch inlet flighting on the screw will help pull feed uniformly out of the entire supply bin discharge area. Reduced pitch flighting on the remainder of the feeder screw also will help minimize feed surging. Stainless steel screws and trough housings often are cost-effective, especially when handling corrosive materials. AC variable-speed electronic motor drives for the feeder are reliable and provide an easy and accurate method to control feed rate.

Steam distribution system

An adequate, well-regulated supply of steam to the conditioner is essential for efficient pelleting operations. Poor pellet quality and production rates often are attributable to problems with steam supply and regulation (Maier and Gardecki, 1993). The following are some steam distribution system guidelines to follow:

- Take the main steam line off from the top of the boiler header to minimize entrained moisture.

- Slope all lines away from the boiler and toward the condensate return (2.54 cm for every 12 meters).
- Install a drip leg and steam trap at the end of each main and at every rise in the line.
- Do not install valves in vertical lines where water may collect above them.
- Install a final drip leg as close as possible to the pellet mill steam control valve.
- Install a pressure regulator in front of the pellet mill steam control valve to ensure a uniform supply of steam. The regulator pressure should be set below the minimum cycle pressure of the boiler. Also install a pressure gauge in front of the regulator to verify operation.
- Install strainers in front of the pressure regulator, separators and steam traps to collect line debris.
- Install pellet mill steam control valves that have a linear response to gain better conditioning control. For example, opening the valve 20% should provide 20% more steam. Standard gate valves do not open in a linear manner.
- Check steam traps regularly using one or more of the following methods: 1) Install a test port and valve in the condensate line. If live steam exits the test port when the valve is opened, the trap is leaking. 2) Monitor the sound created by condensate flow with a mechanical stethoscope, ultrasonic detector or other devices. The flow and sound of condensate should peak and then drop to near zero if the steam trap is cycling properly. Considerable experience is required to obtain accurate testing results through sound monitoring. 3) Monitor the steam line temperature before and after the trap using infrared guns, surface pyrometers or other devices. Failed-close traps will have low or cold condensate lines. Failed-open traps will have higher than “normal” condensate line temperatures. However, the “normal” condensate line temperature often is difficult to

determine because of common condensate return lines and return line pressure. As a result, it may be very difficult to determine if a trap is leaking by using temperature monitoring.

Conditioning

The conditioning process influences pellet quality more than die specifications (Behnke, 2001). In contrast, thicker dies that lower production rates often are used in an attempt to improve pellet quality. Here are some conditioning guidelines to consider:

- Increasing conditioner retention time generally improves pellet quality. The longer retention time improves heat and moisture absorption in feed. Lengthen the retention times of an existing conditioner by adjusting pick angles or reducing the conditioner shaft speed.
- Steam pressure does not influence pellet quality (Briggs, Maier, Watkins and Behnke, 1999). The thermodynamic properties of low- and high-pressure steam are very similar. To optimize energy costs, maintain steam pressures only high enough to provide the steam quantity necessary to reach desired conditioning temperatures and for adequate condensation removal and return.
- Steam typically cannot provide more than 6% moisture to feed during the conditioning process (Leaver, 1988). Each percentage of moisture added to feed through steam raises the mash temperature about 13°C.
- Steam quality—the percentage of steam in the vapor phase—is important to pellet durability and production rates. Research has shown that conditioning feed with 70-80% steam quality optimizes pellet durability (Gilpin, Herrman, Behnke and Fairchild, 2002). High-quality steam has more energy to raise mash temperature than lower-quality steam that contains condensation. Steam quality determines the maximum mash temperature that can be reached during conditioning because of moisture limits (Reimer and Beggs, 1993).

Conditioner components should be made of stainless steel to minimize corrosion. Paddle tip speed should be between 183-274 meters per minute for light feeds (321 kilograms-per-cubic meter or less) (Leaver, 1988). For heavy feeds, paddle tip speeds of 274-366 meters per minute are best. Steam addition should take place at the bottom of the conditioner inlet for good mixing. Add other liquids, such as molasses, through the top of the conditioner near its inlet. Typically, a well-maintained conditioner can mix up to 6-8% molasses. Routinely check conditioner paddles for wear and condition. Worn or bent paddles can cause poor feed conditioning and an uneven feed supply to the pellet mill. Establish a regular cleaning schedule for the conditioner to remove feed build-up on walls and paddles.

Pellet mill operation

Finding the appropriate balance between the need for production capacity and pellet quality can be a difficult task. Often methods to increase production rates have a detrimental impact on pellet quality and vice versa. Ultimately, a compromise must be reached that can satisfy the mill's needs in both areas.

Once the feed mill determines its requirements, the proper equipment needs to be specified and purchased that is designed to meet these needs. During the process of purchasing a new pellet mill or upgrading an existing one, the probability of achieving a satisfactory outcome increases proportionally to the amount of accurate information about the pelleting process that the feed mill can provide to its equipment supplier. At the same time, reputable suppliers should ask for a comprehensive list of information in order to accurately quote equipment that will match the mill's needs.

As a starting point, this information should include: 1) Types of ingredients and feed formulations pelleted; 2) quantities of each type of feed pelleted (product mix); 3) desired production capacity by type of feed; 4) average run length by type of feed; 5) run changeover time requirements; 6) liquid

requirements for each type of feed; 7) pellet quality requirements by type of feed; 8) desired conditioning parameters for each type of feed; 9) level of mill automation; and 10) any other unique conditions. After this preliminary information is provided, suppliers can ask for more specific information necessary to identify the appropriate equipment.

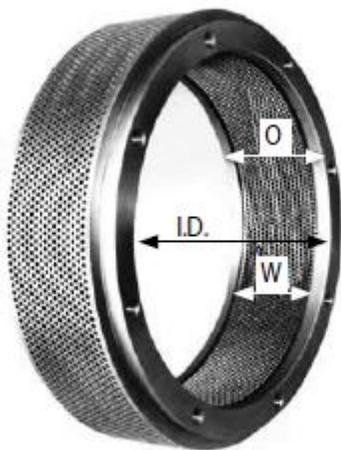
With the right equipment in place, optimizing pellet mill productivity and pellet quality depends on establishing and following sound operating guidelines and avoiding pellet mill downtime associated with plugs. Plugging a pellet mill die can wreak havoc on mill productivity, drive up production costs and create pellet quality problems. Severe plugs can take hours to address and may cause significant equipment damage.

The following are some pellet mill operating guidelines to help avoid die plugs, improve pelleting capacity and enhance pellet quality:

- **Mash moisture content:** The moisture in feed mash affects pellet quality and production rates. Moisture in feed mash comes from two sources: Bound moisture present in the feed's ingredients and added moisture from water and steam addition. The moisture of cold feed entering the conditioner limits the amount of steam that can be added to the mash during conditioning. The plug point of a pellet mill is approximately 18% total meal moisture. Varying cold mash moisture affects the conditioning process and pellet mill operation. Research has shown that there is a high correlation between cold mash moisture and pellet durability (Greer and Fairchild, 1999). Adjusting cold mash moisture to 14% through mixer water addition can optimize pellet mill operation and pellet durability (Muirhead, 1999).
- **Die speed:** Higher die speeds improve pellet mill capacity. However, high die speeds can undermine pellet quality and capacity if there is excessive pellet breakage when pellets leave the die and hit the pellet mill door. A die speed of 610 meters per minute is recommended for small diameter pellets (2.38-6.35 mm). For cubes—15.88 mm and larger—the recommended die speed is 366-396 meters per minute (Leaver, 1988).
- **Die chamber/feed chute seal:** Regularly inspect and maintain the seal between the die chamber feed cone and the feed chute discharge. Feed mash may drop directly into the cooler and bypass the die chamber if there is excessive clearance in this area, resulting in lower production rates and greater pellet fines.
- **Rolls:** Two general types of pellet mill roll shells are available—tungsten carbide and hardened steel. Tungsten carbide roll shells have a rough surface comprised of tungsten carbide particles embedded in a weld matrix. This surface provides excellent traction and wear characteristics. However, since these roll shells are very hard, careful adjustment of this type of roll is necessary to prevent “rolling over” or peening shut holes in the pellet die. Typically, tungsten carbide shells are not used with small hole diameter dies of less than 3.97 mm because of the potential to rollover these dies. Meanwhile, hardened steel roll shells come in a variety of styles. These include open or closed-end corrugated, dimpled or indented, helical and combinations of these designs. Choice of style depends upon the type of feed being pelleted and the preference of the mill manager.
- **Roll adjustment and maintenance:** Proper roll adjustment is the most important factor in achieving maximum pellet mill capacity, prolonging die and roll life and eliminating undue pellet mill stress (CPM Roskamp Champion, 1997). Establish a routine schedule to inspect and adjust rolls based upon the mill's operation; do not wait until the rolls slip and the pellet mill plugs. See Chapter 22: Die Maintenance and Die Change Operations for procedures on how to correctly adjust die rolls. The following are some roll maintenance guidelines to consider: Establish a schedule to regularly inspect and adjust rolls; lubricate rolls every four hours of operation with an approved high-temperature, high-pressure grease; start new dies with new rolls; and rotate rolls to evenly disperse wear.

- **Die specifications and material:** Understanding the terminology used to describe dies is important when choosing die specifications. **Figure 23-1** illustrates the important dimensions of a pellet mill die.

Figure 23-1. Dimensions of a pellet mill die. ID=inside diameter of the die. The inside diameter is the most common identifying dimension of a die and is always specified during die selection. O=overall width of the die. The overall width of a die may vary. Often, there is more than one width available for each die diameter. W=working width. Die working width is measure between the two inside edges of the die grooves.



Die working area is defined as the area between the two inside die grooves. This working area increases as die width and diameter increase. Die working area is important because different feeds and ingredients require specific amounts of time in the die hole—die retention time—to be able to bind together to form a pellet. Larger die working areas provide more retention time to form pellets, reduce power consumption per tonne of feed pelleted and improve production efficiencies.

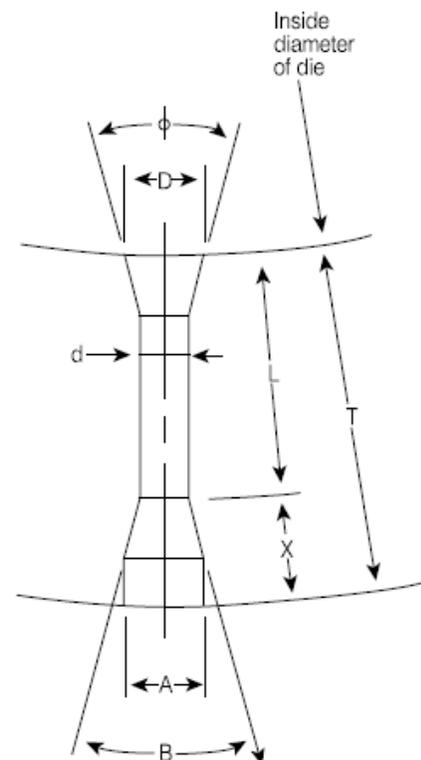
Figure 23-2 illustrates the terminology used to describe the characteristics and dimensions of die holes. The most important terms to understand when selecting a pellet die are:

D = hole diameter

L = effective length. The effective length is the die thickness that actually performs work on the feed.

- **L/d ratio.** The L/d ratio is the effective length divided by the hole diameter. High L/d ratios provide high pellet die resistance as feed moves through the hole. Low L/d ratios provide less resistance. Each material has an L/d ratio requirement to form the material into a pellet.
- **T = total thickness.** Total thickness is the overall thickness of the die. Overall thickness provides the necessary die material to avoid die breakage.
- **X = counterbore depth.** Counterbore depth measures the “relief” provided in the die as the pellet exits the die hole. Enlarged holes are counterbored into the die to reduce its effective thickness and provide the proper L/d ratio while maintaining the total thickness needed to prevent die breakage. Specific rows of die holes, such as the two inner and outside rows, also sometimes are counterbored to greater depths to encourage feed flow through these outer rows of holes to help dies wear more evenly.

Figure 23-2. Terminology used to describe the characteristics and dimensions of die holes. Courtesy of Sprout-Matador.



Holes in dies typically are drilled in three different patterns. Close hole pattern spacing provides more open die area and more retention time. The open area of dies with close hole patterns is about 43%. Wide hole pattern spacing provides less open die area and greater die strength. Wide hole pattern spacing provides about 32% open die area. Standard or medium hole pattern spacing provides a compromise between die open area and die strength.

Choosing the right die material is important. Pellet dies are made from steel that has been selected for certain carbon and chromium contents and heat-treated for desired properties. The steel’s carbon content affects the corrosion resistance and the wear resistance of the die. Dies usually are classified as alloy, stainless or high chrome. Steel with a free chromium content exceeding 12% is classified as stainless. Each of these types of die materials has characteristics that make it more desirable for certain applications:

- Alloy dies are made of medium-grade carbon steel. They are designed for heavily abrasive applications and typically are the most breakage-resistant dies available. Alloy dies generally are less expensive than stainless steel or high chromium dies.
- Stainless steel dies provide corrosion resistance and good wear resistance for moderately abrasive materials. Stainless steel often is chosen for “all purpose” dies.
- High chrome dies provide the most corrosion resistance of the different die materials. Because of the chrome content, they usually start-up very easily and allow high pelleting production rates. However, high chrome dies typically provide less resistance as feed moves through the die holes and the effective thickness of the die may need to be increased to achieve desired pellet quality.

Table 23-1 shows general die specification and material guidelines for the major feed groups. Specific L/d ratio requirements will depend upon particular feed formulations and their fat content.

Feed Category	Die Material	Die hole pattern	L/d ratio
High grain	Stainless/ high chrome	Close hole spacing	10-12
Low protein, high roughage	Stainless/allow	Medium hold spacing	12-14
High natural protein	Stainless	Close/medium hole spacing	10-12
Low protein, heat sensitive	Stainless	Medium hole spacing	9-11
High protein, urea/high mineral	Alloy	Wide hole spacing	8-9

Die condition

Die life and performance are optimized by proper feed distribution and die maintenance. Here are some die guidelines to consider:

- Inspect the die face during each roll adjustment for wear. Uneven wear—which consists of excessive wear in the front or back of the die—typically is caused by uneven feed distribution. Based upon experience and feed type, adjust the feed plows that direct the flow of feed into the die chamber to achieve even wear.
- Establish procedures to routinely inspect for tramp metal and remove it from the die. Tramp metal that fills holes can reduce die throughput, cause uneven die and roll wear and hinder proper roll adjustment.
- Routinely inspect the clamps or bolts that secure the die to the pellet mill die housing. In addition, inspect die wear rings and die housing clearances for proper tolerances. Improper die fit or loose die clamps or bolts are the major causes of die breakage.

- Install adequate magnetic protection before the pelleting system and immediately before the pellet die chamber. Inspect and clean all magnets on a scheduled basis.

Applying fat to pellets

Generally, adding more than 2% fat at the mixer will lower pellet quality. To achieve higher fat levels while maintaining pellet quality, fat may be sprayed onto hot pellets as they leave the die inside the pellet mill door or applied after cooling and screening through a low-speed ribbon conveyor or drum tumbler. Usually, the maximum amount of fat that can be added through either system is 5%.

Applying fat to pellets using either method requires accurate measurement and correlation of pellet dry flow rates and liquid flow rates. Mill maintenance personnel should routinely check and calibrate both dry and liquid flow metering devices. Inspection and calibration frequency will depend on the desired accuracy and volume of feeds produced.

For fat-at-the-die systems, fines returning to the pellet mill for re-processing can influence the accuracy of fat addition. To compensate for fines return, operators should evaluate the accuracy of the fat addition of production runs for various feed types over time and establish liquid settings that produce accurate results.

Adding fat to pellets can produce undesirable downstream consequences in the pelleting system, such as fat balls in finished products or fat build-up in the cooler, air ducts and distribution equipment. Mill maintenance personnel should regularly inspect and clean pellet equipment at and downstream from fat addition points. Preheating fat to 60-71°C through a heat exchanger prior to application can help improve absorption of the fat into pellets and minimize these occurrences.

Pellet cooling

Inadequate cooling can create several pellet problems—including pellets that are susceptible to mold growth; flowability problems; and poor

durability. The temperature of cooled pellets with a diameter of 4.76 mm or less should be within 6-8°C of ambient air temperature. Cooled temperatures of larger pellets, such as cubes, should be within 11°C of ambient air temperature. Pellet mill operators should regularly check cool pellet temperature.

To help ensure proper cooling:

- Cool with “ambient” or outdoor air. Pellets typically will reach a final cooled temperature of 6-8°C greater than the temperature of the air at the cooler intake. Significantly higher cooled pellet temperatures may result if the cooler uses warmer air from the mill’s interior.
- Keep all cooler air inlets, screens and trays clean from feed build-up.
- Prevent airflow restrictions that may result from product build-up in the air system ductwork. If build-up occurs, cooler air volume decreases, because the cooler fan cannot produce the static pressure required to pull air at a high enough velocity to off-set the reduced duct diameter and higher duct resistance.
- Inspect the air duct work for leaks. Air leakage, especially just ahead of the fan, can reduce airflow through the system.
- Maintain an even and level pellet bed. Airflow through a cooler follows the path of least resistance, so an even pellet bed promotes uniform airflow and cooling of all pellets.
- Routinely check cooler bed leveling devices to ensure they are properly working.

Crumble roll operation

A good-quality and well-cooled pellet is essential to produce good crumbles. Crumbling poor-quality pellets generates excessive fines that can dramatically reduce pellet production rates and the quality of the finished feed.

Crumbles usually are made from a 4.76-3.97 mm pellet because those sizes provide high production

rates at the pellet mill, and yet are small enough to crumble easily without generating too many fines. For highest crumbling efficiency, pellet diameters must be in the proper relationship to the crumble roll diameter. Typically, pellet diameters should not exceed 4.76 mm for 15.2 cm diameter rolls and 6.35 mm for 22.8 cm diameter rolls. The capacity ratings for crumble rolls typically are based on a crumble roll gap setting that is $\frac{2}{3}$ of the diameter of the pellet.

Here are some operating guidelines for crumble rolls to optimize performance:

- Measure and test pellet quality to ensure good-quality pellets are being crumbled.
- Ensure that the crumble rolls are parallel and in a level position (in tram). The gaps between rolls must be parallel to maximize efficiency. Routinely inspect the roll gap to ensure it is consistent along the entire length of the rolls.
- Out-of-tram rolls cause un-even roll wear and reduced throughput.
- Feed the entire width of the rolls evenly with pellets. Poor feed distribution results in inconsistent particle size reduction, reduced capacity and un-even roll wear.
- Inspect and re-corrugate rolls as needed. Dull roll corrugations reduce capacity and increase fines.

Screening operations

Proper pellet screener operation is necessary to sort pellet sizes and remove fines. Use stainless steel screens when corrosion is a problem. Larger wire diameters increase screen life, but reduce open area and screener capacity. Inspect screens regularly to ensure that they are free of holes and not plugged.

Post-pellet liquid addition systems

Post-pellet liquid application (PPLA) systems provide a means to apply heat-sensitive ingredients to pelleted feeds. PPLA systems can be designed

for volumetric or mass measuring of dry feed flow.

Volumetric dry flow systems work best when feed density is constant. Once calibrated, this type of system is very accurate and requires little adjustment during operation. Mass dry flow systems measure mass and can compensate for feed density changes. This type of system is also very accurate, but requires routine calibration to ensure proper dry flow indication.

Typically, liquids are applied either with atomizing spray nozzles or centrifugal atomizing discs. Nozzles generally work on a narrower range of liquid volumes, while centrifugal discs can handle a wider liquid application range.

For many mills, the best location for a PPLA system is at the top of the mill structure, either downstream from the pellet screener or just before the feed enters the distribution system. Most systems use positive displacement pumps that can achieve enough head pressure to apply liquids at the top of the mill. Flow rates from this type of pump also are easily controlled by adjusting either pump stroke or speed. The PPLA system must be designed for the types and quantities of liquids and pellets and within the parameters of the mill's upstream and downstream equipment.

The accuracy of PPLA systems depends on the precise measurement and correlation of pellet dry flows and liquid flow rates. In addition, an accurate system needs to eliminate pellet dry flow surging and spread the pellets into a thin curtain prior to liquid application to ensure uniform distribution of the liquid on the pellets.

PPLA systems require periodic inspection and maintenance to ensure accurate operation. Here are some operating guidelines to consider:

- Check and calibrate dry and liquid flow rates using an established schedule. Frequency of calibration may be semi-annually, quarterly or more often—depending on the quantity of liquids applied and desired accuracy.
- At initial start-up and periodically thereafter, perform a uniformity test to measure the

homogeneity of liquid application to the pellets. Good PPLA systems should achieve a 10% or less coefficient of variation.

- Routinely inspect and clean liquid spraying devices and equipment areas where pellets are sprayed and mixed with liquids.
- Clean liquid strainers and filters following an established schedule.
- Reconcile theoretical and actual liquid usage periodically as another method to verify the accuracy of liquid addition.

Finished pellet load-out

Ideally, finished pellet load-out bins should have hoppers with two adjacent vertical sides and two other sides with differing slopes that produce a shearing effect to aid pellet flow and bin clean-out. Whenever possible, one side should have a minimum 60° slope to the horizontal and the other side should have a minimum 70° slope to the horizontal. The pellet load-out bin hopper also should have a vibrator of adequate force mounted to it to ensure the complete clean-out of feed at the end of the loading process.

Adding flow agents to pellets can help facilitate load-out of pellets that contain urea or other hydroscopic ingredients, which may cause “sticky” pellets. Typical flow agents include finely-ground bentonite or limestone. Normal addition rates for flow agents range between 1-2 kilograms per metric tonne. Flow agents typically are added to pellets after cooling and screening using a vibratory feeder or other metering equipment that discharges the flow agent into the pellet distribution system. Pellets are “coated” with the flow agent as they are conveyed to the finished feed bin.

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