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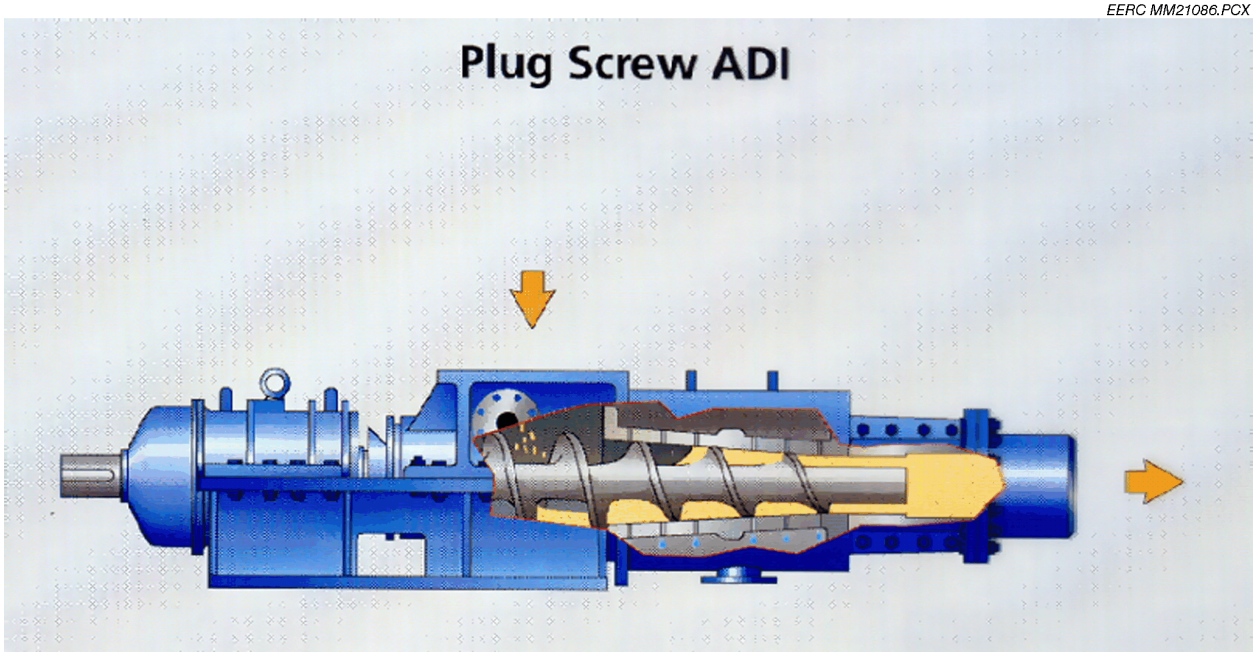

Figure 44. Cutaway diagram of Metso plug-screw feeder.

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Figure 45. Plug-screw feeder system used in wood chip pulping process.

Figure 46. Wood chip-feeding system for plug-screw feeder.

Figure 47. Throat section of plug-screw feeder.

Figure 48. Plug-pipe section in plug-screw feeder.

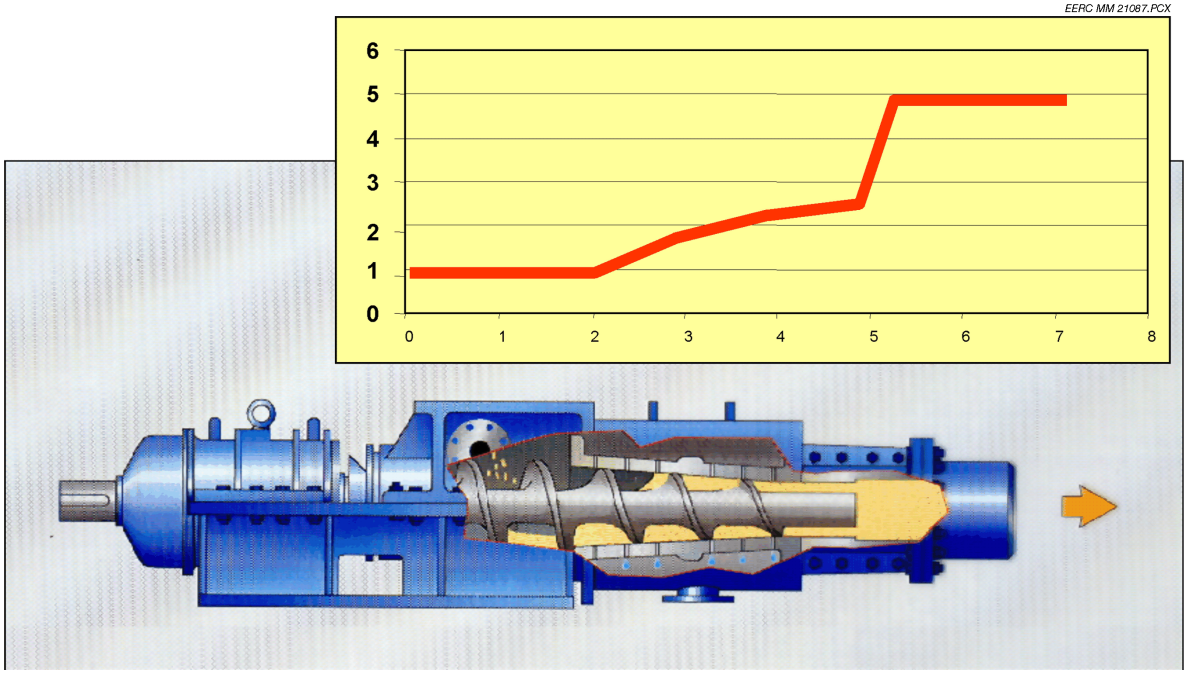

Figure 49. Diagram depicting wood chip densification with axial position in plug-screw feeder.

Another plug-forming feeder designed for the pulp-to-paper industry is the CO-AX feeder by Stake Technology Ltd. The CO-AX feeder is actually an integral component of Stake Technology's StakeTech steam explosion thermomechanical pulping system. The system has been utilized for wood chips and straw chips and claims continuous solids feeding for feedstocks with moisture contents of 10 to 65 wt% (73, 74). With the CO-AX feeder, material enters the feed chamber via a shallow-angle live-bottom hopper and is transferred to a precompression screw by two sets of twin screws. The feed is then conveyed by the precompression screw from the hopper discharge to the piston zone through a fluted tube. The precompression screw coaxial passes through the center of a ring piston, delivering the feedstock at the downstream face of the ring piston. The feedstock is compacted into a firm plug by the coaxial motion of the ring piston. Moisture expelled by the compaction is drained through a dewatering sleeve. The biomass plug is continuously advanced through a tapered compression tube to the steam explosion digester. The combination of compression tube taper and length dictates the plug density and, consequently, sealing against digester pressure. As with a plug screw feeder, the plug is forced against a conical choke that functions to break up the plug. The vendor claims adaptability to a variety of feedstocks, woody and nonwoody, and distinguishes itself from plug-screw feeders by lower specific power consumption. At 150 psig, for example, the power consumption is about 10 kWh/ton feedstock versus nearly 35 kWh/ton for a plug screw. The steam explosion technology with CO-AX feeder was utilized by Weyerhaeuser (Springfield, Oregon) at the demonstration scale (64 wet tons/day) for straw pulping at 200 psig. The process apparently was successful but was discontinued for nontechnical reasons (75). One requirement to operate properly was a feedstock moisture content of 35% to 45%, as free moisture was needed as a lubricant and to help reduce piston and compression tube wear.

The Ingersoll–Rand Reciprocating Screw Feeder, shown in Figure 50, and the Vattenfall Screw-Piston Feeder (76) are similar constant cross-section plug-forming feeders that utilize a screw to both advance and compact the feedstock. The former was developed and tested with coal while the latter was developed specifically for utilization with fibrous biomass.

In these systems, the feedstock is delivered via gravity to the compression-piston screw with the screw essentially functioning as the live bottom on the feed hopper. The screw advances the feedstock down the cylindrical material chamber until a sufficient amount of material is deposited adjacent to the existing plug. The screw than retracts and advances, compressing the fresh biomass against the downstream plug. With the Ingersoll–Rand system, the plug acts against a pressure valve that opens when the system pressure is exceeded. While not described, it is envisioned that a single distinct disc-shaped plug is expelled through the valve with each cycle. Compression of new feed against the previously formed plug produces a distinct nonbinding, noninterlocking interface between plugs. This is akin to reciprocating coal or mineral briquetting. The pressure-sealing component of the Vattenfall system is not adequately described. The description indicates that a single plug is formed within a "pressure chamber." This suggests that the pressure chamber is actually a lock hopper (completely filled by the biomass plug) and the densification to a plug is intended to reduce the consumption of pressurization gas. In fact, the developers claim 50% to 60% reduction in pressurization gas relative to a traditional lock hopper system.

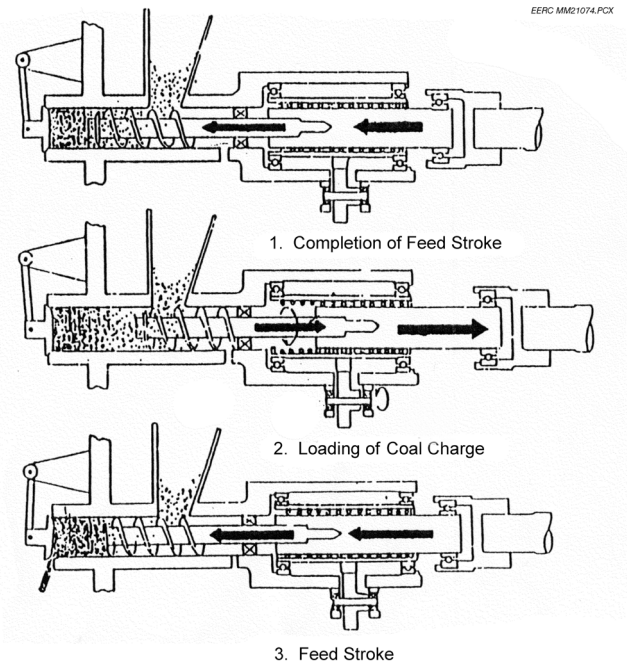

Figure 50. Ingersoll–Rand reciprocating screw feeder.

A most recent development in plug-forming feeders is that of TK Energi piston feeder, shown in Figure 51 (77). This system is a three-stage feeder with a rated capacity of almost 8 tons/hr of wood chip at 20% moisture. This system relies on the pistons to both compress and advance the biomass within the device. Within the feed hopper, the biomass falls in front of the retracted first piston and then is pressed into a "free space" in front of the second piston. After the first piston, biomass densities of 400 to 900 kg/m^3 (25 to 56 lb/ft^3) are attained. The second piston pushes the biomass plug downward into the free space ahead of the third piston. The third piston advances the biomass plug through the "sealing" section, with density within the sealing section determined by the "control" section. (This description appears to be purposely vague to protect intellectual property, but it suggests that there may be a tapered section or some restriction that provides resistance for plug formation). The plug density at discharge must be in the range of 1000 to 1700 kg/m^3 (62 to 106 lb/ft^3) for sealing. The third piston advances the plug to the plug breaker, a rotating cutting head, which functions to grind the plug. Safety against blow back of process gas is achieved by ensuring that at least one piston is positioned within the biomass flow path. The biomass charge will also function to inhibit backflow. The piston stroke rate is 1200 cycles per hour maximum. The system is designed to wear at the walls of the piston cylinders which will not affect plug densification. Add-on features include weigh belt feeder, dosing screw, and near infrared moisture measurement systems upstream of the feed hopper. Specific power consumption is presented as up to 100 kW for soft wood chips and up to 130 kW for hardwood chips, both fed at 6.5 tons/hr against 360 psig. The system is designed for biomass of 0 to 2 inches and input bulk densities of 150 to 250 kg/m^3 (about 9 to 16 lb/ft^3). TK Energi is in the process of patenting the feed system.