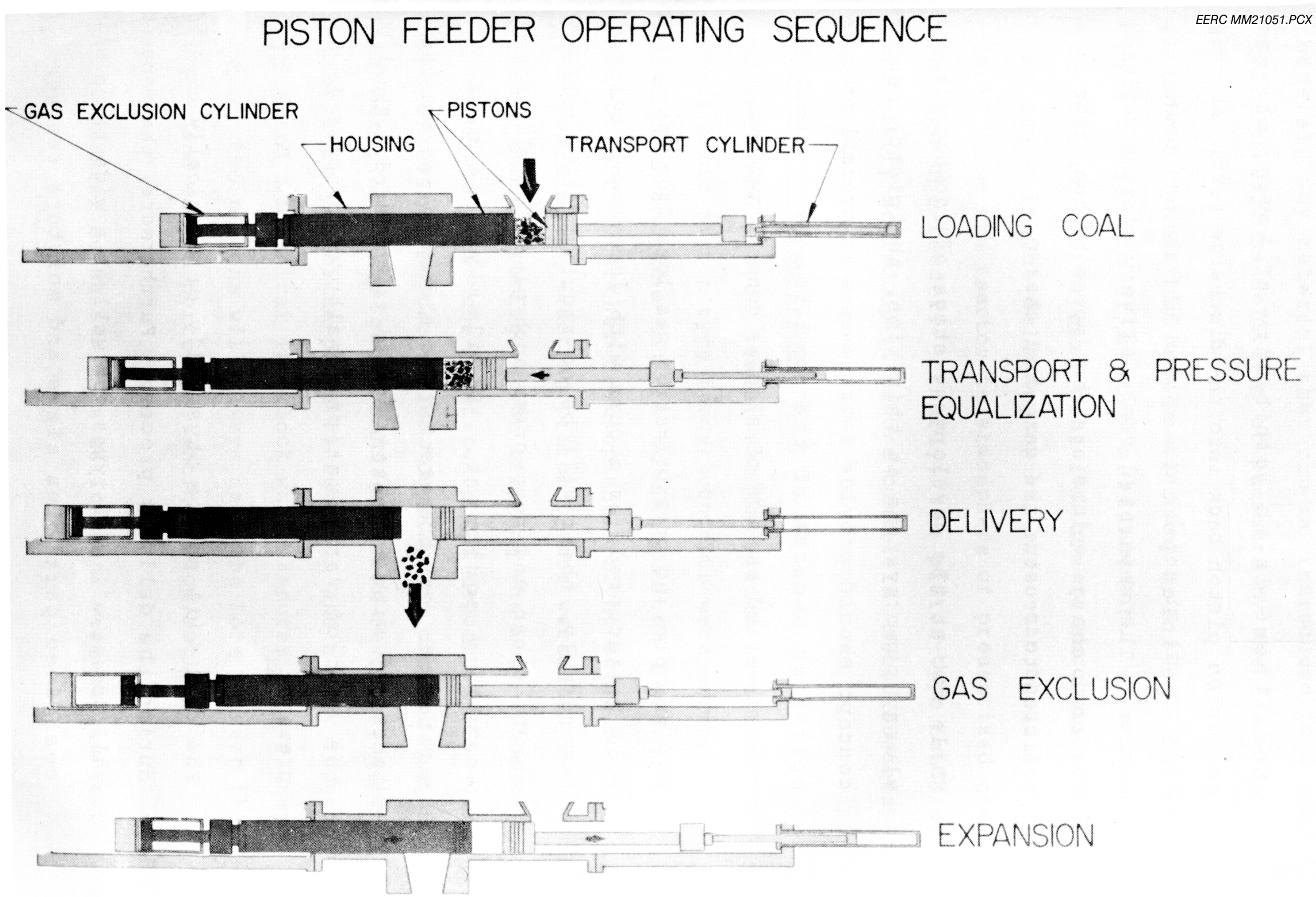

Figure 54. Five-stage feeding cycle with Ingersoll–Rand coaxial feeder.

the gas exclusion piston. In the fifth sequence, the pistons separate by the required face-to-face distance and then move back to the fuel charging opening to start the cycle over. The process used a system of inflatable piston seals to allow movement of the piston across discontinuities (e.g., feed charge opening) in the material cylinder. The developmental system utilized material cylinders of 9-inch ID to attain mass rates up to 2.5 tons/hr.

The Fortum system was designed specifically for feeding biomass to pressurized gasification and combustion systems. Materials tested included peat, wood chips, sawdust, and bark. Development activities were halted in 1995 after the developer (Imatran Voimas Oy) believed pressurized gasification to have a limited future (82). Foreign patents were apparently obtained, although the developer was not forthcoming with patent numbers or the estimated cost of the system.

The Fortum feed system comprises two primary components: the feed bin and piston feeder. The feed bin is equipped with a live-bottom screw that functions to meter the fuel into the material cylinders of the high-pressure piston feeder. The piston feeder consists of two horizontal material cylinders with one cylinder located above the other. Each material cylinder is equipped with its own hydraulically actuated piston. In the normal position, the upper material cylinder (and piston) is positioned to receive fuel from the feed bin, and the lower material cylinder (and piston) is positioned to feed fuel into the pressurized process. With the upper material cylinder positioned to receive fuel, the feed bin screw advances the fuel into the material cylinder, partially compressing the fuel against the retreating piston. Fuel charging stops after the piston reaches its fully retracted position. Simultaneously, the piston on the lower cylinder advances "until the pressure in the lower cylinder is raised to that of the process." The valve (pressure interlock) between the feeder and the process is opened, and the piston delivers the fuel to the process. After the valve closes, the upper and lower cylinders rotate 180° to continue the cycle. The pilot-scale feeder utilized a 200-mm (about 8-inch)-ID by 1-m (3.3-ft)-long material cylinder and was capable of feeding 10 m^3/hr (350 ft^3/hr) against 360 psig with a power consumption of 20 kW. Although not ever constructed or tested, a design was advanced for a commercial feeder with a capacity of 50 m^3/hr (1760 ft^3/hr), a cylinder with an ID of 400 mm (about 16 inches) and length of 2 m (6.6 ft), and a power consumption of 100 kW, again delivering against 360-psig process pressure. Although not part of the presented specifications, calculations indicate a cycle rate of 200 times an hour. Claims of the technology include no possibility of sudden pressure release through the feeder and no consumption of inert pressurization gas. The level of densification of biomass by the screw was not measured as it was the developer's intention to maintain "loose" biomass and avoid formation of pellets or briquettes.

The Foster–Miller linear pocket feeder, shown in Figure 55, was developed for feeding coal to fixed-bed, fluidized-bed, and entrained-flow gasifiers and was developed under DOE sponsorship (83). Performance tests were conducted with coarse and pulverized coal at pressures up to 6.89 MPa (1000 psig) and 4500 kg/hr (10,000 lb/hr). The feeder functions like a tube conveyor, with sealing pistons replacing the drag flights. The sealing pistons are connected by a chain, forming a series of pockets. The pockets are gravity-filled with coal and then the pistons pass through a "sphincter," a self-adjusting contact seal that functions to prevent backflow of gas to the atmospheric feed inlet. The pistons then pass through a sealing tube wherein the close tolerances between piston and tube wall function as a labyrinth seal to reduce the gas pressure acting at the "sphincter." The coal-laden

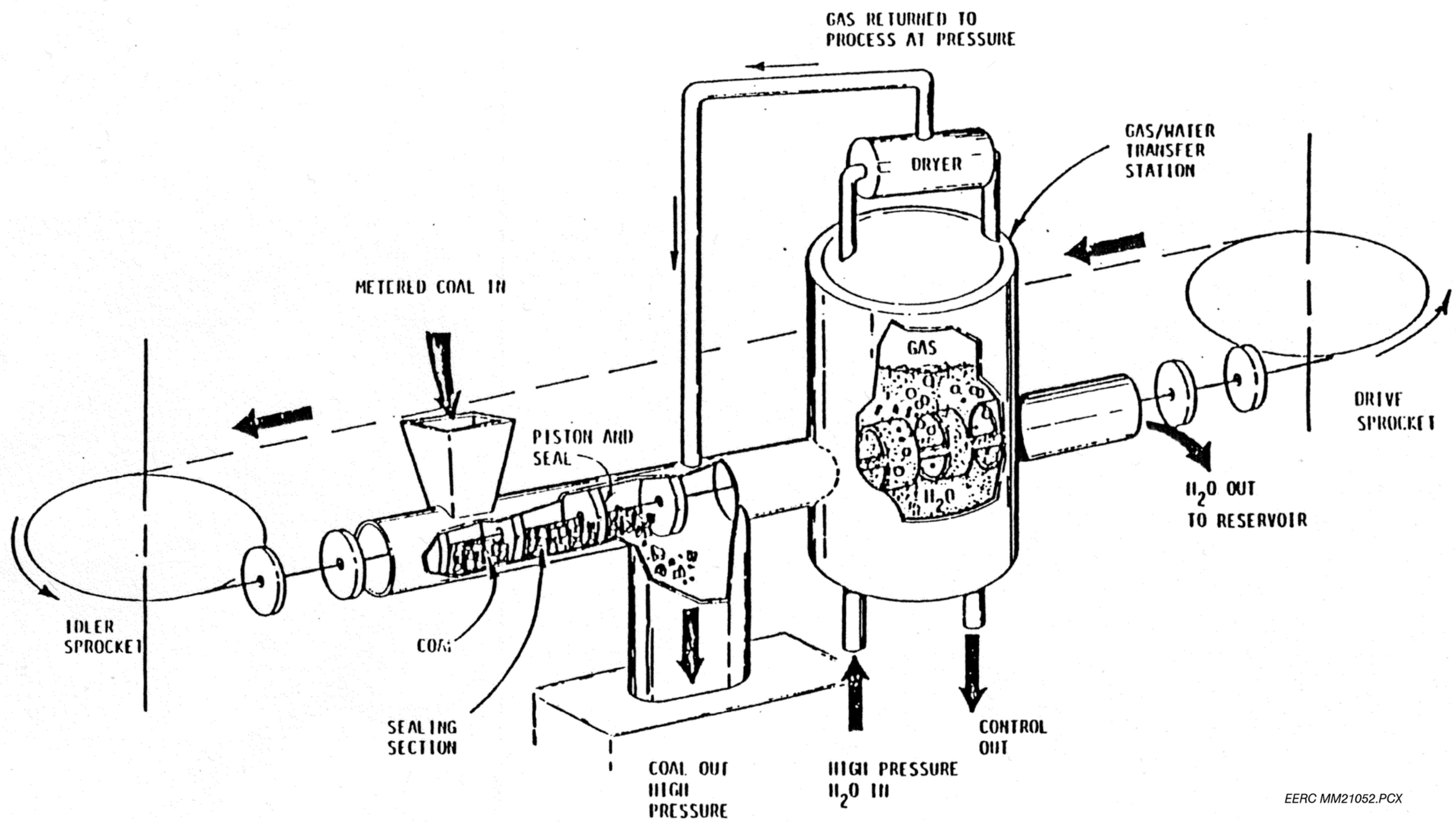

Figure 55. Foster–Miller linear pocket feeder.

pockets then pass over the discharge with the coal then expelled via gravity. When pulverized coal is fed, a high-pressure gas “chase” may be necessary to efficiently discharge the coal. The gas-filled pockets enter the gas–water transfer station where the gas in the pockets is displaced by water. The displaced gas is returned to the process owing to the fact that the gas–water transfer station is maintained at a slightly higher pressure than the process. A proper water level is maintained in the transfer station using a high-pressure pump. The water contained within the pockets is discharged to an atmospheric pressure receiver for cleanup and reuse. Excess water on the chain and pistons are removed in a dryer section that uses a blower to induce a cross-draft air flow. The pocket-filling efficiency and the coal feed rate are controlled through the chain speed.

Patent Database Search for High-Pressure Solids Feed Systems

A Web-accessible database of U.S. and foreign patents (Delphion Intellectual Property Network, http://www.delphion.com/home) was searched to determine the status of dry feed systems for high-pressure applications (84). Queries were limited to U.S. patents only. A list of related patents is presented in Appendix D.

Review of the patents indicated that the systems were principally based on extrusion feeding of powdered or pulverized coal. A gas-tight pressure seal was apparently demonstrated to be achieved by one of two means: 1) attaining the plastic deformation state of the coal, resulting in void sealing or 2) adding an uncompressible filler/binder such as water or a hydrocarbon liquid to fill voids. The forces of extrusion, however, resulted in sufficient compaction of the coal to require the feed system to also incorporate a means of repulverizing or delumping the compact. This was typically achieved using a directed stream of high-pressure fluid (gas or liquid).

Procurement of Feedstock Samples

A number of feedstocks were procured to allow evaluation for potential utilization within several select commercial and developmental biomass feed systems. Feedstocks included corn stover, switchgrass, soybean hulls, RDF, wheat straw, E-grass, and wood waste. Corn stover was procured from Tom Schechinger of Biomass Agri Products (Harlan, Iowa). Switchgrass was obtained from Chariton Valley Resource Conservation and Development (CVRCD) of Centerville, Iowa. Corn stover has principally been evaluated for production of high-value products such as furfural, fibers, and ethanol. The corn stover consists of the stocks, leaves, and cobs left standing in the field after corn harvesting. Corn stover can be tilled back into the ground or harvested and baled for use as animal feed. Switchgrass is currently being promoted as a fast-growing, energy crop. Harvesting and bailing of corn stover and switchgrass can be performed using conventional farm equipment. For utilization as a fuel or chemical feedstock, the baling would be performed after the stover or switchgrass had field-dried to about 15 wt% or less moisture.

Soybean hulls (whole, shredded, and pelleted) were obtained from Darcy Ehmann of Ag Processing Inc. (Omaha, Nebraska). Soybean hulls are typically shredded and extruded into pellets as cattle feed, commanding prices between $50 and $70 per ton. The unpelleted soybean hulls would appear to be an ideal fuel for entrained-flow gasification in that they are of sufficiently small size and low density to preclude any requirement for size reduction. Cedar wood waste fractions were obtained from a local wood furniture manufacturer. The cedar sawdust would probably not need further processing for entrainment.

Samples of RDF were obtained from two separate producers. A coarse RDF material was procured from the Ramsey/Washington County Resource Recovery Facility (Newport, Minnesota), owned and operated by NRG Energy, Inc. (85). A smaller, nominally −4-inch RDF was obtained from a 2000-ton/day MSW processor on the East Coast. The NRG facility can process 1500 tons/day of MSW, which comprises 60% commercial waste and 40% residential waste. The facility achieves about 80% recovery as RDF. Approximately 5% of the MSW is recovered as ferrous using magnetic separation, and 1% is recovered as aluminum using eddy current separation. The Newport RDF facility was toured to observe the scale and complexity of the operation and to retrieve a sample of RDF. Fuels from both processors are consumed in WTE facilities.

RDF Sorting

An approximately 1.4-kg (3-lb) sample of the NRG RDF, filling a volume equivalent to three 5-gallon pails, was hand-sorted and classified into the following categories: cardboard, paper, plastic, textiles, wood, aluminum, ferrous, food waste, and glass/ceramic. A fluff fraction was also generated that appeared to consist primarily of paper fiber and grit that was apparently adhered to the RDF. The results of the sorting are presented in Table 26, and photos of the sorted fractions of the NRG RDF are presented in Appendix E.

Table 26. Coarse RDF Sorting Results

Material	Mass, grams	Weight Percent	Comment
Cardboard	238	11.3	
Paper	632	30.1	
Plastic	248	11.8	Mostly film plastic (from grocery bags or similar to envelope windows), styrofoam, pop jugs, little dense plastic
Textiles	146	7.0	Foam padding, carpet fibers, fiber fill for jackets, some rubber
Fluff	288	13.7	Material too small to sort by hand; estimate 90% paper
Wood	44	2.1	
Aluminum	16	0.8	6 grams of aluminum foil, 10 grams of aluminum castings or stamped product
Ferrous	3	0.1	Single piece of wire
Food Waste	4	0.2	Orange peel, dried bread chunks
Glass, Ceramic	8	0.4	
−4 × 10 mesh	157	7.5	Styrofoam beads, wood splinters, colored foil, glass/plastic fragments, paper fiber fluff
−10 × 20 mesh	136	6.5	Wood splinters, colored foil, glass/plastic fragments, paper fiber fluff, dirt?
−20 mesh	180	8.6	Paper fibers, dirt?, wood splinters, colored foil, glass/plastic fragments
Total	2100		

An 18-kg (40-lb) sample of −4-inch RDF was subjected to nondestructive physical analysis testing and manual sorting. First, the bulk density was determined at several compaction levels, including as-received, loose, and spill. The as-received density was determined from the mass and for the RDF after it was removed from the plastic package and then allowed to attain an expanded