INDIRECT DRYING FOR EFFICIENT RECOVERY OF WET COAL FINES

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Coal fines are typically generated in the crushing and drying processes during coal preparation prior to combustion in utility boilers. To avoid particulate emissions, coal fines are captured by mechanical separation and wet scrubbers. The separated solids are typically processed into fuel, and the wet scrubber effluent, containing ultra-fine coal particles, is pumped to surface impoundments where the fine sediment is deposited and stored as a waste. Indirect drying can be used to convert this waste into a fuel.

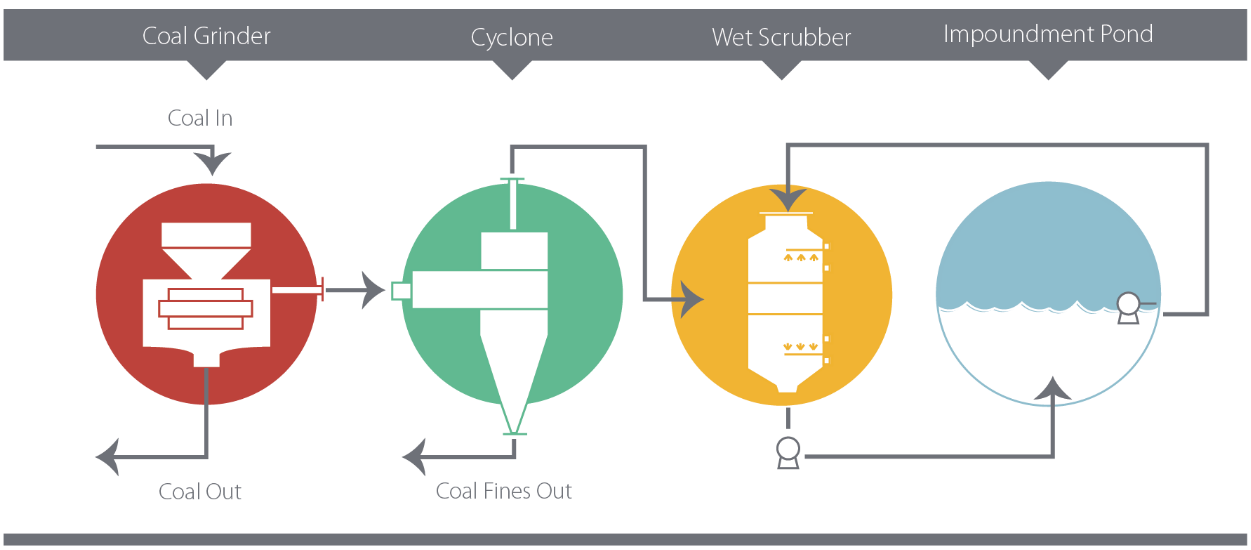


Figure 1
Coal Fines Process Flow Diagram

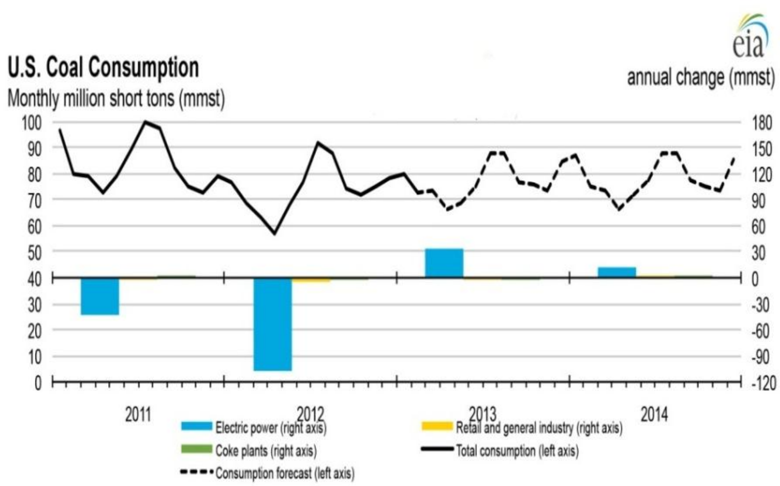
The Department of Energy (EPRI, 1994) estimated that 30–50 million tons of coal fines[1], representing 0.7-1.2 Quads (10^{15} Btu) of energy, are discarded annually into impoundments adding to the 2.3 billion tons of coal already in 700+ fine coal impoundments, most of which are located east of the Mississippi River in central Appalachia. This also represents 0.7-1.2 Quads, about 1% of total U.S. energy consumption (98 Quads, 2011) [2].

Figure 2
Ben Creek Slurry Impoundment (Max capacity) 15,970 acre-feet

Annual US coal consumption by power plants is projected to reach 858 million short tons in 2013.[2] An estimated 30-50 million[3] new short tons are added to coal fines impoundments each year. Presently only an estimated 11 million short tons a year are currently being recovered. Recovering and drying 100% of new coal fines produced while maintaining the current rate of waste coal recovery would provide for 5% to 7% of the current coal demand by US power plants.

Table 6. U.S. Coal Supply, Consumption, and Inventories
U.S. Energy Information Administration | Short-Term Energy Outlook - February 2013

	2012				2013				2014				Year		
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	2012	2013	2014
Supply (million short tons)															
Production	266.4	241.4	259.0	253.7	244.6	242.5	258.5	262.8	253.7	247.4	262.0	265.1	1020.5	1008.5	1028.2
Appalachia	80.6	76.1	69.3	77.8	74.9	74.2	74.2	75.2	76.0	74.9	74.4	74.9	303.9	298.5	300.2
Interior	44.3	44.1	46.4	41.5	39.9	38.3	40.0	40.0	40.4	40.0	41.5	41.3	176.2	158.1	163.3
Western	141.5	121.1	143.4	134.4	129.9	130.0	144.3	147.7	137.3	132.5	146.1	148.8	540.4	551.9	564.7
Primary Inventory Withdrawals	0.4	0.5	3.8	-0.2	5.5	-1.1	1.6	-2.6	1.0	-0.1	0.6	-2.3	4.5	3.5	-0.8
Imports	2.0	2.3	2.4	2.9	2.3	2.4	3.3	2.9	2.3	2.4	3.3	2.9	9.7	11.0	10.8
Exports	28.6	37.5	31.6	26.5	26.9	27.5	27.0	26.9	26.6	28.4	28.5	28.5	124.3	108.3	111.9
Metallurgical Coal	17.5	20.2	17.0	14.3	16.2	16.6	16.1	16.5	16.1	16.8	17.1	17.2	69.0	65.4	67.1
Steam Coal	11.1	17.4	14.6	12.2	10.7	10.9	10.9	10.3	10.5	11.6	11.4	11.3	55.3	42.9	44.8
Total Primary Supply	240.2	206.6	233.7	229.8	225.5	216.4	236.4	236.2	230.4	221.4	237.4	237.1	910.3	914.6	926.3
Secondary Inventory Withdrawals	-21.1	-3.0	15.9	-6.8	3.7	-9.0	12.7	-5.8	2.0	-8.5	12.8	-5.9	-15.0	1.6	0.4
Waste Coal (a)	2.8	2.5	3.2	3.0	2.8	2.5	3.2	3.0	2.8	2.5	3.2	3.0	11.4	11.4	11.3
Total Supply	222.0	206.1	252.7	226.0	232.0	209.9	252.3	233.4	235.1	215.4	253.4	234.2	906.8	927.6	938.0
Consumption (million short tons)															
Coke Plants	5.3	5.2	5.1	4.5	4.5	4.7	5.0	4.7	4.8	5.0	5.4	5.1	20.1	18.9	20.3
Electric Power Sector (b)	190.8	186.2	238.4	208.9	210.7	194.2	236.6	217.1	218.1	198.6	236.6	216.8	824.3	858.7	870.1
Retail and Other Industry	11.8	10.4	11.1	12.2	11.3	11.0	10.7	11.6	12.1	11.8	11.4	12.3	45.4	44.6	47.6
Residential and Commercial	0.7	0.4	0.6	1.1	0.8	0.7	0.7	0.8	0.9	0.8	0.7	0.8	2.8	3.1	3.2
Other Industrial	11.1	9.9	10.5	11.1	10.4	10.3	10.0	10.8	11.2	11.0	10.7	11.5	42.6	41.5	44.4
Total Consumption	207.8	201.8	254.6	225.5	226.5	209.9	252.3	233.4	235.1	215.4	253.4	234.2	889.8	922.2	938.0



U.S. Coal Summary

	2011	2012	2013	2014
Prices	(dollars per million Btu)			
Electric Power Sector	2.39	2.40	2.41	2.45
Supply	(million short tons)			
U.S. Coal Production	1095.6	1020.5	1008.5	1028.2
Consumption	(million short tons)			
Electric Power Sector	932.5	824.3	858.7	870.1
Other Sectors	70.5	65.5	63.5	67.9
Total Consumption	1002.9	889.8	922.2	938.0

Figure 3
U.S. Coal Supply, Consumption and Inventories

Conventional techniques to recover coal fines from impoundments typically include mechanical dewatering using filter presses[4], or belt presses, followed by convective thermal drying. Coal fines recovered from impoundments using re-slurry methods, are typically 25–30% moisture content by weight. Prior to being used as fuel, the coal fines need to be further dried to ideally less than 9% and 5% moisture content is common. The most commonly used coal drying technologies are convective thermal dryers[4]. In a convective dryer, hot gases pass over and through the wet coal, heating it and carrying away evaporated water. Traditional convective dryers have a number of potential drawbacks. Convective dryer technology is limited in application by energy inefficiency or high capital cost due to expensive air-pollution control (APC) equipment required to process the large quantities of exhaust air. Use of indirect dryers such as screw dryers, offer several advantages over conventional convective dryer technologies.

A direct fired rotary drum dryer is one of the more common convective dryer technologies for coal fines[6]. A rotary drum dryer consist of a long cylindrical body which rotates on trunnions. The coal fines are feed into the dryer and conveyed from the inlet to the discharge end by gravity due to a slight decline, and/or with shovel plates that line the inside of the drum. Hot gas is passed through the rotating drum in direct contact with the coal fines. The feed is tumbled up and over the shovel plates to maximize the agitation and contact with the hot gasses to induce drying. The dryer fill level is typically only 10% of the internal diameter. The low fill level aids in agitation of the product to insure direct contact with the hot gas. Due to the agitation and gas velocities, there is a substantial entrainment of particulate in the exhaust gas. The gas flow in the rotary dryer is typically co-current with the feed. The moisture and particulate have to be removed from the exhaust gas. A 125,000 ton/year, rotary dryer will generate process exhaust gases at a rate of approximately 10,000 ACFM at 230°F. The moisture is typically removed by using a direct contact condenser and the 10,000 ACFM of non-condensable gas is treated with air-pollution control (APC) equipment. The capital and operational cost associated with treating 10,000 ACFM of exhaust gas make the operation potentially uneconomical.

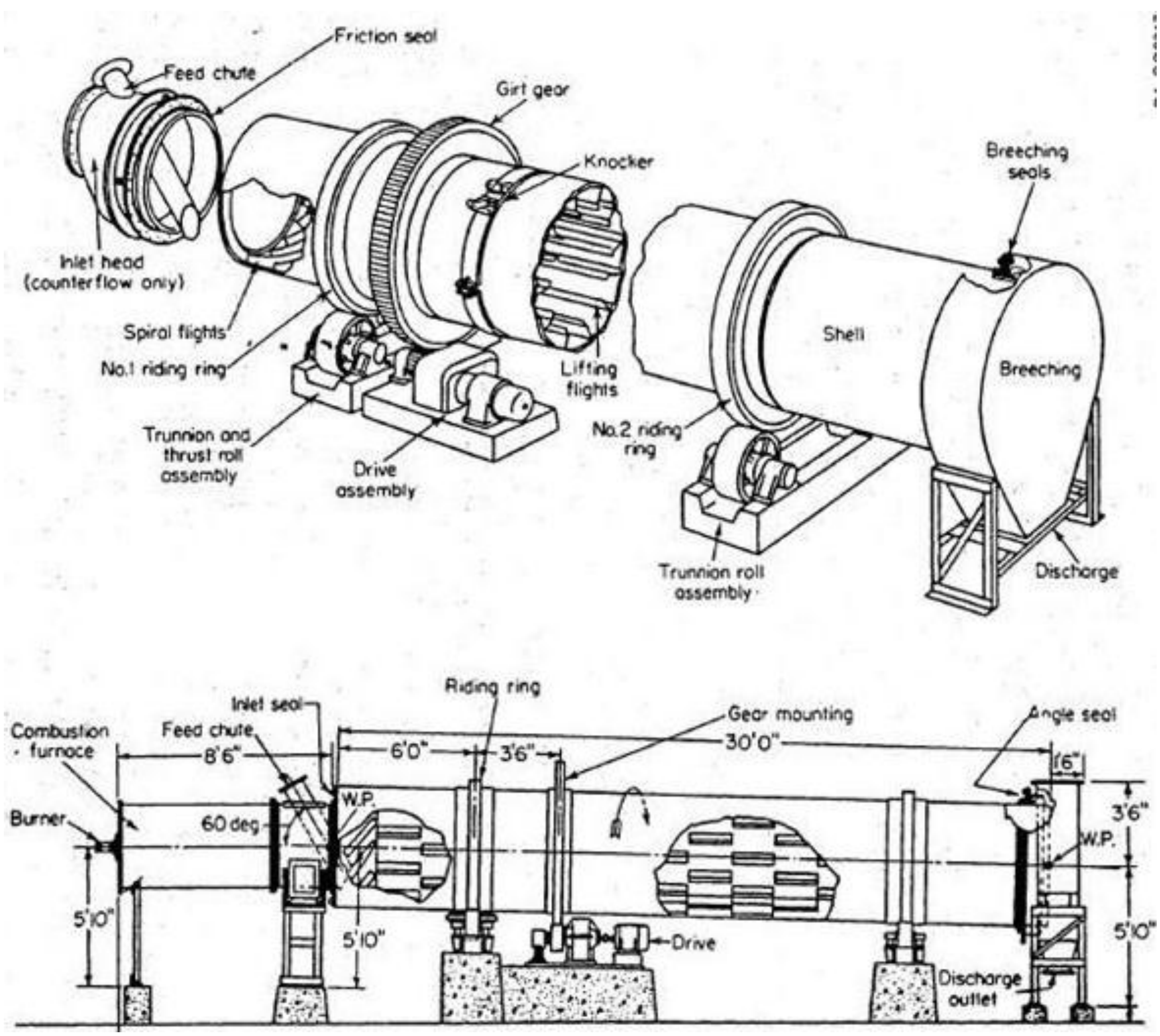


Figure 3
Rotary Drum Dryer

In a convective dryer, air is typically heated with a direct fired gas burner. The hot air is passed through the feed and water vapor from the feed saturates the air. This air and water vapor is cooled, to allow the water vapor to condense. The cooled air is then typically recirculated to the combustion burner along with additional fresh air, to be reheated, and reintroduced into the dryer. Indirect dryers typically are insulated to prevent environmental losses of greater than 6%. The gas burner used to heat the combustion air is typically 86.5% to 90% (LHV) efficient. The purged water, air, and products of combustion from the exhaust air recirculation loop, accounts for some additional energy losses. Due to the enthalpy lost with using hot air as a heat transfer medium, thermal efficiency for convective dryers tends to be low when compared to indirect (conductive) dryers [5].

In an indirect dryer the coal fines and the heating medium do not come in contact. A steel heat exchange surface separates the heating medium from the feed. The heating medium can be hot gas, steam, hot water, thermal oil or molten salt. The heat is transferred from the thermal fluid to the steel membrane, heating the steel which is in direct contact with the feed. Heat transfer rates are determined by the "U" factor for the product and machine. A indirect dryer's capacity is limited only by the heat exchange surface area in contact with the feed. There are several types of indirect dryers; the most commercially available are Screw Dryers and Disc Dryers.

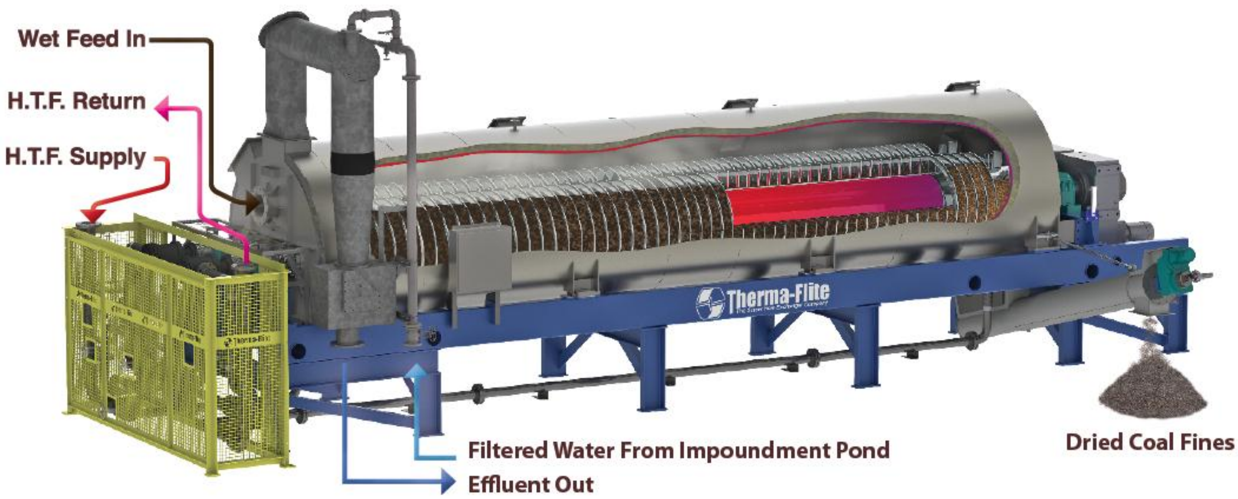


Figure 4
Dual Screw Dryer

Screw dryers are typically constructed with one, two or four rotors located in a jacketed trough. A thermal fluid such as steam or thermal oil is circulated through the jacketed housing; a hollow cavity in the flighting, and the rotor shaft pipe, maximizing the heat transfer surface area. The flow of heat transfer fluid is typically counter current to the movement of the feed in the conveyor. Counter current flow offers better heat exchange and minimizes square footage requirements. The screws rotation conveys the feed from the inlet to the discharge. The bed of material is typically maintained at 80% of the available bed depth to maximize the contact of the coal fines with the heated surface area. The rotation of the screws is very slow, typically less than 1 to three rpm. The bed is static. The gentle handling and minimal agitation of the feed minimizes particulate in the exhaust gas. Coal fines are heated in an indirect screw dryer under a slight negative pressure in an anaerobic atmosphere. Rotary air-lock valves on the feed and discharge limit air intrusion into the dryer to only that which is entrained in the feed and rotation of the rotary airlock. The moisture in the vent is condensed and only the limited non-condensables in the exhaust are treated with air-pollution control equipment. For a 125,000 ton/year application, an indirect screw dryer will generate approximately 50-100 ACFM of non-condensable gases. This non condensable vent from an indirect dryer is less than 1% of the vent from direct fired equipment with a corresponding reduction in APC costs.

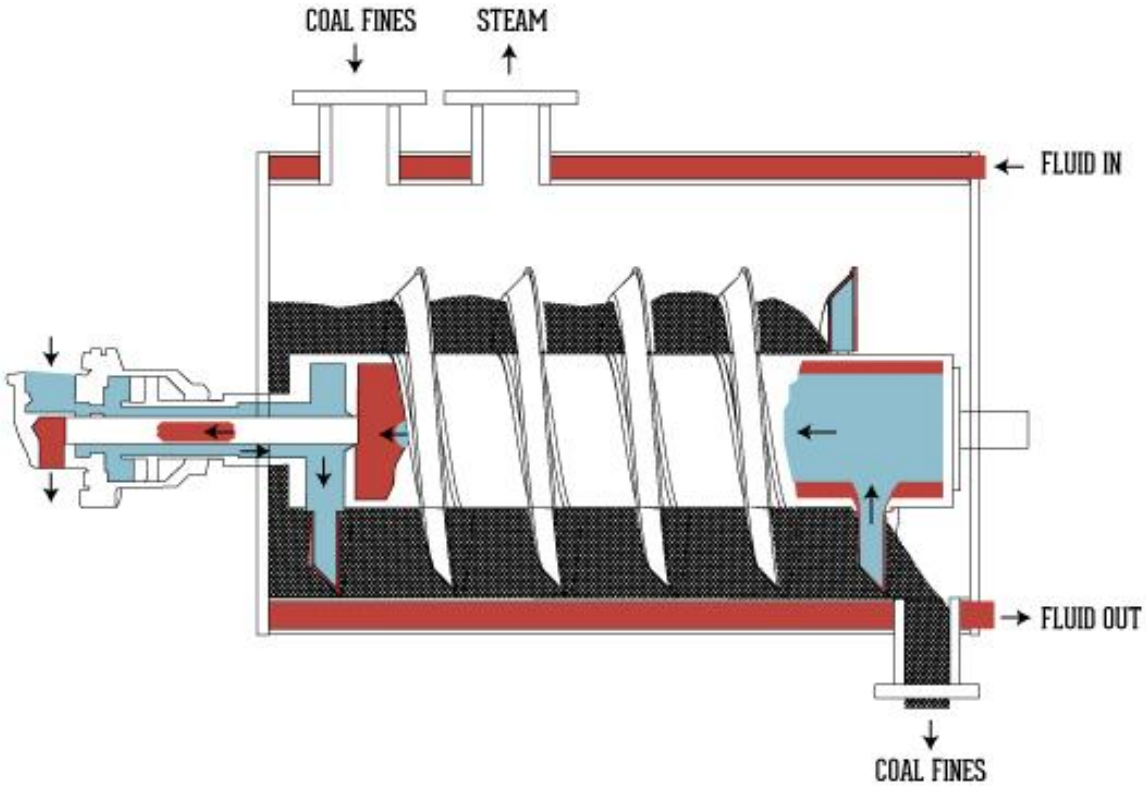


Figure 5
Screw Dryer Thermal Fluid Flow

Indirect dryers using thermal fluid as the heating medium are typically more efficient than convective drying technology. In an indirect dryer, the heating loop starts with heat being added to the thermal fluid via a heat exchanger. The heat typically comes from a coal or gas fired thermal fluid heater or boiler flue gas. The heated thermal fluid then is circulated through the heat exchange surfaces of the dryer. Heat is removed from the thermal fluid when cooler coal fines come into contact with the steel plate which is being heated by the thermal fluid. The fluid is then returned and reheated. An indirect dryer is typically insulated to insure less than 4% environmental losses. Aside from environmental losses, the only place for the heat to go is into the feed. A well-insulated indirect dryer will have an efficiency of around 96% or greater. Total drying requirements are less than 450 Btu/lb recovered fines which is less than 5% of the recovered fuel value of the coal fines themselves.

Drying coal fines in a indirect screw dryer is to some degree, still an emerging technique. The screw dryer technology has been in use since the 1930's, drying a large variety of feeds ranging from slurry to high solids. Having incorporated much technology, design and capacity improvements since then, indirect screw dryers offer a cost-effective means of recovering the energy value of coal fines in today's economic and regulatory environment.

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